NO. 1

JICA

BASIC DESIGN STUDY REPORT ON THE PROJECT FOR IMPROVEMENT AND DEVELOPMENT OF ELECTRIC POWER SYSTEM IN THE REPUBLIC OF PALAU

DECEMBER 1993

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE REPUBLIC OF PALAU
MINISTRY OF RESOURCES AND DEVELOPMENT

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ON
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AND
DEVELOPMENT OF ELECTRIC POWER SYSTEM
IN
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PACIFIC CONSULTANTS INTERNATIONAL

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Preface

In response to a request from the Government of the Republic of Palau, the Government of Japan decided to conduct a basic design study on the Project for Improvement and Development of Electric Power System in the Republic of Palau and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Palau a study team headed by Mr. Hidenao Watanabe, Grant Aid Division of the Economic Cooperation Bureau of the Ministry of Foreign Affairs and constituted by members of Pacific Consultants International, from August 9 to September 1, 1993.

The team held discussions with the officials concerned of the Government of Palau, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Palau in order to discuss a draft report, and as a result the present report was finalized.

I hope that his report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

December 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

December , 1993

Mr. Kensuke Yanagiya,
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Project for Improvement and Development of Electric Power System in the Republic of Palau.

This study was conducted by Pacific Consultants International, under a contract to JICA, during the period from August 6, 1993 to December 27, 1993. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Palau, and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

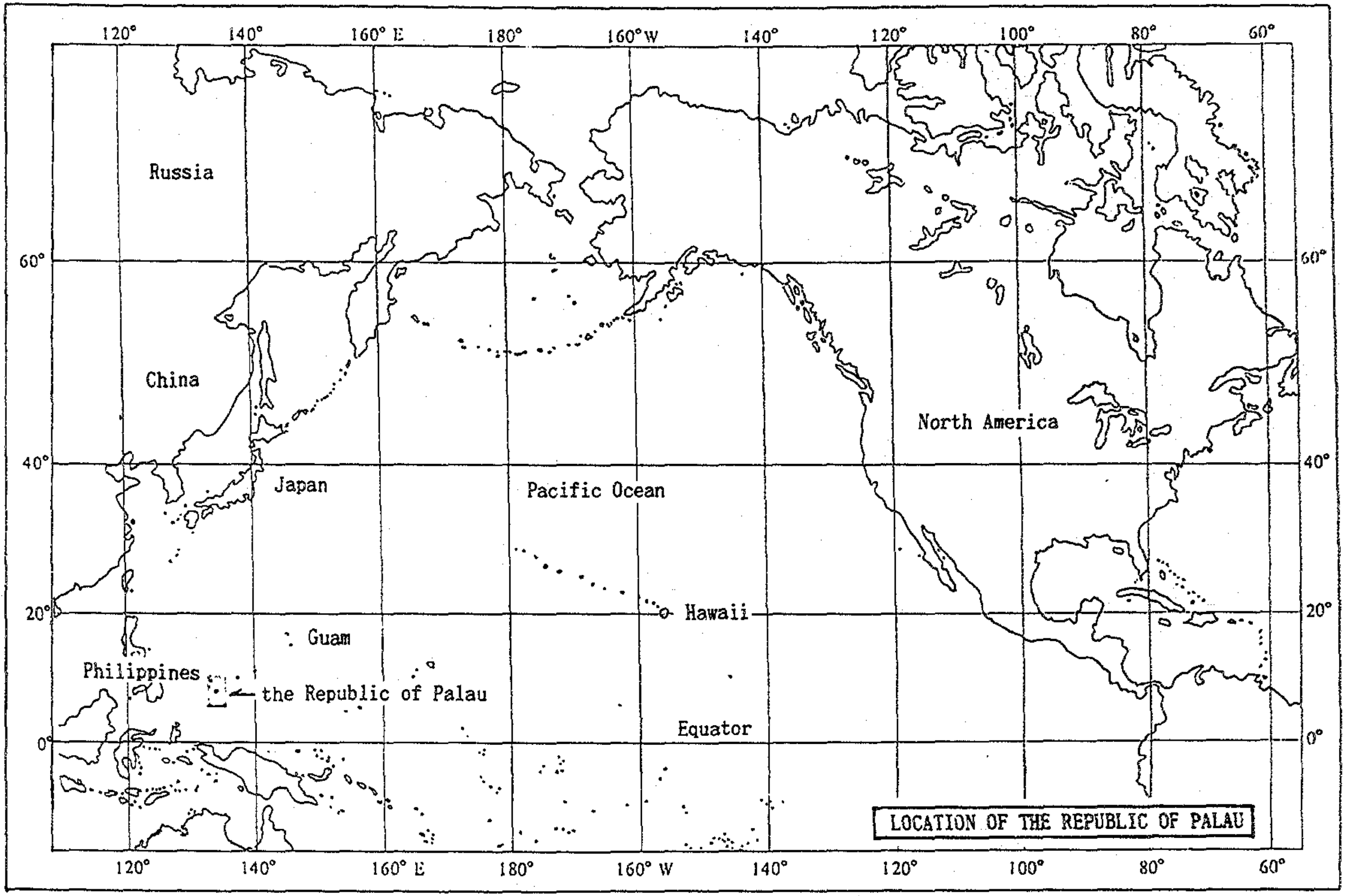
We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs and the Ministry of International Trade and Industry. We would also like to express our gratitude to the officials concerned of the Ministry of Resources and Development of Palau and Consulate-General of Japan in Agana, Guam for their cooperation and assistance throughout our field survey.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours

Yuko Obuchi
Project manager
Basic design study team on
the Project for Improvement and Development
of Electric Power System in the Republic of Palau
Pacific Consultants International

LOCATION MAP AND PERSPECTIVE


LOCATION OF THE REPUBLIC OF PALAU
Russia
China
Japan
Pacific Ocean
North America
Hawaii
Guam
Philippines
the Republic of Palau
Equator
120°
140°
160° E
180°
160° W
140°
120°
100°
80°
60°
60°
40°
20°
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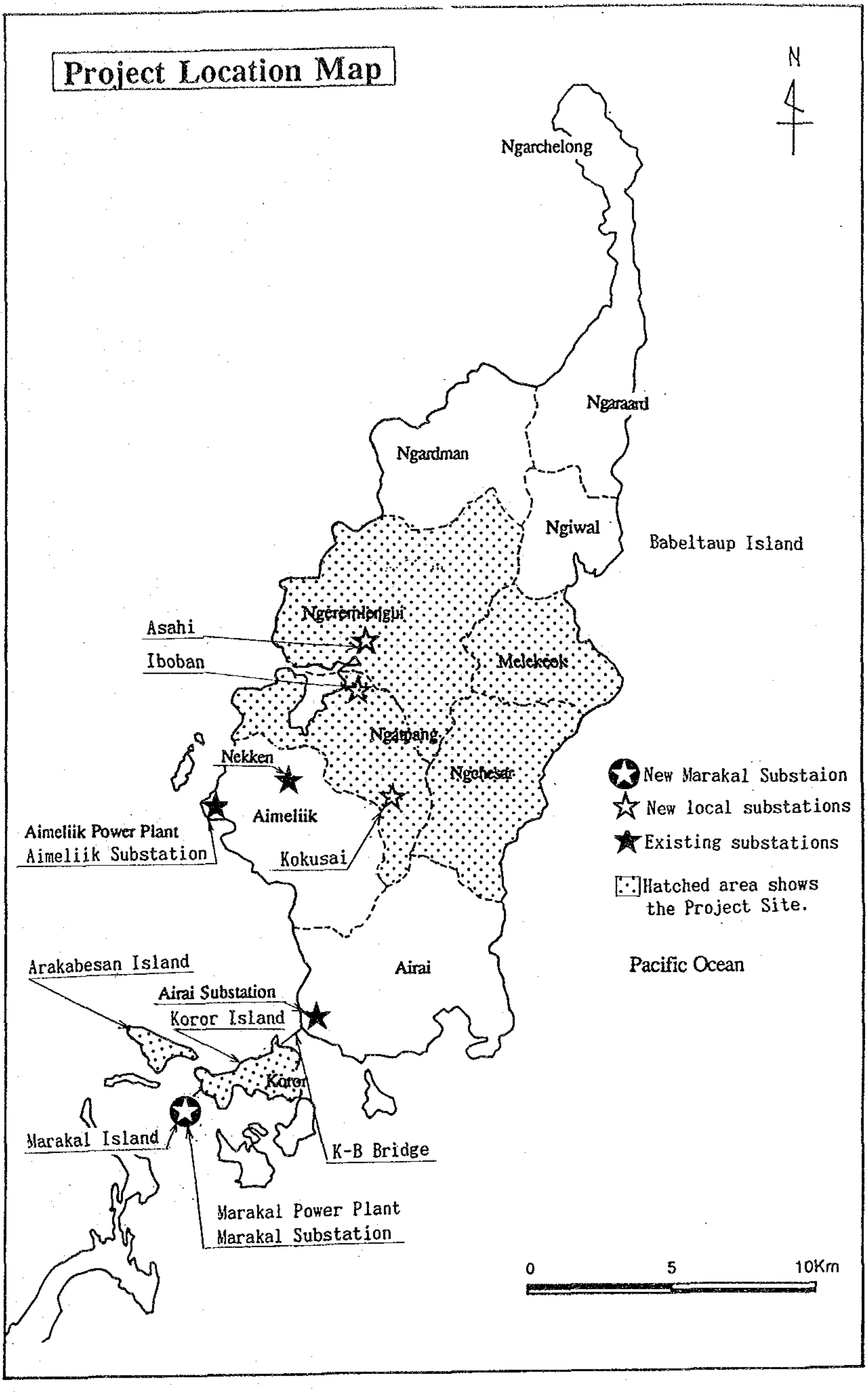
Project Location Map
N
Ngarchelong
Ngaraard
Ngardman
Ngiwal
Babeltaup Island
Asahi
Iboban
Melekeok
Ngatpang
Nekken
Ngchesar
Aimeliik
Aimeliik Power Plant
Aimeliik Substation
Kokusai
New Marakal Substaion
New local substations
Existing substations
Hatched area shows the Project Site.
Pacific Ocean
Airai
Arakabesan Island
Airai Substation
Koror Island
Koror
Marakal Island
K-B Bridge
Marakal Power Plant
Marakal Substation
0
5
10Km

1. Condition of 13.8 KV Distribution Line in Koror District

Photo 1-1

There are many places where trees come in contact with electric wires which have an excessive sag. This causes frequent power blackouts resulting from disconnections, line-to-ground faults and short circuits.

Photo 1-2

Telephone and cable TV lines are haphazardly installed to the electric pole. There is a threat to electric poles because of their strength.

Photo 1-3

Wooden electric poles are antiquated. In addition, the tension of telephone lines has caused the electric poles to near collapse. Under this project, concrete poles with greater strength will be used.

Photo 1-4

It has been decided that installation of these telephone and cable TV lines to electricity poles provided under this project will not be permitted.

2. Airai Substation and Malakal Substation

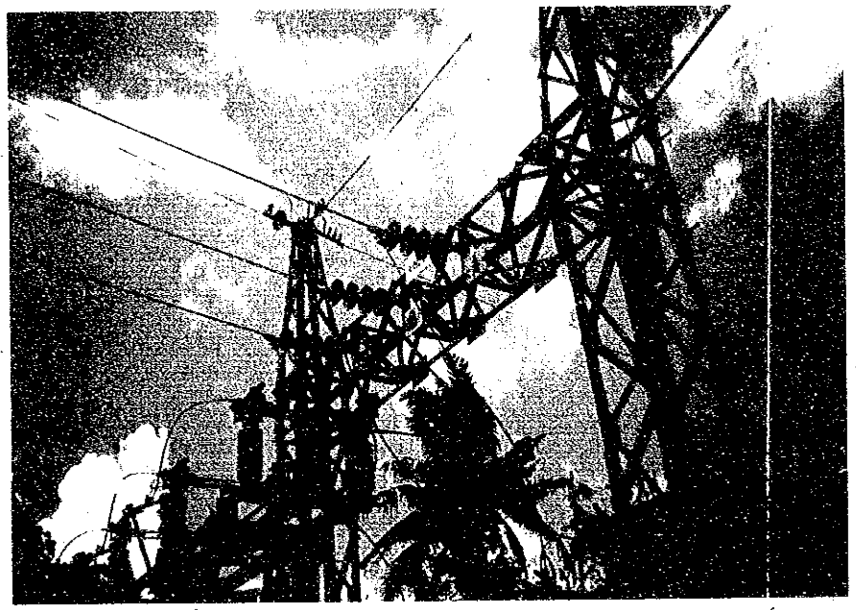

Photo 2-1
Airai Substation was built under the fiscal 1984/1985 Japanese Grant Aid Project.

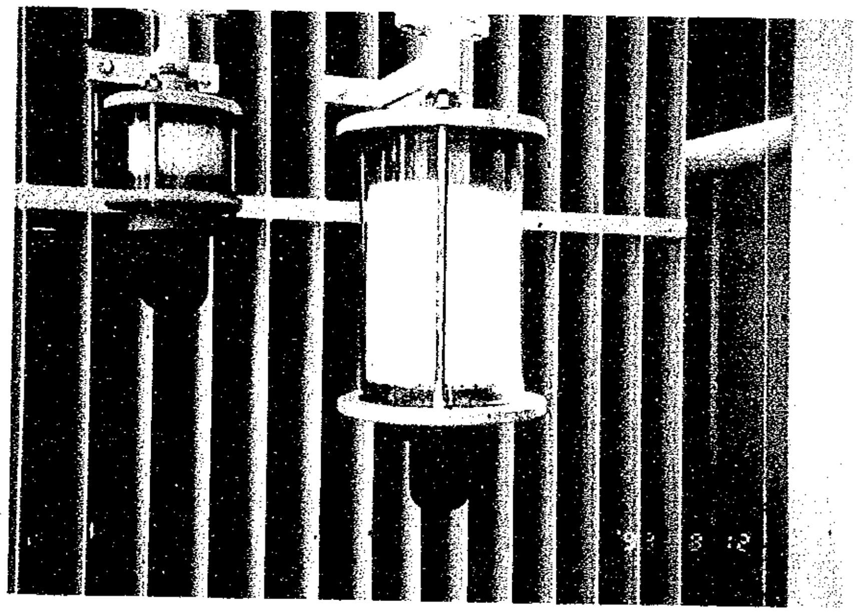

Photo 2-2
10 MVA transformer located in Airai Substation. The construction of the new Malakal Substation which will allow this transformer to be maintained and inspected is a key component of this project.

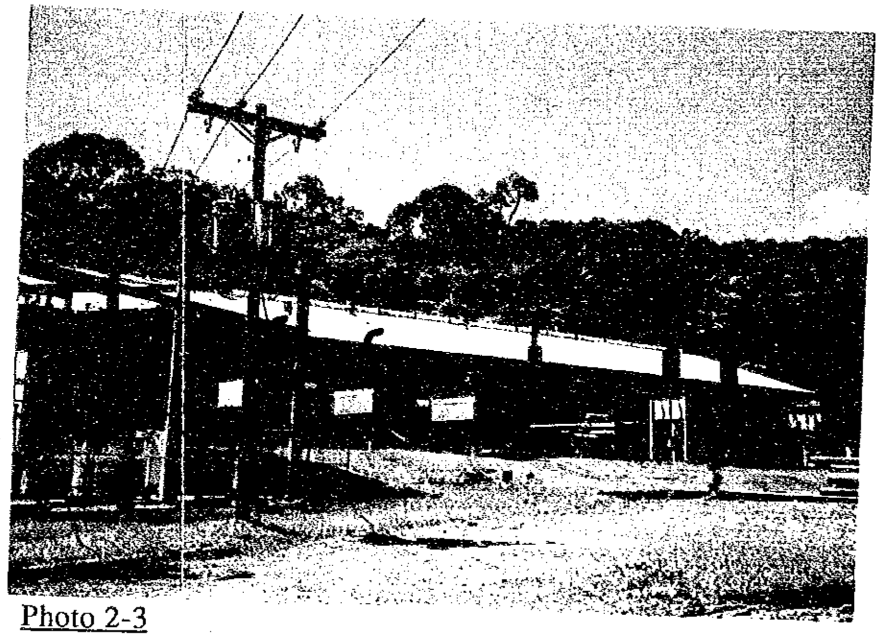

Photo 2-3
Site where the new Malakal Substation is scheduled to be built. The building located on the left is the existing Malakal Substation.

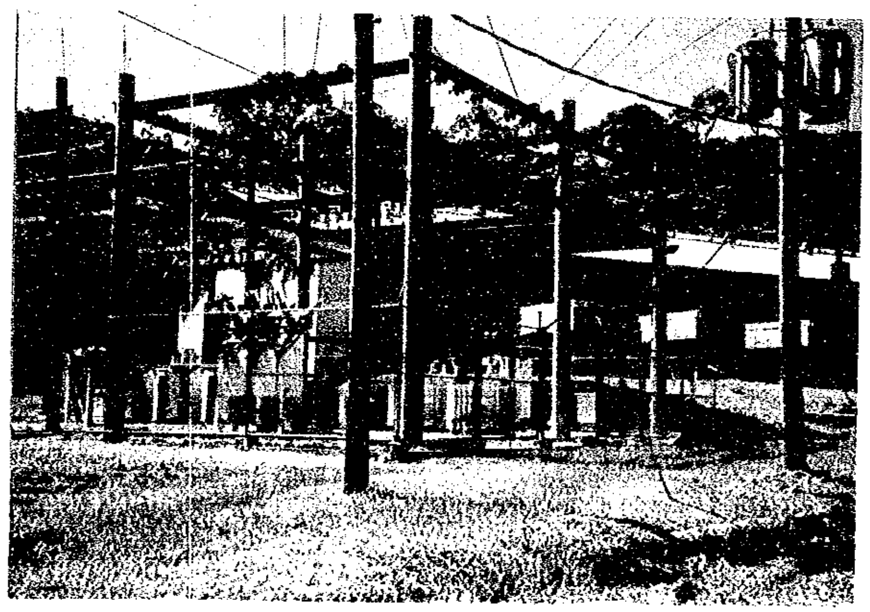

Photo 2-4
Malakal Substation. With antiquated equipment, this substation is unreliable. This substation will be eliminated under this project.

3. Plan for Power Transmission and Distribution Lines

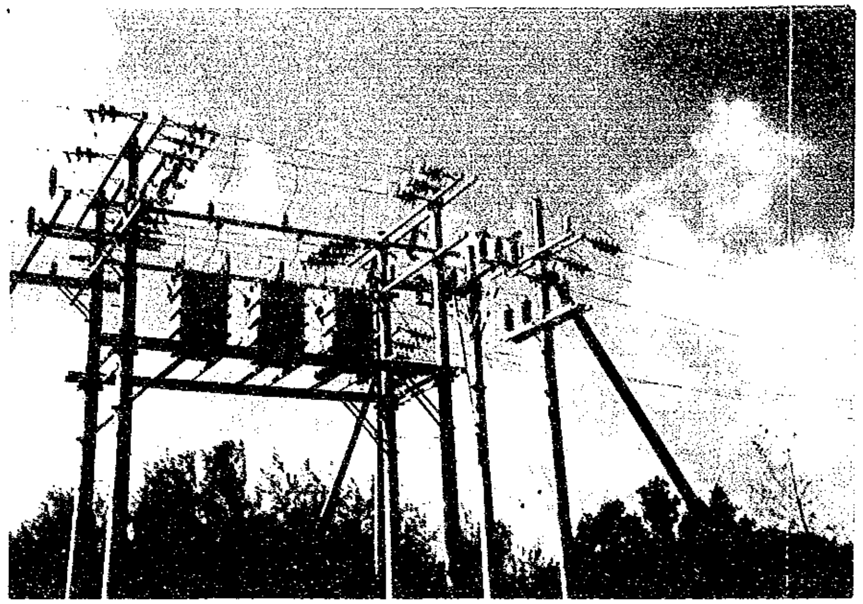

Photo 3-1

Pole mounted substation in the Nekken district. Here, a 34.5 KV power transmission line is branched and transmission lines are constructed to extend to the Kokusai district.

Photo 3-2

Kokusai district. 34.5 KV/13.8 KV transmission and distribution lines will be constructed to supply electricity to the four non electrified states.

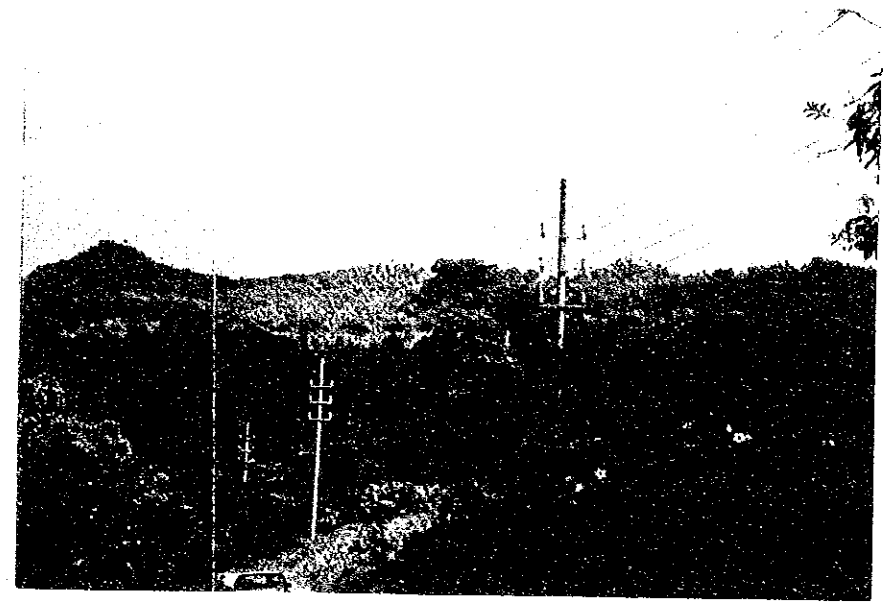

Photo 3-3

34.5 KV transmission lines. Under this project, in order to ensure compatibility with existing facilities, similar power transmission lines will be constructed.

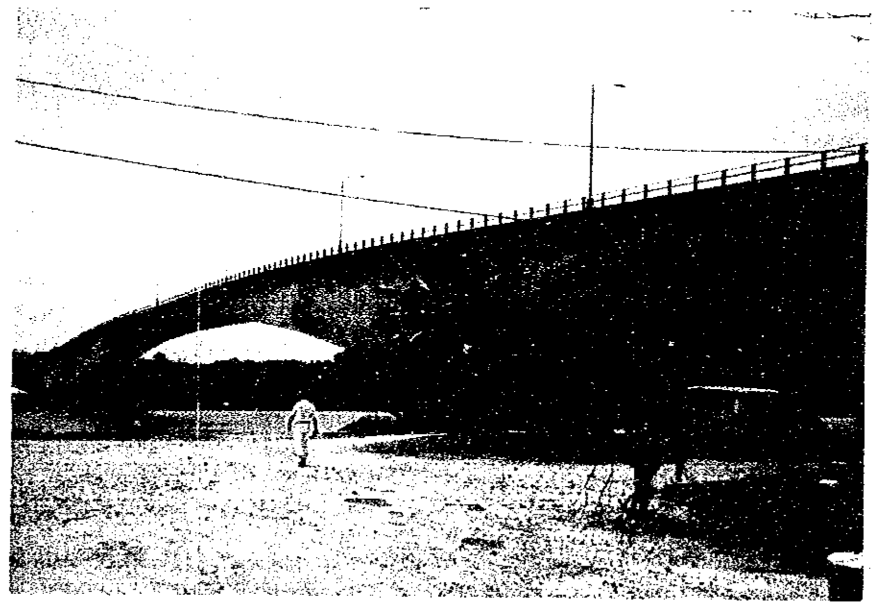

Photo 3-4

K-B Bridge. Inside this bridge where there is sufficient space, 34.5 KV/13.8 KV transmission and distribution cables will be installed.

4. Diesel Generators in Four Non Electrified Areas

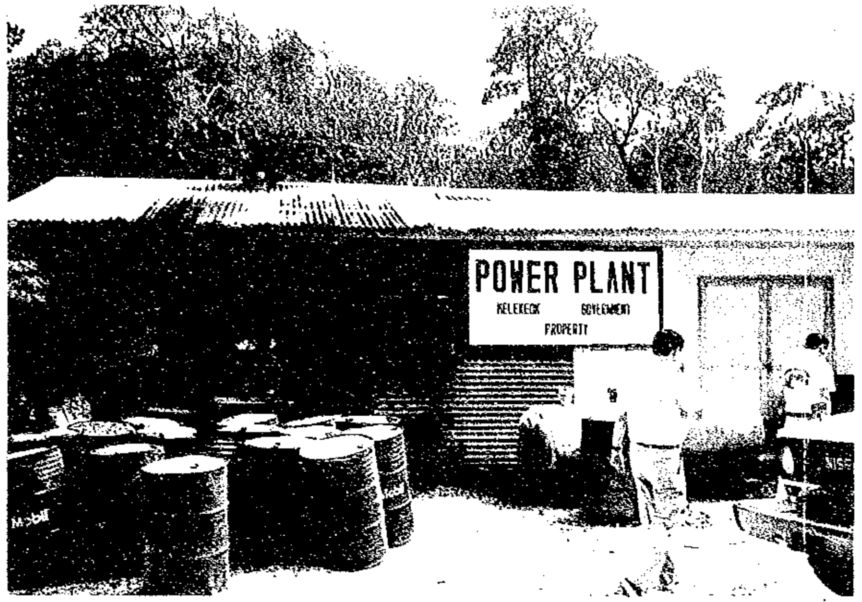

Photo 4-1
Melekeok State 150 KW diesel generator

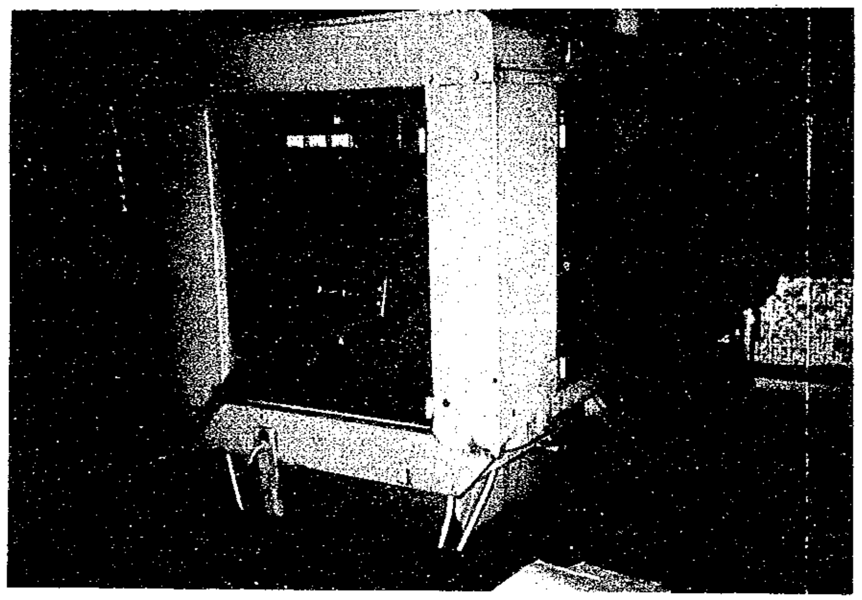

Photo 4-2
Ngcnesar State 90 KW diesel generator

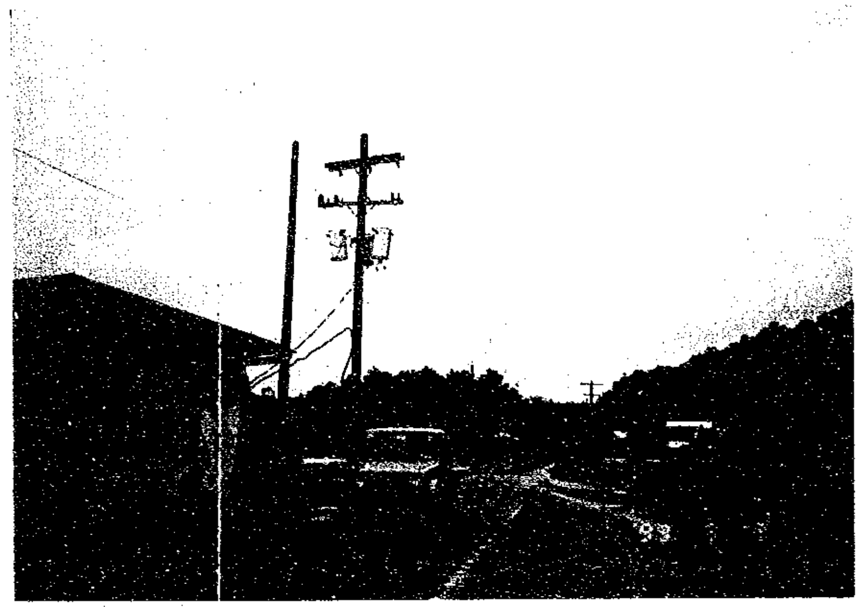

Photo 4-3
Ngeremiengui State 125 KW diesel generator

Photo 4-4
Ibboban district in Ngatpang State 50 KW diesel generator

SUMMARY

Summary

The Republic of Palau consists of about 200 islands, including Koror and Babelthaup Islands, situated in the west Carolines, in the southwest Pacific. The country has a total land mass of 489 square kilometers, with the area of 630,000 km^2 for the territorial sea, and a population of 15,122, of whom 10,501 live in the Koror State, were the capital is located. Palau is under the trusteeship of the United States, as a United Nations Trust Territory. In 1990, the nation achieved a gross domestic product (GDP) of $50 million. However, Official Development Assistance (ODA) accounts for 63 % of this figure.

A key issue for the country is thus to establish an economic foundation. Promising industries for the future include tourism, agriculture and fisheries. However, the lack of social infrastructure is a barrier to economic and social development. In particular, improvements in electricity supply have been slow. The only areas which are electrified are in and around the Koror State. Even here, the antiquation of power transmission and distribution facilities has reached its allowable limit and has resulted in many instances of power blackouts resulting from equipment breakdowns, disconnected conductors, line-to-ground faults and short circuits. Furthermore, shortages in transformer and electric wire capacity have caused significant fluctuations and drops in power voltage and have thus created a situation where there is no steady supply of electricity.

In the non electrified states, electricity is only provided for illumination at night by means of emergency diesel generators. Therefore, the standard of living in these non electrified states remains markedly inferior to Koror. Although these areas hold great potential for agricultural, commercial and industrial development, they are unable to promote these industries. The nation has consequently set as priority policies for its development improving the supply of electricity quickly, instituting out economic and social development and creating employment.

Given these conditions, the Government of the Republic of Palau requested the Government of Japan to provide Grant Aid to improve and enhance power transmission and distribution facilities in the Koror State, and provide electricity to the non electrified areas on Babelthaup Island, the nation's largest island, where potential for economic development is high. Upon receiving this request, the Government of Japan decided to carry out the basic design study, and the Japan International Cooperation Agency examined its contents and the appropriateness and effect of the project. At the same time, in order to determine the optimum contents and scale of the project, JICA dispatched a basic design study team to Palau from August 9 to September 1, 1993. Later, from November 9 to November 17, 1993, the Government of Japan sent a study team to explain the draft final report to Palau.

The basic design study was carried out with the cooperation of the Ministry of Resources and Development, which is the executing agency representing the Government of Palau, the Bureau of Public Works, which comes under the Ministry and which will be responsible for the administration, maintenance and control of the facilities after the project is completed, and the Office of Planning and Statistics, which will act as a coordinator.

Based on the results of the study to examine the actual state of power transmission and distribution facilities in the Koror State and the non electrified areas on Babelthaup Island, as well as to predict electricity demand, the contents of the request presented by the Republic of Palau were examined and agreed between the basic design study team and Government of the Republic of Palau to the extent and contents of the project implemented with Japanese Grant Aid.

The scope of responsibilities through Japanese Grant Aid under this project will be as follows.

(1) Improve and enhance 34.5 KV power transmission and 13.8 KV distribution facilities in the Koror State

1) Construct 34.5 KV transmission lines and 13.8 KV distribution lines between Airai and Malakal

2) Replace the 13.8 KV distribution network in Koror, and establish distribution loop circuits and automatic section switches.

3) Enhance existing power distribution lines following the improvement in the 13.8 KV power distribution network in Koror.

4) Construct a 13.8 KV/34.5 KV substation in Malakal

(2) Construct 34.5 KV/13.8 KV power transmission and distribution lines to connect the four non electrified states on Babelthaup Island

1) Construct 34.5 KV transmission lines between the existing substation in Nekken district and Kokusai district and construct a 34.5 KV/13.8 KV substation in Kokusai district.

2) Construct 34.5 KV power transmission lines between Kokusai district and Negeremiegui State and construct 34.5 KV/13.8 KV substations in Ibboban district, Ngatpang State and Ngeremiengui State.

3) Construct 13.8 KV distribution lines between Kokusai district and Melekeok State and between Kokusai district and Ngchesar State.

(3) Provide the materials and equipment to construct 13.8 KV distribution lines in the four non electrified states on Babelthaup Island.

1) Distribution lines in Ngeremiengui State

2) Distribution lines in Melekeok and Ngchesar States

3) Distribution lines in Ibboban district

The scope of responsibilities of Palau is as follows:

(1) Secure and improve the project area.

(2) Cut trees which hinder the route taken by the transmission and distribution lines and eliminate other obstacles.

(3) Remove those existing facilities which will become unnecessary after the improvement and enhancement of the transmission and distribution network.

(4) Improve roads.

Under this project, facilities constructed will have the similar specifications as existing transmission and distribution facilities, which were constructed with the fiscal 1984/85 Japanese Grant Aid "Babelthaup Electrical Transmission and Distribution Lines Project". It is judged that the existing organization of the Bureau of Public Works will be able to maintain and control facilities.

The construction work will be divided into three stages. Construction for the first stage will require 9.5 months, the second stage 10.5 months and the third stage 8.5 months.

The following effects can be expected to accrue from the implementation of this project:

(1) An improved and enhanced power transmission and distribution network will decrease power blackouts caused by equipment breakdowns and accidents in the power distribution lines. In addition, minimizing voltage fluctuations and drops will ensure a steady supply of electricity. The improved power transmission and distribution network will be a boost for the national goals of promoting economic independence and stabilizing and improving the living standards of the residents of Palau.

(2) Improving and enhancing the power transmission and distribution network will reduce the loss in electricity, resulting in greater economy in fuel expenses for power generation. Furthermore, the repair and maintenance expenses required to maintain and control the antiquated transmission and distribution facilities will be significantly reduced. This will contribute to improving the account balance of the electric business carried out by the Bureau of Public Works, which often finds itself in financial difficulties. It will also contribute to a subsequent financial strengthening.

(3) The electrification of the four non electrified states on Island will bring local residents up to a basic standard of living and promote improvement in social foundations. It will also lead to the implementation of development projects to promote economic and social development, improve the living standards and encourage decentralization. This will subsequently form a basis for the sound development of the entire country.

This project will thus contribute to the economic development of the nation and improve the living environment for residents. Consequently, it is considered appropriate to implement the project with Grant Aid. With regard to the administration and control of the project, there appears to be no problems with the administrative organization, personnel allocation and other systems that Palau provides.

The following measures will enhance the project's effects and ensure maintenance and control over a long period:

(1) In order to properly maintain the function of facilities, ensure that daily inspection and maintenance are carried out in accordance with the facility maintenance regulations.

(2) The Bureau of Public Works should strive to improve electric power system account balance. One way of doing this is to set up appropriate rates for electricity charges -- the sole financial resource -- and be sure to achieve 100 % collection of charges.

(3) Prepare plans and documents incorporating the latest information on the operations and maintenance of facilities. Use these in the maintenance and control of facilities and as materials to prepare preventive maintenance.

Table of Contents

List of Tables

List of Figures

CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

Since 1947, the Republic of Palau has been under the political jurisdiction of the United States of America as the world's sole United Nations Trust Territory. The Republic of Palau depends on the United States' Department of Interior funds, Federal Grant Aid and similar sources for most of its financial resources. Japanese Official Development Assistance (ODA) reaches about $3,000,000 each year (1986 ~ 1990 average). However, to achieve economic independence, it is essential that tourism, agriculture, commerce and industry be promoted. To improve the social infrastructure in order to facilitate economic development, 60% of the total budget of the First National Development Plan (1987 ~ 1991) was appropriated. Of this, energy received 17% of the total budget. In this field, particular importance has been placed on improving the reliability of electricity supply in Koror, the capital, and providing electricity to non electrified areas. At the moment, however, only two states receive electricity through the government's electric power system, Airai and Aimeliik, both located in the south of Babelthaup Island, neighboring Koror State. Of 16 states comprising the Republic of Palau, six states have not been electrified.

Koror State is home to 69% of the total population and is the center of politics, economics, administration, commerce and industry. Koror also contains the majority of the nation's social facilities, including education and medical facilities. However, this region experiences frequent power blackouts caused by disconnections and line-to-ground faults involving electric wires, which result from breakdowns in the antiquated power distribution facilities and contact with trees. Falls and fluctuations in voltage owing to the insufficient capacity of transformers and electric wires are also frequent, and Koror does not therefore receive a steady supply of electricity. As a result, improving the reliability of electricity supply by enhancing power transmission and distribution facilities and improving the power distribution network has become an urgent need.

On the other hand, although Babelthaup Island has not seen progress in development because of delays in improvements to social infrastructure, it is the largest island in the country, accounting for about 80% of the country's total land mass. The island therefore possesses outstanding potential for agricultural, commercial and industrial development, and the Government of Palau has placed great priority on attempting to decentralize through economic and social development, improvements in lifestyle and the creation of employment, by supplying electricity to non electrified regions on Babelthaup Island. The Government has set these as priority policies for national development.

Given these conditions, the Government of Palau requested the Government of Japan to provide Japanese Grant Aid in order to improve and enhance power transmission and distribution facilities and supply electricity to non electrified areas on Babelthaup Island. The details of the request are as follows:

(1) Improve and enhance power transmission and distribution facilities in Koror.

(2) Construct 34.5 KV power transmission and 13.8 KV distribution lines in the four non electrified states on Babelthaup Island.

(3) Provide materials and equipment to construct power distribution lines in the four non electrified states on Babelthaup Island.

In response to this request, the Government of Japan decided to carry out a basic design study, and the Japan International Cooperation Agency dispatched to Palau a basic design study team, headed by Mr. Hidenao Watanabe of the Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs, from August 9 to September 1, 1993, in order to examine the required and optimum contents and scale for the implementation of the project as well as to examine the nature of the request and its appropriateness and effects.

The team checked and held discussions concerning the contents of the requests, researched into the background of the project and the conditions of power transmission and distribution at the sites and confirmed the method of implementation. The team also explained to the parties concerned in Palau the system and procedures for grant aid provided by the Government of Japan. The team confirmed the scope of works shared between the Governments of both countries, in the event that the project is implemented.

Based on this site survey, JICA examined in Japan the appropriateness of the plan, its contents and scale as well as the schedule for the plan and project expenses. From November 9 to November 17, 1993, JICA sent to Palau a team to explain the draft final report, and the team compiled the results in this report.

A member list of the study team, survey schedule, a list of concerned parties in Palau, minutes of discussions and other materials are included at the end of this report as attachments.

CHAPTER 2 BACKGROUND OF THE PROJECT

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2.1 Bacground of the Project

The 34.5 KV power transmission lines, built using Japanese Grant Aid in fiscal 1984/85 between Aimeliik Power Plant and Airai Substation, and running about 20 km in length, constitutes the main power transmission system in Palau. The voltage of power generated at Aimeliik Power Plant is reduced to 13.8 KV at Airai Substation.

The Airai Substation has one 10 MVA transformer. However, with no consideration paid to design redundancy (multiplexing of systems) in the power transmission and distribution system, it is not possible to systematically stop operations for maintenance and inspection. Therefore, since the commencement of operations in 1986, not even one maintenance operation has been carried out. Therefore, concerns have been raised over the drop in insulation resistance and cooling capacity resulting from the deterioration in insulating oil, thus requiring urgent and appropriate maintenance.

A 13.8 KV power distribution line between Airai Substation and Malakal Substation supplied electricity to meet requirements in Koror and Airai States. However, power distribution lines of size to match the density of electricity needed are not installed, many examples occurred of voltage fluctuations of drops of 10% or more from the regulated 120 V at the receiving end in power distribution lines. Further, concerning the transformer for power distribution, excessive loading resulting from a shortage in capacity, the decline in life which stems from excessive loading, and flashovers resulting from high humidity and salt contamination have taken place. Also, a lack of systematic, preventative maintenance of the power distribution network and improper trimming of trees have caused grounding during strong winds and rain as well as short circuits and disconnections in the line, resulting in large-scale blackouts. Furthermore, the use of wooden electric poles has caused excessive advance in deterioration of the strength of poles. In addition, telephone and cable TV lines have been attached haphazardly to electric poles, so that the tension has caused many poles to lean markedly, creating a situation where they are about to collapse. The sag in electric lines is significant. A minimum isolation distance (clearance) is unable to be secured. This can not be allowed for safety reasons and is an undesirable eyesore in urban regions.

On the Babelthaup Island, only Airai and Aimeliik States, located in the South, are supplied with electricity. Ngeremiengui, Ngatpang, Melekeok and Ngchesar on

Babelthaup Island are yet to receive electricity despite the urgent need for agricultural, commercial and industrial development.

Based on the above conditions, the Government of Palau requested the Government of Japan to provide Japanese Grant Aid for the improvement and enhancement of power transmission and distribution facilities and the supply of electric power to areas on Babelthaup Island. The Government of Japan has decided to implement a basic design study concerning these plans.

Electricity operations in the Republic and Palau are planned and administered by the Bureau of Public Works, which is under the jurisdiction of the Ministry of Resources and Development. The Bureau controls water and sewage operations as well as electricity. As shown in Figure 2.1, the Bureau comprises two main divisions: Division of Utilities and the Division of Maintenance. Four branches come under the Division of Utilities: the Power Generation Branch, Power Distribution Branch, Water System Branch and the Sewer System Branch. Three branches come under the Maintenance Division: the Facilities Maintenance Branch, Equipment Maintenance Branch and Support Services Branch. Furthermore, a Staff Division consists of an Energy Office, Design & Engineering Office, Controlled Maintenance Office and Capital Investment Planning Office.

The Bureau controls facilities for power generation, transmission and distribution.

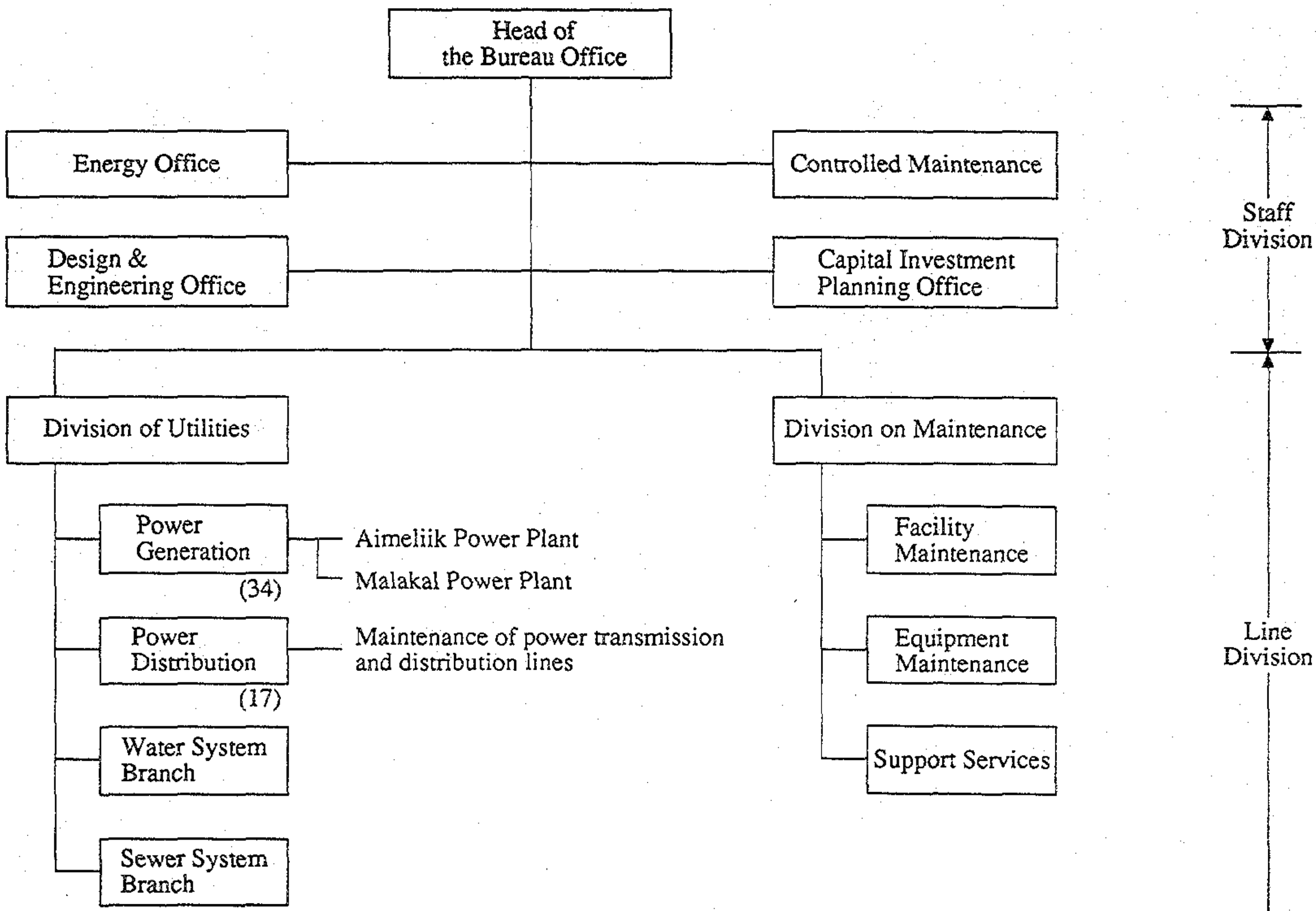


Figure 2.1 Organization of Bureau of Public Works

(Note) Figures in brackets show the total number of managers, operators and maintenance staff.

2.2 Outline of the Request

The Request deals with improving stability and reliability of the electricity supply through improving and enhancing the power transmission and distribution facilities in the Koror State, and contributing to the improvement in infrastructure and the standard of living of local residents through the supply of electricity to four non electrified states on Babelthaup Island.

The Request presented by Palau contains three phases 1–3, indicating the degree of urgency of the Request.

(1) Phase 1

1) Construction of 34.5 KV power transmission lines between Aimeliik and Airai.

2) Expansion of 9 km of 34.5 KV power transmission and 9 km of power distribution lines between Airai and Malakal/Koror.

3) Construction of 34.5 KV/13.8 KV Substation in Malakal within Koror State.

(2) Phase 2

1) Replacement of inadequate sections of 13.8 KV power distribution lines between Airai and Malakal and the installation of sectionalizers.

2) Replacement of 13.8 KV electric wire branch circuits, electricity poles and stringing.

3) Replacement of transformers, service wires and service poles where shortage in capacity is identified.

(3) Phase 3

1) Provision of 38 km of 34.5 KV power transmission lines and construction of four 34.5 KV/13.8 KV Substations.

2) Construction of 30 km of 13.8 KV power distribution lines in four States on Babelthaup Island where electricity has yet to be supplied.

The Republic of Palau was consulted about these Requests. Palau presented changes in the priorities and contents, and requested some additions. However, we explained that providing maintenance vehicles considered not necessary, and providing equipment for unidentified areas would be inappropriate, and the Republic of Palau agreed. The scope and priorities confirmed by both countries for Study are as follows:

(1) Improvement and enhancement of 34.5 KV/13.8 KV power transmission and distribution lines in the State of Koror.

1) Construction of 34.5 KV transmission line and 13.8 KV power distribution line between Airai and Malakal.

2) Renovation of 13.8 KV power distribution network in the State of Koror and installation of power distribution loop circuits and automatic sectionalizers.

3) Enhancement of existing power distribution lines following the improvement in the 13.8 KV power distribution network in the Koror State.

4) Construction of 13.8 KV/34.5 KV Malakal Substation.

(2) Construction of 34.5 KV and 13.8 KV power transmission and distribution lines in four States on Babelthaup Island where electricity has yet to be supplied.

1) Construction of 34.5 KV power transmission lines between existing substation in the Nekken district and Kokusai district and construction of 34.5 KV/13.8 KV substation in the Kokusai district.

2) Construction of 34.5 KV power transmission lines between Kokusai district and the State of Ngeremlengui and construction of one 34.5 KV/13.8 KV substation in Ibboban district in Ngatpang State and in Ngeremlengui, respectively.

3) Construction of 13.8 KV power distribution lines between the Kokusai district and the Melekeok State and between the Kokusai district and the Ngchesar State.

(3) Provision of materials and equipment for the construction of power distribution lines in four States on Babelthaup Island where electricity has yet to be supplied.

1) Power distribution lines in the Ngeremlengui State
2) Power distribution lines in the States of Melekeok and Ngchesar
3) Power distribution lines in Ibboban District

2.3 Outline of the Project Area

2.3.1 Existing Power Generation Facilities

(1) Outline

The power generation facilities of Palau use diesel engines. The power generation plants that are operational are shown in Table 2.1. The Aimeliik Power Plant is used for the base load to meet electricity demand in Koror State, where the population is concentrated. The Malakal Power Plant is looked upon as a supplier for peak load; namely, it fulfills a standby role.

Table 2.1 Power Generating Facilities

Name of Plant	Location	Capacity	Remarks
Aimeliik	Aimeliik State	4 x 3,270 KW Total 13,080 KW	#1 unit does not have an engine installed. The Government plans to purchase an engine within two to three years.
Malakal	Koror State	1 x 700 KW 2 x 1,250 KW 1 x 2,500 KW Total 5,700 KW	These units will be operational by August 1993. Of these units, 1 x 700 KW is scheduled for retirement by the end of 1994.
		1 x 600 KW 1 x 1,250 KW Total 1,850 KW	These units are expected to be operational by January 1994. In addition, the Government plans to purchase 1 x 2,500 KW (used) by the end of 1994.
Melekeok	Melekeok State	1 x 150 KW	Each of these plants come under State Government jurisdiction. They operate 6 to 7 hours a day to provide illumination at night.
Ngchesar	Ngchesar State	1 x 90 KW	
Ngeremlengui	Ngeremlengui State	1 x 125 KW	
Ibobban	Ngatpang State	1 x 50 KW	
Angaur	Angaur State	1 x 100 KW	
Peleliu	Peleliu State	1 x 300 KW	
Ngiwal	Ngiwal State	1 x 125 KW	
Ngaraad	Ngaraad State	1 x 30 KW	

(2) Aimeliik Power Plant

The Aimeliik Power Plant commenced operations in 1986 with diesel generators supplied by IPSECO of Britain. The Plant supplies electricity to Koror, Airai and Aimeliik States. The plant was originally planned to have a capacity of 5 x 3,270 KW. However, although the foundation and generator have been installed for #1 unit, the engine has not been installed. From the commencement of the operations, GICC of the Philippines was commissioned to carry out operations and maintenance work. However, in August 1991, the contract with GICC was terminated. From that time, power plant has been operated by the staff of the Bureau of Public Works of the Government of Palau under the instruction of foreign engineers. As the implementation of preventive maintenance has been relatively good, the Plant has experienced few breakdowns. However, plant trips (halts in power transmission) resulting from problems in the power transmission and distribution lines have been frequent occurrences. Although diesel engines must be overhauled after 24,000 hours of operation, the overhaul scheduled for 1991 has not been carried out yet as stopping the plant is difficult as the plant is responsible for supplying the base load and because the plant is unable to obtain the funds required for the overhaul. Furthermore, cracks in the engine foundation and excessive engine vibration have forced operations below capacity. However, even with four units that must be operated at rated capacity, total output will still be 13,080 KW. With one unit on standby, total firm output will be 9,810 KW. On the other hand, peak output in June 1993 was 9,900 KW with four units in operation. The facilities of the Aimeliik Power Plant are shown in Table 2.2.

(3) Malakal Power Plant

To date, ten diesel generators have been installed at the Malakal Power Plant. However, at present, four number of units are considered to be operational, with a total output of 5,700 KW. The Malakal Power Plant continues to operate as a supplier of electricity for peak load and as a stand by should there be an accident at Aimeliik Power Plant. However, these four units are antiquated, spare parts are in short supply, and the units suffer from a malfunctioning cooling system. As a result, the Plant operates under a condition where the availability and duty factor are far below the expected level, and output of about 3,500 KW only may be achieved. With an output of 700 KW, #2 unit is scheduled to be retired by the end of 1994. However, #8 and #9 units, each generating 1,250 KW and installed in 1980, and #10 unit generating 2,500 KW and installed in 1984, are under pressure to be able to sustain output close to rated capacity by systematically promoting an overhaul, in anticipation of a situation in the near future where the supply capacity of the Aimeliik Power Plant can not meet demand. Whether this overhaul is implemented on schedule depends on whether the Government of Palau will be able to obtain the funds needed for the maintenance of facilities. It will be essential that the Operation and Maintenance Improvement Project (OMIP), under which the United States aims to provide technical and financial assistance for power generation, transmission and distribution facilities in trustee territories, be implemented smoothly. Table 2.3 provides an outline of the facilities of the Malakal Power Plant.

Table 2.2 Outline of Aimeliik Power Plant

Location: Imelsbech District, Aimeliik State

	Unit No.	1	2	3	4	5
Engine	Capacity (HP)	Engine not installed yet	4,660	4,660	4,660	4,660
	Number of cylinders		10	10	10	10
	Rotation (rpm)		450	450	450	450
	Manufacturer		NEI-A.P.E. (Britain)			
Generator	Capacity (KW)	3,270	3,270	3,270	3,270	3,270
	Voltage (V)	13,800	13,800	13,800	13,800	13,800
	Manufacturer	Brush Electrical (Britain)				
Year installed		-	1985-3	1985-4	1985-5	1985-6
Operation conditions		Not-operational	Operational (difficult to operate each unit at capacity)			

Table 2.3 Outline of Malakal Power Plant

Location: Malakal, Koror State

Unit No.		1	2	3	6
Engine	Capacity (HP)	1,620	1,060	1,415	
	Number of cylinders	12	12	12	16
	Rotation (rpm)	600	600	600	1,200
	Manufacturer	White Superior (U.S.)			Caterpillar (U.S.)
Generator	Capacity (KW)	750	750	1,000	900
	Voltage (V)	4,160	4,160	4,160	4,160
	Manufacturer	Ideal Electric (U.S.)			Kato (U.S.)
Year installed		1970	1970	1970	1970
Operation conditions		Not-operational	Operational 700 KW	Not-operational	Operational from September 1993 600 KW

Unit No.		7	8	9	10
Engine	Capacity (HP)	1,750	1,750	1,750	-
	Number of cylinders	12	12	12	18
	Rotation (rpm)	720	720	720	900
	Manufacturer	Alco (U.S.)			
Generator	Capacity (KW)	1,250	1,250	1,250	2,500
	Voltage (V)	4,160	4,160	4,160	2,400
	Manufacturer	Ideal Electric (U.S.)			Beloit Power (U.S.)
Year installed		1980	1980	1980	1984
Operation conditions		Scheduled to be operational from January 1994 1,250 KW	Operational 1,250 KW	Operational 1,250 KW	Operational 2,000 KW

(4) Power Plants owned by State Governments

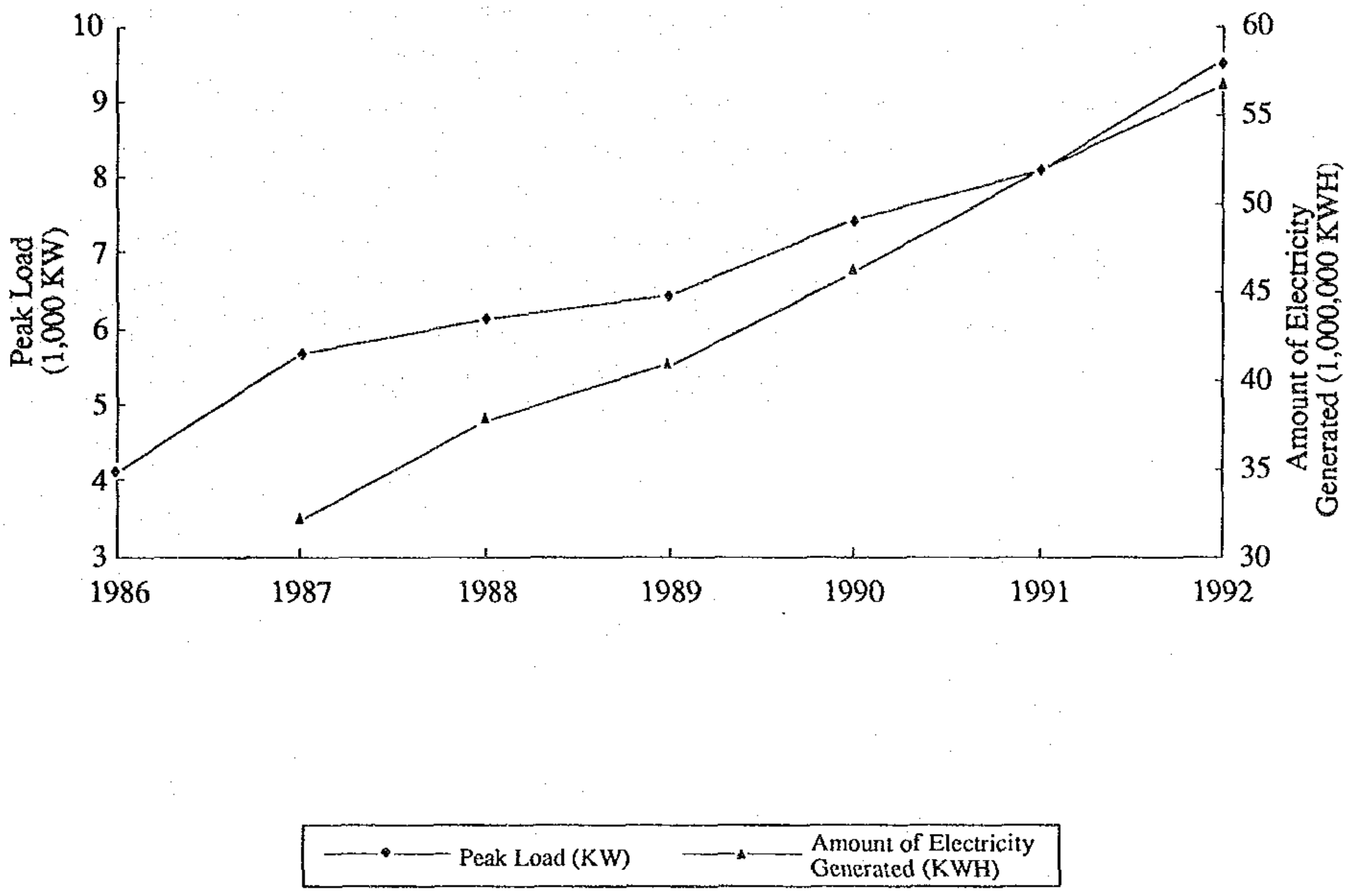
The power plants owned by State Governments are not linked to the power transmission and distribution network of the Government of Palau because they are located in depopulated areas. Furthermore, because these power generating facilities are small in capacity and are intended for emergency use and not for continuous rating, these are operated about 6 to 7 hours only a day, in order to provide lighting at night.

(5) Private Power Generating Facilities

Because the reliability of the power supply facilities of the Government of Palau is low, large power consumers in the private sector, particularly hotels and supermarkets, operate their own diesel generators. The Palau Pacific Resort (PPR) alone has capacity of 1,800 KW. Although these large consumers possess diesel generators for daily or emergency use, they hope to receive electric supply constantly from the Government once the supply improves.

(6) Changes in the amount of power generation

Figure 2.2 shows changes in the amount of power generation at Aimeliik Power Plant. For six years, between 1987 and 1992, peak load increased by 70 % and the amount of power generation increased by 76 %, registering steady growth.



Year	Peak Load (KW)	Amount of Electricity Generated (KWH)
1986	4,100	
1987	5,660	32,251,483
1988	6,120	37,768,595
1989	6,425	40,975,848
1990	7,380	46,280,670
1991	8,100	51,900,360
1992	9,500	56,685,714

Figure 2.2 Changes in Power Generation at Aimeliik Power Plant (1986~1992)

2.3.2 Electricity Development Plan

The first Five Year National Development Plan indicated that constructing Aimeliik Power Plant and 34.5 KV power transmission lines are measures needed to respond to the rapidly increasing demand for electricity and the aging of Malakal Power Plant. The Plan also identified the unit cost of power generation, electricity charges, collection of accounts, and areas to which electricity is distributed, as issues in the energy field. There are also plans to promote purchase of diesel generators (second hand) and to rehabilitate Aimeliik and Malakal Power Plants using funds from the United States' Operation and Maintenance Improvement Project (OMIP). However, as the country has not concluded a Free Association Agreement, the implementation of these plans has been delayed.

CHAPTER 3 OUTLINE OF THE PROJECT

CHAPTER 3 OUTLINE OF THE PROJECT

3.1 Objectives

The Government of the Republic of Palau considers improvement of the power distribution network in Koror State, the center of political and economic activity, an issue of great importance. The distribution of electricity to all areas on Babelthaup Island not currently connected to the power grid is also considered a significant part of the project to improve infrastructure.

The antiquated power distribution facilities in Koror State will not support further demands or extension. Accidents such as line-to-ground faults, short circuits and disconnection of power distribution lines are occurring frequently resulting in power blackouts for many hours. Voltage fluctuation and drops have exceeded acceptable limits because of a deficiency in capacity and maintenance. The conditions of power distribution remains very poor, and fall far short of the objective of the power utilities, which is to provide a reliable high-quality electric power to those requiring it. As a result, trust has been lost, and the situation is obstructing the development of the national economy. On the other hand, despite high potential for agricultural, commercial and industrial development on Babelthaup Island, progress has been restricted because of the delay in improving the infrastructure. By providing an electricity supply to non electrified areas, the population can be decentralized, assisting economic and social development, improving citizens' lives, and creating urgently needed employment.

This project therefore aims to provide a reliable electricity supply through improvement and enhancement of the power distribution network in Koror State with Grant Aid provided by the Government of Japan. This project also aims to promote extension of the power distribution network to other States by extending transmission and distribution lines on Babelthaup Island.

3.2 Study and Examination on the Request

3.2.1 Project Appropriateness and Justification

(1) Outline

Based on information obtained from the Government of Palau and existing related information, the project will extend over ten years in terms of planning period, commencing in 1995. The process will commence with design of power transmission and distribution facilities, and extend until the commencement of use of facilities scheduled in 1995. When examining the capacity and size of transformers, power distribution lines and other components, it is necessary to consider the increase in electricity demand during the period of the project. Therefore, the electricity demand in Koror State as well as in areas currently without electricity will be forecast.

(2) Scale and Function of Power Transmission and Distribution Facilities in Koror State

The 34.5 KV power transmission lines between Aimeliik Substation and Airai Substation were constructed in anticipation of a maximum electricity demand of 9,000 KW. However, in June 1993, a record output of 9,925 KW at the generating end occurred. Even when the supply capacity of Aimeliik Power Station is enhanced, any requirement above 9,000 KW in Koror and Airai States will be supplied by the Malakal Power Plant. This will be necessary to compensate for the loss of electricity during transmission, and restrictions of transmission line capacity. As Malakal Power Plant is close to the demand center, voltage drops, fluctuations and power loss should also be reduced. As will be mentioned in the next section (3), the forecast maximum electricity demand in 2005 will be 19,200 KW. Of this, power transmission lines between Aimeliik and Airai will supply 9000 KW. The remaining 10,200 KW will be supplied by lines between Malakal and Airai. The application of these two systems is considered to be rational. Furthermore, it has become an urgent issue to shut down the 10 MVA transformer located at Airai Substation, which began operating in 1986, for inspection and maintenance. As it will be necessary to continue power transmission to Koror and Airai States while the Airai Substation is shut down, a switch will be installed at the incoming feeder at Airai Substation, enabling flow of power from Aimeliik Power Plant to be bypassed to Malakal Substation. A 10 MVA transformer will be installed at Malakal Substation. The power transmission lines connecting Malakal Substation will be 34.5 KV and 10 MVA lines, the same as those between Aimeliik and Airai. The existing line voltage of 13.8 KV is appropriate for power distribution lines in Koror State.

Improving the supply capacity of Malakal Power Plant, enhancing Malakal Substation and upgrading the power transmission lines between Aimeliik and Airai will need to be reconsidered to respond to mid and long term electricity demand growth in Koror and Airai States.

(3) Forecast Electricity Demand in Koror State and Neighboring Areas

1) Present Electricity Demand (Generating End Base)

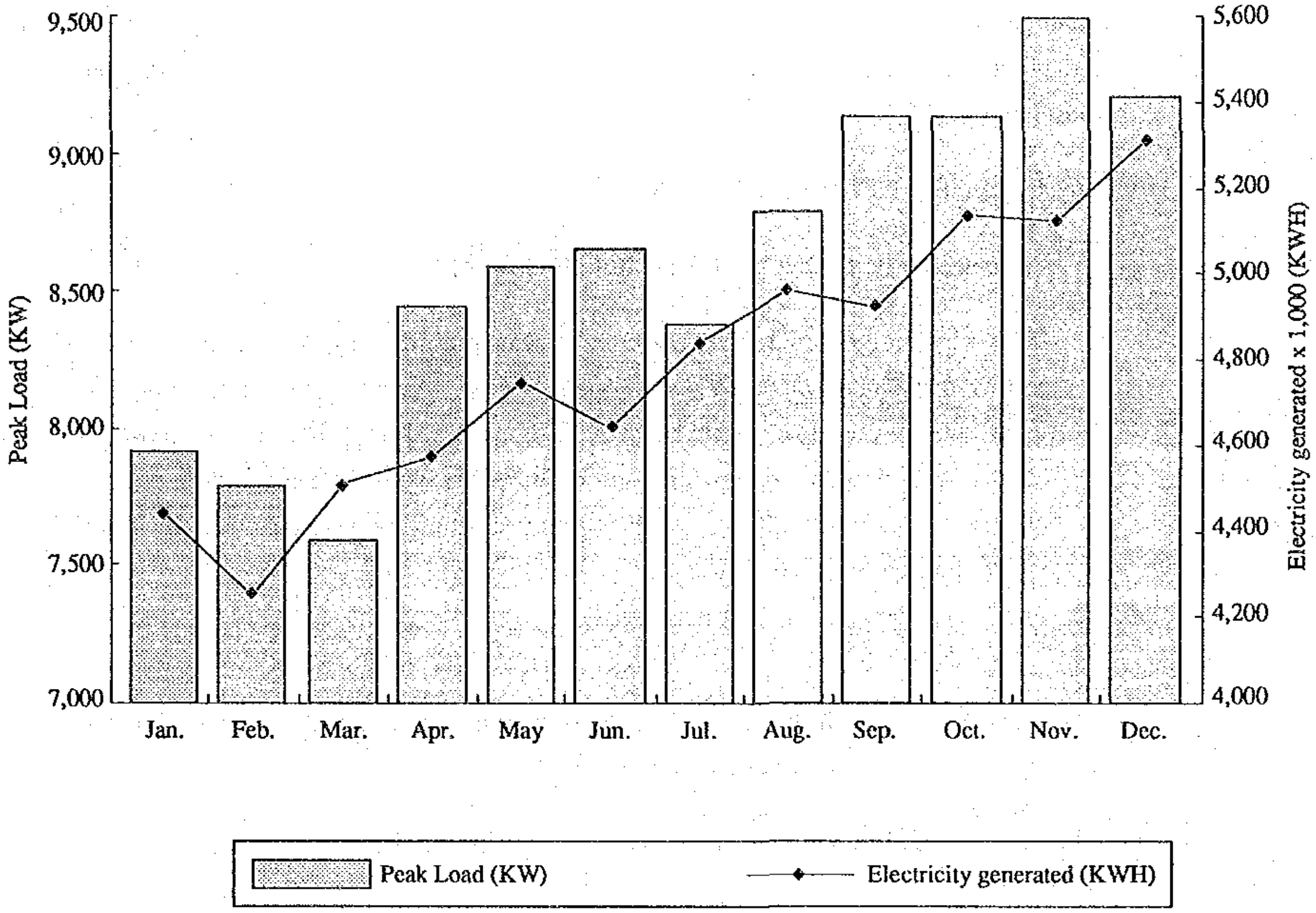
Peak electricity demand of 9925 KW was recorded in June 1993, closely followed by an estimated 9,700 KW in August. Average electricity output is 7,200 KW, with a load factor of 74 %. Figure 3.1 shows changes in maximum electricity demand and power generation in 1992. November is a month of peak electricity generation, in response to high use of air conditioners. To illustrate, Figure 3.2 shows the daily load curve on November 17.

2) Present Electricity Demand by Use

Table 3.1 shows the electricity used and the number of subscribers, based on the collection of electricity charges (July 1993).

Table 3.1 Electricity Consumption by User

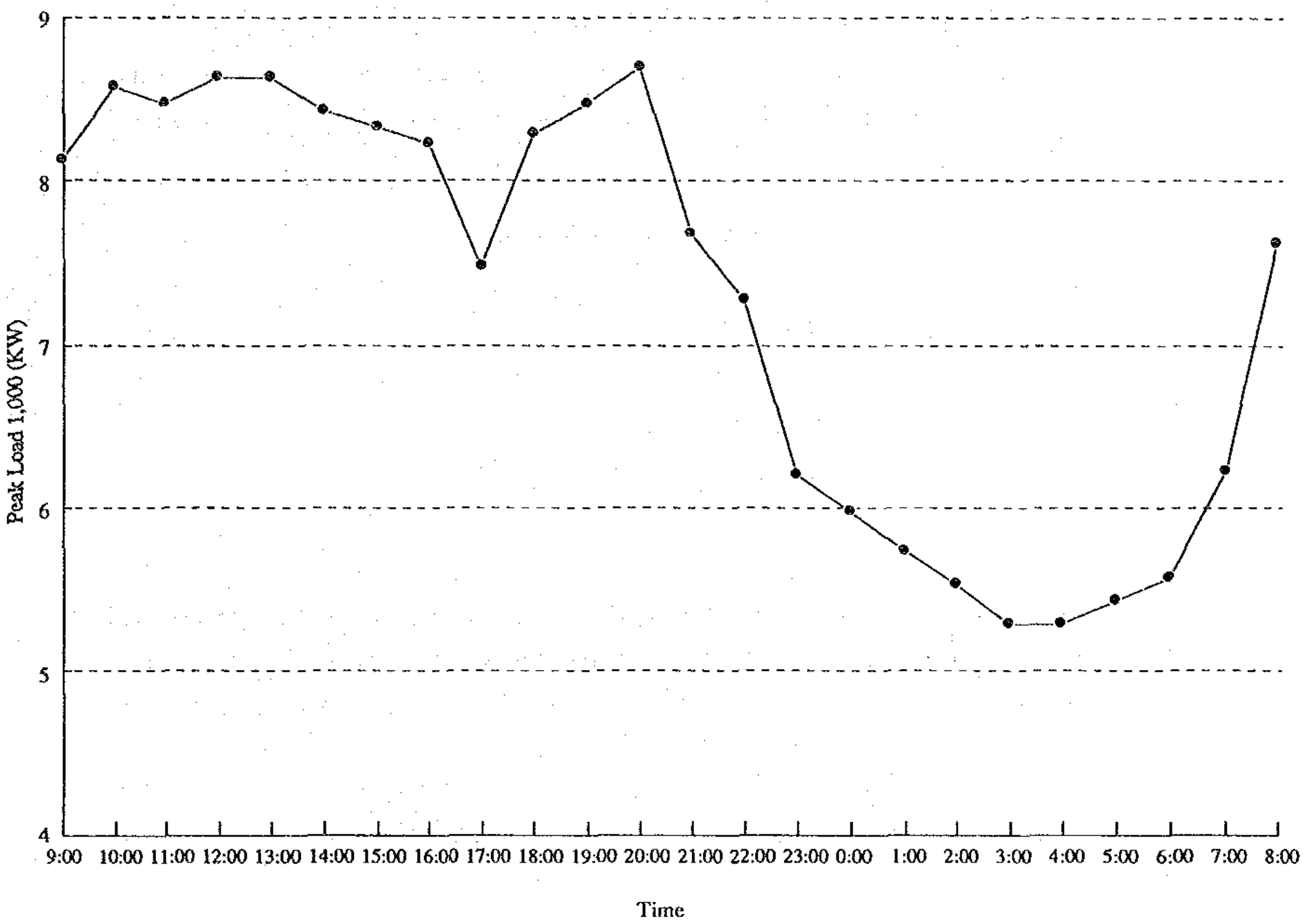
Use	Electricity Consumed (KWH)		Number of subscribers (Accounts)
① Household	1,353,033	(38.3 %)	2,352
② Commercial	1,651,259	(46.8 %)	292
③ Government	526,816	(14.9 %)	134
Total	3,531,108	(100 %)	2,778



	Jan.	Feb.	Mar.	Apr.	May	Jun.
Peak Load (KW)	7,930	7,800	7,600	8,450	8,600	8,660
Electricity generated (KWH)	434,960	4,250,305	4,512,029	4,575,060	4,747,290	4,642,040

	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Peak Load (KW)	8,390	8,800	9,150	9,150	9,500	9,220
Electricity generated (KWH)	4,837,990	4,965,220	4,927,870	5,138,990	5,127,040	5,315,310

Figure 3.1 Changes in Amount of Electricity Generated at Aimeliik Power Plant



Time	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00
Average	8,050	8,500	8,400	8,550	8,550	8,350	8,250	8,150	7,400	8,200	8,400	8,320

Time	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00
Average	7,600	7,200	6,125	5,900	5,650	5,450	5,200	5,200	5,350	5,500	6,150	7,550

Fig. 3.2 Daily Load Curve at Aimeliik Power Plant (November 1992)

Many government facilities do not have watt-hour meters installed, and payment of electricity charges is based on estimated use. Therefore, the 14.9 % figure for Government facilities is probably much lower than actual consumption, which we estimate to be about 25 % of the total based on the site survey. Using this adjusted figure of 25 %, the corrected proportions of electricity use are presented in Table 3.2.

Table 3.2 Proportion of Electricity Use

① Households	34
② Commercial	41
③ Government	25
Total	100 %

3) Forecast of Electricity Use

The load curves for general households, commercial operations and government facilities vary, reflecting the hours of maximum electricity demand for each of these user groups. Therefore, although there is no strict relationship between maximum electricity demand and the amount of electricity consumed, it is believed that the movement of the former can be estimated based on the growth of the latter. Such estimations will be used as a reference to forecast electricity demand.

(1) Households

Electricity generated by both the Aimeliik and Malakal Power Plants is mostly consumed in the three States of Koror, Airai and Aimeliik. The total population in these areas is estimated to be about 13,000 in 1993, based on the 1990 figure of 12,174. The electricity generated in 1992 was 56.7 GWH. The electricity generated in 1993 is estimated to be 60 GWH, based on past growth rates, enabling an estimate of the electricity consumed per month per capita:

60,000,000 KWH x 34 %/12 = 1,700,000 KWH/month
1,700,000/13,000 = 130 KWH/person/month

As it is expected that home electric appliances installation will increase along with economic development, and that per capita electricity consumption will also increase, the growth rate ten years from now is estimated to be 30 %, with consumption of

170 KWH/person/month. It is estimated that the combined population for the three States will increase from 13,000 in 1993 to 16,500 in 2005 (2.5 % annual increase). Based on these figures, electricity consumption will be:

170 KWH/person/month x 16,500 = 2,805,000 KWH/month
2,805,000/1,700,000 x 100 = 165 %

This consumption will be a 65% increase on 1993 consumption. The maximum electricity demand in 2005 is estimated to be 5600 KW, based on maximum electricity demand in 1993 of 10,000 KW (10,000 KW x 34% x 165%).

(2) Commercial Users

If we estimate that commercial users will be responsible for 41 % of maximum electricity demand (10,000 KW), the electricity demand of this sector will be 4,100 KW. Palau Pacific Resort (PPR) operates its own generators with a capacity of 1,800 KW, and a maximum load of 800 KW. PPR has requested to receive 500 KW from the Government's power distribution system, as they intend to increase their number of guest rooms. In any event, PPR wishes to receive electricity for existing demand if power distribution conditions improve. Therefore, PPR alone will have a maximum electricity demand of 1,300 KW. Apart from PPR, it is expected that others may wish to change from generating their own electricity to purchasing electricity from the Government. Given this scenario, present electricity demand for commercial users is estimated to be 5,400 KW. Assuming that gross domestic product will continue to rise at an annual rate of 10% as in the past 5 years, and that electricity demand will increase accordingly, demand from commercial users is expected to reach 11,900 KW (5,400 x 220 %) by the year 2005.

(3) Government Users

Electricity demand from government users accounts for 25 % of all the electricity used. However, if we assume that the growth rate of maximum electricity demand from this sector will be 50%, lower than that of households, the electricity demand will be 3,800 KW (10,000 KW x 25 % x 150 %).

4) Total Maximum Electricity Demand

Forecast maximum electricity demand in the year 2005 is presented in Table 3.3.

Table 3.3 Forecast for Maximum Electricity Demand

① Households	5,600 KW
② Commercial Users	11,900 KW
③ Government Users	3,800 KW
Total	21,300 KW

5) Total Maximum Electricity Demand After Correction Through Promotion of Economy in Electricity Use

As most government facilities do not have watt-hour meters installed and charges are kept low in relation to the cost of power generation, government as well as private sector awareness about economical use of electricity is poor, resulting in waste of valuable energy. It is vital to restrain the growth in electricity demand by implementing systematic programs to promote the wise use of electricity, as well as adopting more efficient electrical equipment. If we set the targeted value of electricity restraint implemented through economy measures at 10 %, the total maximum electricity demand in 2005 will be 19,200 KW (21,300 KW x 90 %). For reference, Figure 2.2 shows the maximum electricity demand in the past five years (based on the generating end).

1989	6,425 KW
1990	7,380 KW
1991	8,100 KW
1992	9,500 KW
1993	10,000 KW (projected)

Assuming continued annual growth of 900 KW, the maximum electricity demand in 2005 will be 21,000 KW.

6) The Balance of Electricity Supply and Demand

Maximum electricity demand is expected to increase from 10,000 KW in 1993 to 19,200 KW in 2005. The present supply capacity at Aimeliik Power Plant is 12,800 KW, even when the project's reserve capacity is mobilized, and

3,500 KW for Malakal Power Plant, a total of 16,300 KW. If we assume that the power generation capacity can be maintained at the present level, and that spare capacity of 20 % can be secured, the supply capacity will be 13,000 KW. It is forecast that this capacity will meet demand until around 1997 (Figure 3.3). Even if electricity controls such as peak cut and peak shift operations, and measures to economize electricity use are taken, it is believed that the supply capacity will be inadequate before the year 2000. It will be necessary to implement mid- and long-term measures such as installation of an engine to the #1 unit at Aimeliik Power Plant to secure reserve capacity, and installation of two additional 2,500 KW class generators at Malakal Power Plant, along with the rehabilitation of existing facilities at that plant.

(4) Forecast Electricity Demand on Babelthaup Island

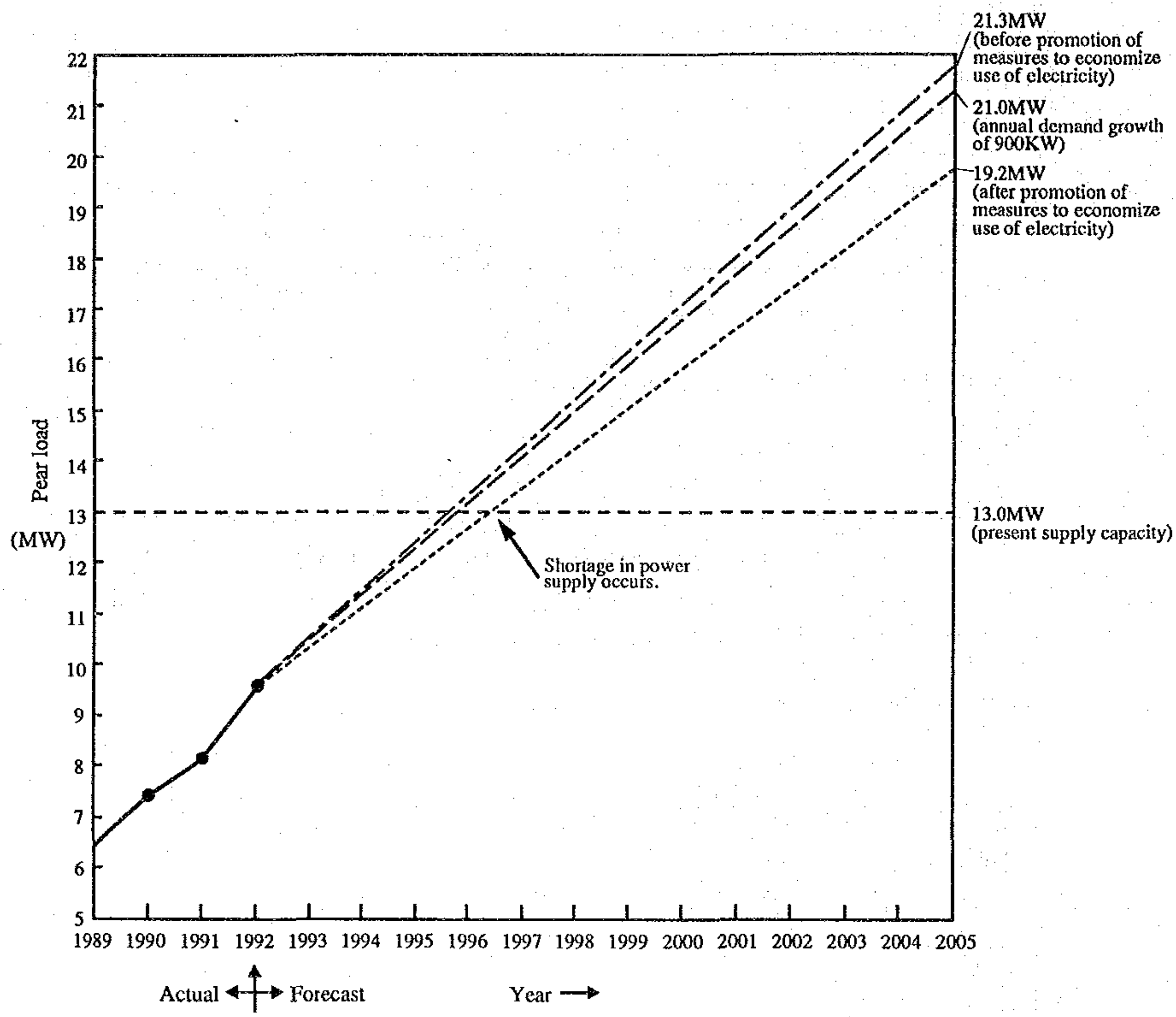
1) Present Electricity Demand

Diesel generators located in areas without electricity are used for night lighting. These generators are located in places where electricity demand exists. Table 3.4 indicates the capacity of existing generators, electricity demand, and the population likely to benefit from electricity provision.

Table 3.4 Electricity Conditions in Four States without Electricity

State	Capacity of generators (KW)	Average electricity demand (KW)	Population	Number of households
Melekeok	150	100	244	49
Ngchesar	90	50	287	61
Ngeremiengui	125	80	281	55
Ngatpang	50	(40)	62	29
Total	415	270	874	194

While the electricity supply in these regions remains poor and economic development is slow, electricity demand will remain small.



Year	1989	1990	1991	1992	1993	1994	1995	1996
Peak load	6.4	7.4	8.1	9.5	10	10.8	11.6	12.4

1997	1998	1999	2000	2001	2002	2003	2004	2005
13.2	14	14.8	15.6	16.4	17.2	17.9	18.6	19.2

Fig. 3.3 Forecast for Electricity Demand and Supply Balance

2) Forecast Maximum Electricity Demand

In 2005, the maximum household, commercial and government electricity demand in the three States of Koror, Airai and Aimeliik will be 19,200 KW. The estimated population of these areas will be 16,500, giving a per capita consumption of 1.2 KW. However, the pace of supply establishment in these regions may vary, depending largely on whether large-scale development projects are implemented. If we assume that most of the electricity demand comes from households, and degree of electricity consumption is about the same as that of the three States with electricity, per capita electricity demand is calculated at 0.34 KW (5,600 KW/16,500 persons). However, as the Government of Palau has indicated the high priority it places on the provision of infrastructure on Babelthaup Island, decentralization and development are likely to raise the per capita electricity demand to 0.5 KW, and the population growth rate to 5 %.

3) Forecast Maximum Electricity Demand by Region

Table 3.5 indicates the forecast electricity demand in 2005.

Table 3.5 Forecast for Maximum Electricity Demand in Four States without Electricity

State	Maximum Electricity Demand (KW)
Melekeok	200
Ngchesar	230
Ngeremiengui	230
Ngatpang	50
Total	710

Note: Areas other than the Ibboban district in Ngatpang State received electricity in fiscal 1984/85 through Japanese Grant Aid. However, this forecast electricity demand includes demand from populations living in areas other than the Ibboban district.

3.2.2 Implementation and Administration

(1) Principal Implementation Body

The principal body for the implementation of this project will be the Ministry of Resources and Development of the Republic of Palau, and maintenance and control of facilities after completion will be carried out by the Bureau of Public Works, which comes under the jurisdiction of the Ministry. The Bureau of Public Works administers public works, principally electricity, water and sewerage.

Electricity charges are currently set at 9¢ per 1 KWH. This covers fuel and personnel expenses, but not facility depreciation or repair expenses. As a consequence, there is a chronic shortage of financial resources for the administration, maintenance and control of the electricity supply facilities, resulting in difficulty in maintaining the facility capacity at a rational level.

(2) Establishment of PUC and Outline of its Administration

The Government of the United States has been making strong requests to the Government of Palau to separate the electricity sector from the Bureau of Public Works, and form an independent authority such as a Public Utilities Corporation (PUC), as is the case in other countries in the southwest Pacific.

Establishment of the PUC would create an independent business body capable of generating finances to support efficient operations projects in a wide field covering organization, human resources, administration, finance and so forth.

A bill concerning the establishment and administration of the PUC has been discussed in the Palau legislature for a long time, and the PUC is expected to be set up in the near future. Key features of the PUC are outlined below.

1) The debt repayment obligations of Aimeliik Power Plant will not be borne by PUC.

2) After the bill is passed, the President of Palau will appoint five PUC Directors (all Palauan). The Board of Directors will select the Chairman and Vice Chairman, and will appoint a President to oversee the organization. The President will supervise employment of workers to establish an administration system in accordance with policies set out by the Board of Directors.

3) Until the PUC's administration system is established, the Ministry of Resources and Development will carry out operations on its behalf.

4) Electricity charging schemes in other Pacific countries will be examined to find appropriate models for the setting of charges in Palau.

3.2.3 International Assistance and Related Projects

In response to increasing electricity demand, the Government of Palau expects to purchase one 2,500 KW diesel generator (second hand), using funds scheduled to be supplied under the Operations and Maintenance Improvement Project of the Government of the United States. The establishment of the PUC is imposed as a precondition to the application of these funds. Purchase of the diesel generator has therefore not been finalized. There is no project involving assistance from international institutions.

3.2.4 Elements of the Project

This project involves providing electricity supplies to four States on Babelthaup Island, as well as the improvement and enhancement of the power distribution network in Koror State. The project comprises the following elements:

(1) Improvement and enhancement of 34.5 KV/13.8 KV power transmission and distribution lines in Koror State.

(2) Construction of 34.5 KV and 13.8 KV power transmission and distribution lines to the four non electrified states on Babelthaup Island.

(3) Provision of materials and equipment for construction of power distribution lines on Babelthaup Island.

The objectives of this project are to secure a reliable supply of electricity, and to distribute power to four non electrified areas. Improving power transmission and distribution facilities is a vital element in this project. The provision of electricity to these communities is considered a worthwhile and necessary project, and the whole request is therefore considered to be an appropriate project for funding assistance.

3.2.5 Facilities and Equipment Requested

The major elements of this project are the three items shown in the previous clause, 3.2.4. All these items are believed to be the minimum required in order to secure a reliable supply of electricity and expansion of the supply grid, both of which are primary objectives of this project.

(1) Improvement and Enhancement of Power Distribution in Koror State

Makeshift expansion of the power distribution network has been made concerning the power transmission and distribution facilities in Koror State, in order to respond to increasing electricity demand. This has resulted in frequent voltage drops (10% or more against 120 V at the receiving end) because of the inadequate capacity of electric wires, disconnection, line-to-ground faults and power blackouts resulting from contact with trees. Furthermore, objects such as telephone lines and cable TV lines are haphazardly attached to power utility poles. This has led to the risk of pole collapse while stretching and excessive sag of electricity lines raise concerns for the contact of electric wires with houses and trees. Such serious deficiencies are common. These problems should not be ignored, not only from a technical viewpoint, but in the interest of human safety, and the preservation of landscapes.

Furthermore, as design redundancy (multiplexing of systems) has not been taken into consideration in the power transmission and distribution systems, the 10 MVA transformer at Airai Substation has not been checked for maintenance since it commenced operations in 1986. If this transformer breaks down most of Koror State will experience a power blackout.

The following measures can be taken to improve the reliability of electricity supply. By constructing the new Malakal Substation, a 10 MVA transformer, 13.8 KV switchgear and other facilities can be installed. With loop circuits installed in the power distribution network, this will be linked up to an automatic section switch to minimize the duration of power blackouts required for maintenance operations or resulting from accidents. It will be necessary to replace antiquated and inadequate electric poles, wires, transformers and power distribution lines. These measures can be summarized as:

1) Construction of 34.5 KV power transmission lines and 13.8 KV power distribution lines between Airai Substation and Malakal Substation.

2) Improvement in 13.8 KV power distribution network in Koror State and the establishment of power distribution loop circuit and automatic section switch.

3) Enhancement of existing power distribution wires following the improvement in 13.8 KV power distribution network in Koror State.

4) Construction of 13.8 KV/34.5 KV Malakal Substation.

(2) Construction of 34.5 KV and 13.8 KV Power Transmission and Distribution Lines to Babelthaup Island areas not currently supplied with Electricity.

The following three points are taken up as specific measures to provide wider electricity distribution to areas not currently connected to the grid.

1) Construction of 34.5 KV power transmission lines between the existing substation in the Nekken district and Kokusai district of Aimeliik State, and construction of a 34.5 KV/13.8 KV substation in the Kokusai district.

2) Construction of 34.5 KV power transmission lines between Kokusai district and Ngeremiengui State, and construction of one 34.5 KV/13.9 KV substation in each of Ibboban district, Ngatpang State and Ngeremiengui State.

3) Construction of 13.8 KV power distribution lines between the substation in Kokusai district to Melekeok State, and between Kokusai district and Ngcnesar State.

(3) Provision of Materials and Equipment for the Construction of Power Distribution Lines on Babelthaup Island

As the Bureau of Public Works of the Government of Palau has the implementation capacity for a maximum 13.8 KV power distribution lines, it is considered that the provision of materials and equipment for construction will be sufficient for the following four areas:

1) Ngeremiengui State
2) Ngchesar State
3) Melekeok State
4) Ibboban district in Ngatpang State

3.2.6 Technical Assistance Required

The Power Distribution Branch of the Bureau of Public Works has 17 engineers and skilled staff. These staff already carry out operations, maintenance and control of power transmission and distribution facilities. Sending specialists from Japan is therefore considered unnecessary. Furthermore, it is believed that on-the-job training during the test operations period at the site will achieve objectives concerning the 10 MVA transformers, 13.8 KV switchgear, automatic section switch and so forth. Training in Japan is therefore unnecessary.

3.2.7 Policy of Cooperation

The appropriateness and necessity of the project, technical feasibility, implementation capacity of the Government of Palau and so forth have been assessed and confirmed. In addition, the effects expected to be brought about by the project are in accordance with the purpose of Grant Aid. As a precondition for the Japanese Grant Aid, the outline of the project will be examined as follows and basic design will be implemented.

3.3 Project Description

3.3.1 Executing Agency and Operational Structure

The Ministry of Resources and Development will be in charge of administering and controlling the entire project on the Palau side. The Bureau of Public Works, which comes under the jurisdiction of the same Ministry, will be responsible for maintaining and controlling the facilities and equipment after the completion of the project. Figure 2.1 shows the organizational and personnel allocation for the Bureau of Public Works. In order to smoothly implement this project, the Office of Planning and Statistics will serve as a coordinator.

The Bureau has experience in implementing and administering project for power transmission and distribution lines and substations constructed with fiscal 1985/86 Japanese Grant Aid. The Bureau is therefore considered to have an administration system that can satisfactorily manage this project, once materials and equipment are provided.

3.3.2 Plan of Operation (Activity)

This project implements improvement and enhancement of the power distribution network in Koror State and provision of electricity to areas on Babelthaup Island. In planning this project, consideration will be given to compatibility with existing facilities and ensuring minimal outlay to effectively achieve the objectives.

The principal components of the project are:

(1) Improvement and enhancement of power transmission and distribution lines in Koror State

(2) Construction of 34.5 KV and 13.8 KV power transmission and distribution lines to four States on Babelthaup Island

(3) Provision of materials and equipment for the construction of power distribution lines to the four States on Babelthaup Island

3.3.3 Location and Condition of the Project Site

The project sites are Koror State to the south, and the four States on Babelthaup Island in the north. Koror Island comprising Koror State and Babelthaup Island are connected by the K-B Bridge.

Koror State consists of three Islands; Koror, Malakal and Arakabesan. The State contains the capital of the Palau. The city functions are relatively advanced. The project to improve and enhance the power distribution network covers the entire area of Koror State (about 18 km^2). The substation will be located in the Malakal district, in the southern part of Koror State.

The target States for provision of electricity supply on Babelthaup Island are Ngeremiengui State (65 km^2), Ngatpang State (47 km^2), Melekeok State (28 km^2) and Ngcnesar State (41 km^2). The total population for the four States is 874.

3.3.4 Outline of Facilities and Equipment

The facilities and equipment required for this project are outlined below.

(1) Improvement and enhancement of power transmission and distribution lines in Koror State

1) 34.5 KV power transmission lines and 13.8 KV power distribution lines between Airai and Malakal

2) 13.8 KV power distribution network, power distribution loop circuit and automatic section switch

3) Enhancement of existing power distribution wires following the replacement of 13.8 KV power distribution network

4) 13.8 KV/34.5 KV Malakal Substation

(2) Construction of 34.5 KV and 13.8 KV power transmission and distribution lines to four States on Babelthaup Island

1) 34.5 KV power transmission lines between existing substation in Nekken district and Kokusai district, and 34.5 KV/13.8 KV substation in Kokusai district

2) 34.5 KV power transmission lines between Kokusai district and Ngeremiengui State, and 34.5 KV/13.8 KV substations in Ibboban district and Ngeremiengui State

3) 13.8 KV power distribution lines between Kokusai district and Melekeok State, and between Kokusai district and Ngcenesar State

(3) Provision of Materials and Equipment for the Construction of Power Distribution Lines to Four States on Babelthaup Island

1) Materials and equipment for the construction of power distribution lines in Ngeremiengui State

2) Materials and equipment for the construction of power distribution lines in Melekeok and Ngcnesar States

3) Materials and equipment for the construction of power distribution lines in Ibboban district.

3.3.5 Operation and Maintenance Plan

This project requires the same level of facility capacity and design specifications as those of existing power transmission and distribution lines and substations. Therefore, except for the automatic section switch, the maintenance and control of new facilities will remain the same as for existing facilities. As facilities only work at full capacity when they are appropriately operated and maintained, maintaining and controlling facilities is extremely important. In particular, visual inspection of sites and tree trimming will be important activities to reduce the frequency of line-to-ground faults.

In the process of implementing this project, maintenance criteria sheets, maintenance procedures and checklists will be prepared to assist maintenance and control activities conducted by the Republic of Palau.

3.4 Technical Cooperation

As stated in section 3.2.6, no Japanese specialists are dispatched, nor is Japan-based training needed.

CHAPTER 4 BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4.1 Design Policy

The power transmission and distribution facilities of this project will comprise the key component of the electricity supply system in Palau. Basic design will therefore be conducted in accordance with the following design policies.

(1) Reliability and Safety of Facilities

The factor which should be given first priority is that the entire power generation, transmission and distribution system, and the materials and equipment that comprise it, should display high reliability. This reliability must be maintained for a long period at a comprehensively high level, and ensure equipment and human safety. Operations, maintenance and inventory control for spare parts must be jointly planned so that equipment or component breakdowns can be quickly repaired, allowing continuous operation.

(2) Convenience of Maintenance and Control

Design should focus on convenience so that maintenance and control of power transmission and distribution facilities will not require special knowledge or skills, and can be implemented safely and easily. In particular, standard items must be used for electric poles, transformers, switches, electric wires, insulators and metal fixtures. The range of products and sizes should be minimized, and compatibility between equipment and components must be ensured. Design and planning of operations and maintenance should also consider compatibility with specifications of existing facilities.

(3) Economy of Designing

While ensuring convenience and reliability, consideration should be given to the use of standard products at the equipment and component level, and minimal numbers of components.

4.2 Study and Examination on Design Criteria

In carrying out basic design of power transmission and distribution lines, the following design conditions should be followed.

(1) Elevation

The areas where power transmission and distribution lines are installed will be less than 1,000 meters above sea level.

(2) Climatic Conditions

1)	Design temperature	40°C
2)	Relative design humidity	Maximum 100%
3)	Design wind speed	10 min average 40 m/s (Maximum instantaneous wind speed 52 m/s)
4)	Annual average rainfall	4100 mm
5)	Annual number of days of lightning (IKL)	37
6)	Salt deposition equivalent density	0.5 mg/cm^2
7)	Seismic force	

Equipment: Horizontal 0.4 G, Vertical 0.25 G

Foundations: Horizontal 0.2 G

(3) Applicable Standards

The following standards and criteria will be used in designing facilities and equipment.

1) Japanese Industrial Standards (JIS)
2) Institute of Electrical Engineers of Japan Standards (JEC)
3) Japan Electrical Manufacturers' Association Standards (JEM)
4) Japanese Electric Wire and Cable Makers' Association Standards (JCS)
5) Technical Standards on Electric Facilities
6) American National Standards Institute (ANSI) standards
7) National Electrical Manufacturers' Association (NEMA) standards
8) Rural Electrification Administration (REA) standards
9) National Electrical Safety Code (NESC)

Note: The U.S. standards in 6) — 9) are used in part to supplement Japanese standards concerning specifications on transformers located on poles, isolation distance of power transmission and distribution lines, and safety facilities.

(4) Unit System for Usage

The international unit system (SI unit) will be used. However, U.S. unit system will also be used where required for safety considerations in carrying out operations, maintenance and control.

(5) Voltage and Wiring System

Using the formula created by Mr. Still, 54 KV is the most economically advantageous voltage for the power transmission lines. However, as existing facilities use 34.5 KV and technical compatibility with the existing system is considered an important factor, 34.5 KV will be used.

$$V = 5.5\sqrt{0.6 \times L + P/100}$$

$$= 54 \text{ KV}$$

Where V = Voltage of power transmitted (KV)

L = Line length of power transmission lines
= 9 km

P = Capacity of power transmission
= 9000 KW based on 10 MVA transformer

The basic specifications for power transmission and distribution lines are as follows.

Table 4.1 Basic Specifications for Power Transmission and Distribution Lines

Item	Power transmission line	Power distribution line	For lighting	For power
Nominal voltage	34.5 KV	13.8 KV	120/240 V	208 V (3 x 120 V)
Maximum voltage used	36.5 KV	14.52 LV		
Wiring method	3 phase 4 wires	3 phase 4 wires	Single phase 3 wirs	3 phase 4 wires
Frequency	60 Hz	60 Hz	60 Hz	60 Hz
Earthing method	Multiple earth at neutral point	Multiple earth at neutral point	-	-

Note: specifications for lighting and power are shown for reference; they are not included in this project.

4.3 Basic Plan

4.3.1 Site and Layout Plan

Site and layout are planned as follows.

(1) New Malakal Substation

A site adjacent to the existing Malakal Substation will be used for this substation. A 10 MVA transformer, 13.8 KV switchgear and so forth will be installed in the new Malakal Substation. The transformer and switchgear will be designed for outdoor installation. However, in consideration of the operations and monitoring at the switchgear, only the switchgear will be covered with a roof. After construction of the new substation, the existing substation will be removed by Palau.

(2) 34.5 KV/13.8 KV power transmission and distribution lines between Airai Substation and new Malakal Substation.

As houses and commercial facilities are concentrated in the city of Koror, the location of the lines will come under some restrictions. Therefore, 34.5 KV/13.8 KV power transmission and distribution lines will be constructed along the major road in the city as in the case of the existing 13.8 KV power distribution lines. Which side of the road, left or right, these power transmission and distribution lines will be located on in each section will be determined by considering obstacles, the degree of difficulty of installation and so forth. Palau will remove existing power distribution lines as necessary.

(3) Power Transmission and Distribution Lines in Non-Electrified Areas on Babelthaup Island

34.5 KV/13.8 KV power transmission and distribution lines will be constructed along existing roads. Therefore, it should be set as a precondition that both major and access roads will be improved before the commencement of construction to ensure a smooth transportation of equipment and materials. Unmade roads should be surfaced with quarry rubble, and have drainage ditches formed. In accordance with Palau regulations on facilities, a verge of 2.4 meters along existing roads should be maintained for constructing and servicing poles.

4.3.2 Facility Plan

Power transmission and distribution facility design will be based on design policies and conditions described anove. The chief design specifications and functions are set out below.

(1) Basic Design Specifications

1) Insulation Design

By ensuring insulation and compatibility between elements that comprise power transmission and distribution facilities, adequate insulation should be achieved for the entire system. Equipment should be protected from abnormal voltage entering the power transmission and distribution system. A lightning arrestor and overhead grounding wires will protect equipment against lightning strike, and insulation characteristics in the equipment will protect against switching surge and commercial frequency abnormal voltage. Insulation design for switching surge and commercial frequency design are shown in Tables 4.2 and 4.3, respectively.

Basic impulse insulation level (BIL) are: 34.5 KV system - BIL 200 KV, and 13.8 KV system - BIL 110 KV.

2) Design against Salt Contamination

As power transmission lines and distribution lines will be located within a few kilometers of the coast, salty spray will be deposited on the lines by strong winds. Although insulators may get stained or damaged by the salt content, as the annual rainfall is high it is possible that salt deposited on insulators may be washed off and therefore will not accumulate over a long period. For this project, assuming salt deposition equivalent to that caused by typhoons, the equivalent salt deposition density to 250 mm suspension insulators will be 0.5 mg/cm^2. Table 4.4 shows the results of an examination of constant withstand voltage against commercial frequency when the insulator is stained or damaged.

3) Lightning Protection Design

The number of days of lighnting throughout the year (IKL) is 37 days. However, the incidence of lightning strikes entering the lightning arrestor in the substation is minimal. Therefore, lightning arrestors should be installed on the incoming feeder or transformer located in each substation to protect them from lightning strike. To protect 34.5 KV power transmission lines and 13.8 KV power distribution lines, which are key lines, a system of overhead grounding wires and neutral conductors in common will be employed.

Table 4.2 Switching Surge Withstand Voltage Design

Nominal voltage (KV)		34.5	13.8	
Maximum allowable voltage (KV)		36.5	14.52	
Peak value of voltage to ground (KV)		29.80	11.27	$Um \times \frac{\sqrt{2}}{\sqrt{3}}$
Switching surge in multiples (between lines)		2.8 (4.5)	2.8 (4.5)	
Switching surge voltage (KV)		84 (135)	34 (54)	$Um \times \frac{\sqrt{2}}{\sqrt{3}} \times n$
Correction factor		1.2	1.2	
Required insulation strength (KV)		101	41	
Withstand voltage of insulators	1 insulator 250 mm	75	75	
	2 insulators 250 mm	155	155	
	3 insulators 250 mm	220	-	
	4 insulators 250 mm	290	-	
	LP Class 30	180	-	
	LP Class 10	-	95	
Minimum Insulation Clearance	Correction factor	1.10	1.10	
	Required insulation strength (KV)	93	38	
	Required clearance (cm)	16	7.5	
	Minimum insulation clearance (cm)	20	10	
Phase to Phase Insulation Clearance	Correction factor	1.10	1.10	
	Required insulation strength (KV)	149	60	
	Required clearance (cm)	28	12	
	Insulation clearance phase to phase (cm)	30	15	

Table 4.3 Commercial Frequency Design

Nominal voltage Uo (KV)		34.5	13.8	
Maximum allowable voltage Um (KV)		36.5	14.52	
Maximum voltage to ground (KV)		21.1	8.4	
Insulation Clearance in Abnormal Condition	Correction factor	1.1	1.1	
	Voltage withstand required (KV)	24	10	
	Clearance for the above (cm)	9	4	0.35 V
	Insulation clearance in abnormal condition (cm)	9	4	
Insulation Clearance Phase to Phase in Abnormal Condition	Correction factor	1.1	1.1	
	Voltage withstand required (KV)	41	16	
	Clearance for the above (cm)	15	6	0.35 V
	Insulation clearance in abnormal condition phase to phase (cm)	15	6	

4) Protection Relay System

A protection relay system is required to accurately and quickly detect faults in the substations and power transmission and distribution lines, protect equipment, isolate sections where faults have happened and minimize the duration of power blackouts. The outline of the protection relay system in the major equipment and lines is:

a. Main Transformer

Main transformer should be protected by installing proportion ratio differential relay, Buchholtz relay, pressure relay and temperature gauge.

b. Transmission Lines

Over current relays and over current ground relays on power transmission lines should enable detection and isolation of line-to-ground faults and short circuits.

c. Distribution Lines

Lines should be protected by installing a section switch and a fault detection relay on power distribution lines, and linking them to the circuit breaker in the substation (details are explained in Section (4) of 4.3.2.)

Table 4.4 Design Against Salt Contamination

Nominal voltage Uo (KV)		34.5	13.8	
Maximum allowable voltage Um (KV)		36.5	14.52	
Maximum voltage to ground (KV)		21.1	8.4	
Salt deposition equivalent density (mg/cm^2)		0.5	0.5	Lower surface
Distance from sea shore (km)		0 ~ 5	0 ~ 5	
Withstand voltage of insulator	1 suspension insulator (KV)	6.7	6.7	
	2 suspension insulators (KV)	13.4	13.4	
	3 suspension insulators (KV)	20.1	-	
	4 suspension insulators (KV)	26.8	-	
	LP class 1 (KV)	-	16.0	Surface leakage distance 370 mm
	LP class 3 (KV)	29.8	-	Surface leakage distance 840 mm

(2) Design Specifications for the Power Transmission and Distribution Lines

1) Design of Support Structures

a. Support Structures

The support (electric pole) for the power transmission and distribution lines should be made of centrifugal prestressed concrete in order to protect itself from corrosion caused by salt contamination and to ensure strength and durability. The metal used for the poles and installing the lines to electric poles should be treated with galvanized plating. The concrete poles should be between 12 and 16 meters in height, with about 700 ~ 1000kgf of design load.

b. Support Span

The span of the concrete poles is determined by taking into consideration such factors as the tension of electric wires, the relation between the sag of electric wires and the height from the ground, geography, the existence of obstacles and economy. Standard spans are as follows:

Urban: 40 ~ 50 meters
Rural: 50 ~ 60 meters

c. Support Clearance

Tables 4.5 ~ 4.9 show the clearance in accordance with the status of facilities for electric lines, based on NESC standards. Figure 4.1 shows the general support structure and clearance.

d. Example of Assembly

The Basic Design Drawing (Section 4.3.4) provides typical examples of the assembly of concrete poles used for power transmission and distribution lines.

2) Insulator Design

In accordance with the status of electric lines, we will use an LP insulator for straight poles and a combination of suspension and LP insulators for angled poles. Based on the results of the examination in (1) above, Table 4.10 shows the application of insulators.

Table 4.5 Ground Clearance (NESC Table. 232-1)

(Unit : m)

Conditions below Wire and Conductor		Guy wire	Ground wire	Neutral Line	13.8 KV distribution wire	35.5 KV transmission wire
Crossing road	Road	5.5	5.5	5.5	6.1	6.4
	Road in residential area without truck traffic (exceeding 2.5 meters in height)	3.0	3.7	3.7	6.1	6.4
	Farmland, ranch or wood, with vehicle traffic	5.5	5.5	5.5	6.1	6.4
	Road or place with pedestrians only	2.45	4.6	4.6	4.6	4.9
Line along the road	Urban or town roads	5.5	5.5	5.5	6.1	6.4
	Roads without vehicle traffic under the line	4.3	4.3	4.3	5.5	5.8

Notes
1. 4.9 meters at road end.
2. Add 30 mm for every 3 meters of span when the span exceeds 75 m, and when the maximum operating temperature of the conductor is less than 50 °C.
3. The values in the table are the sag at the maximum temperature of the conductor, when its maximum operating temperature is more than 50C.

Table 4.6 Height of Equipment Structure above Ground (NESC Table 232-2)

(Unit : m)

Conditions below Charged Part		13.8 KV distribution line	34.5 KV transmission line
When Charged Part is above Road	Road	5.5	5.8
	Road in residential area without truck traffic (exceeding 2.5 meters in height)	5.5	5.8
	Farm, ranch or wood	5.5	5.8
	Road or place with pedestrians only	4.0	4.3
When Charged Part is not above Road	Urban or town road	5.5	5.8
	Roads without vehicle traffic	4.9	5.2

Table 4.7 Clearance (NESC 234-1)

(Unit : m)

Clearance			Guy wire, ground wire, neutral line	13.8 KV distribution line	34.5 KV transmission line
Support used for illumination, traffic and other power lines		Horizontal	0.9	1.5	1.5
		Vertical	0.9	1.8	2.13
Buildings	Horizontal		0.9	1.8	2.13
	Vertical	Roof or projection not accessible by pedestrian	0.9	3.0	3.4
		Roof accessible by pedestrians	2.45	4.6	4.9
		Roof accessible by truck	5.5	6.1	6.4
		Roof accessibly by vehicles	3.0	6.1	6.4
Other objectives		Horizontal	0.9	1.8	2.13
		Vertical	0.9	2.45	2.7

Notes
1. If the clearance can not be secured, the power line must be provided with protective measures.
2. To be no less than 3 meters when the line passes over a bridge.
3. The increment for the span length and the conductor temperature shall be treated in the similar manner as with ground clearance.

Table 4.8 Vertical Distance for Clearance for Power Lines Installed on Different Supports (NESC Table 233-1)

(Unit: m)

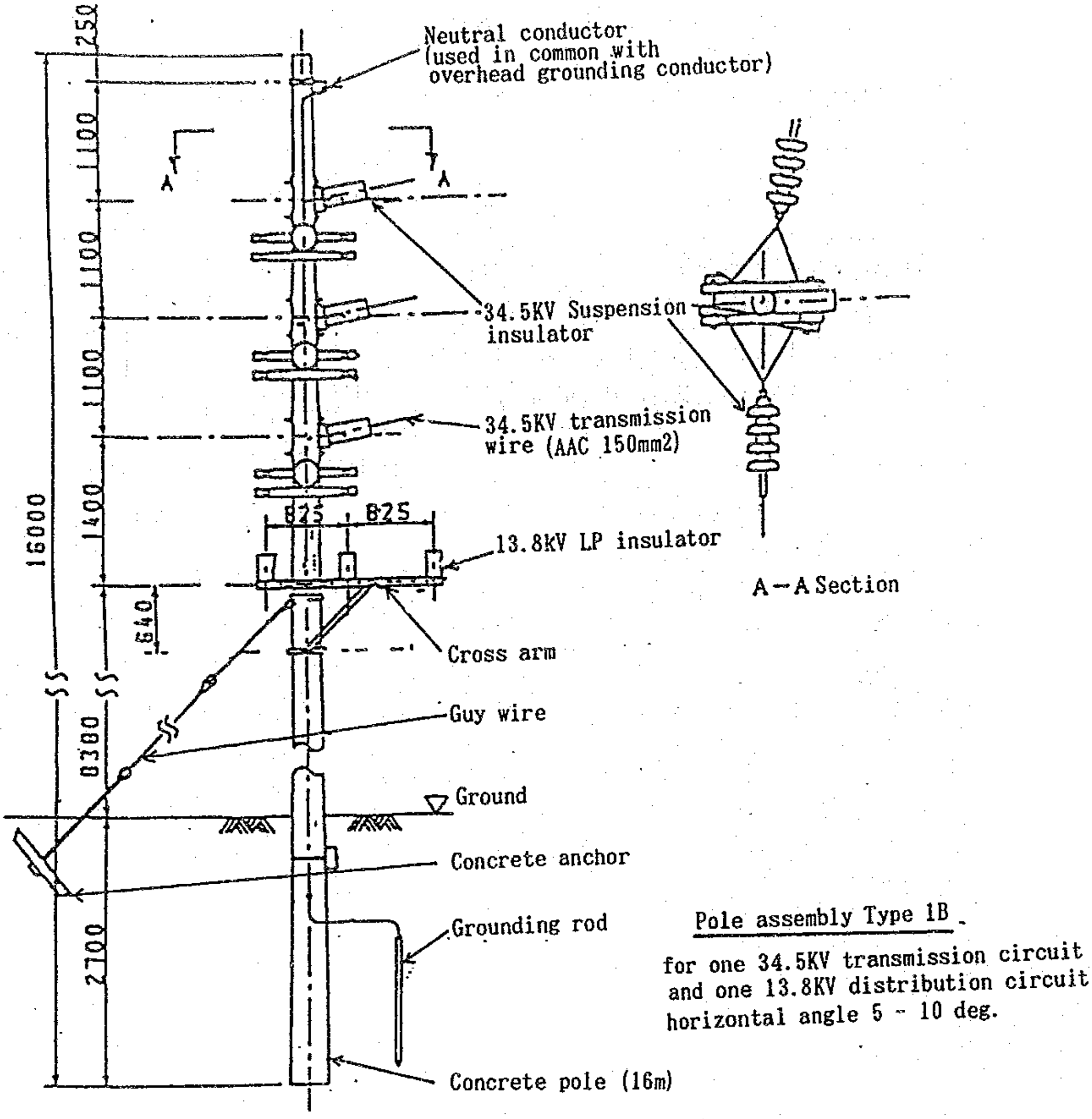
Below \ Above	Guy wire, ground wire, neutral line	13.8KV distribution	34.5KV transmission
Guy wire, ground wire, neutral line	0.6	1.2	1.2
13.8KV distribution	1.2	0.6	1.2
34.5KV transmission	1.2	1.2	1.2

Note A minimum horizontal clearance of 1.5 meters should be obtained for power lines installed in different supports.

Table 4.9 Clearance for Power Lines Installed on the Same Support (NESC Table 235-5)

(Unit:mm)

		13.8KV distribution line	34.5KV transmission line
Horizontal	Voltage line of the same circuit	351	558
	Voltage line of different circuit	351	558
Vertical	Voltage line of the same circuit	461	668
	Voltage line of different circuit	1,051	1,258



Unit:m

Conditions where wires are installed		Clearance acc. to NESC	Clearance applied for this Project
Height from ground	34.5KV Transmission wire	6.400	9.780
	13.8KV distribution wire	6.100	8.380
Voltage line of the same circuit (vertical)	34.5KV transmission wire	0.668	1.100
	13.8KV distribution wire	0.461	0.825

Figure 4.1 Support Structures and Clearance (Example)

Table 4.10 Applicable Insulators

Voltage	Electric Pole	250 mm Suspension Insulator	LP Class 10	LP Class 30
34.5KV	For straight poles	-	-	-
	For angled poles	4	-	1 ~ 2
13.8KV	For straight poles	-	1	-
	For angled poles	2	1 ~ 2	-

Notes
1. The figures in the table show the number of insulators per phase.
2. LP insulators used for the assembly of 34.5 KV poles in Koror District should be of the horizontal installation type in accordance with ANSI standards.

3) Design for Power Lines

a. Conductor Targeted for Examination

Conductors used for transmission and distribution lines must be selected from among those listed below, and the following matters must be carefully examined: Allowable current, voltage drop, tensile strength, anti-corrosiveness and cost. Particular attention should be paid to minimizing the number of different kinds of products used and the number of different sizes.

AAC : All Aluminum Conductor
AC : Aluminum Clad Steel Conductor
ACSR : Aluminum Conductor Steel Reinforced
CU : (Hard) Copper Conductor

b. 34.5KV Transmission Wire

Power transmission capacity should be set as 9,000 KW at the power factor of 90 % of the maximum capacity of the 10 MVA transformer. The drop in voltage along the 9 kilometer line between the Airai Substation and the Malakal Substation should remain within 10 % and the size of the conductor should be calculated.

As the comparison Table 4.11 shows, AAC is believed to be best suited, from an overall perspective, for use as a 34.5KV transmission wire, and its size should be 150 mm^2. As AAC - 150 mm^2 is already used in existing

34.5 KV power transmission wires, it is the most appropriate in terms of coordinating the kind and size of conductor.

We examined neutral lines assuming 1,500 Amps of current for one line-to-ground fault and a duration of one second for such an accident. AC has advantages for use as an electrical wire while in terms of tensile strength and anti-corrosiveness. As AC can be jointly used with 13.8 KV power distribution wires, we decided to use AC and selected a size of 38 mm^2.

Table 4.11 Comparison of Conductors for Transmission Lines

Type	AAC	AC	ACSR	Cu
Size (mm^2)	150	150	120	75
Allowable current (A)	430	403	390	350
Transmission capacity (KW)	23,124	21,673	20,974	18,823
Voltage drop (%)	2.7	4.3	3.4	3.0
Maximum tensile strength (N)	22,246	176,127	54,390	28,518
Anti-corrosiveness	Excellent	Excellent	Good	Excellent
Cost	100	150	95	100

c. 13.8 KV Distribution Lines

As power is distributed from Airai Substation and Malakal Substation, the power distribution capacity of the main line should be set as 9,000 KW, the voltage drop should be within 10 % and the size of the conductors should be calculated. The size of conductors for the branch lines should be selected based on forecast demand between the sections where power is distributed.

As Table 4.12 shows, AC is mechanically strong as an conductor and possesses excellent anti-corrosiveness (Note : The ACC will have an excessive sag at the maximum tensile strength when a maximum wind velocity of 52 m/s is imposed on the conductor, and cannot be adopted for the distribution lines). Given that compatibility with existing facilities is important, AC should be used. The size of conductor should be selected depending on the size of electricity demand. As peak demand by the largest consumers is 1,500 KW (70 A), AC 38mm^2 should be used as the standard. However, the loop main line should be AAC 150 m^2, which is also used for the 34.5 KV power transmission lines, with consideration paid to current capacity, the drop in voltage and other factors.

It is possible to use a voltage line of 38 mm^2 or less as the neutral line. However, with consideration paid to mechanical strength and a reduction in the number of different kinds of products, AC-38mm^2 should be used.

Table 4.12 Comparison of Conductors for Distribution Lines

Type	AAC	AC	ACSR	Cu
Size (mm^2)	38	38	32	38
Allowable current (A)	180	162	160	220
Maximum distribution capacity (KW)	3,872	3,485	3,441	4,733
Voltage drop* (%)	4.9	7.8	6.2	4.7
Maximum tensile strength (N)	5,645	42,658	11,172	14,504
Anti-corrosiveness	Excellent	Excellent	Good	Excellent
Cost	70	100	65	90

* The voltage drop is calculated assuming the current of the electric wire to be 70 A and the line length to be 8 km.

d. Outline of Conductors

Table 4.13 shows the outline of the conductors selected for power transmission and distribution lines.

Table 4.13 Applicable Conductors

Nominal cross-section	AAC 150 mm^2	AC 38 mm^2
Composition (strand/mm)	19/3.2	7/2.6
Calculated cross-section (mm^2)	152.8	37.16
Tensile strength (kg)	2,270	2,340
Outside diameter (mm)	16.0	7.8
Weight (kg/m)	0.4187	0.1184

4) Cable Lines Which Cross the K-B Bridge

Cable will be used for the 34.5 KV transmission lines and 13.8 KV distribution lines in the part which crosses the K-B Bridge, which links Koror Island and

Babelthaup Island. It is planned that space in the inside of the box girder will be used as a wiring route. Around the K-B bridge, stains and damage to electric wires and insulators in the line are noticeable, owing to the salty wind. This will threaten the transmission and distribution system. In addition, in terms of space to install supports on the bridge and strength, it is better to avoid installing overhead power lines. There is sufficient space for wiring cables in the bridge. This space can accommodate cables in the conduits and protect the cables from external pressure and small animals. At both ends of the bridge, polyethelene pipe should be buried in the ground, and the cable should be led into the pipe to connect it to the overhead lines at a nearby electric pole.

A crosslinked polyethelene insulated vinyl sheathed cable should be used because of its excellent function, results, economy and other proprieties. A triplex (CVT) type and copper conductor should be used. Given consideration to the derating factor in current because of installation conditions and 10 MVA transformer capacity, cable size should be selected as follows:

34.5 KV transmission lines : 33 KV CVT 100 mm^2 1 circuit
13.8 KV distribution lines ; 15 KV CVT 100 mm^2 2 circuits

5) Design of Grounding Conductor

With consideration paid to compatibiliy with existing facilities, we will use a method which employs 3 phase four wires and multiple grounding of neutral lines for the 34.5 KV transmission lines and 13.8 KV distribution lines. Under this method, the increase in electrical potential in the neutral line and sound phase during accidents resulting from contact between high and low voltages can be minimized. With the installation of protective devices such as section switches and reclosing relays, and by ensuring harmony among protective devices located in substations, a highly reliable supply of electricity can be obtained. In order to make full use of this, it is vital that the neutral line be earthed properly and that the design and installation be made in such a manner to avoid disconnection or loose connection of neutral lines.

(3) Substation Design

The Malakal Substation will be built in order to distribute electricity generated at Aimeliik and Malakal Power Plants. The electricity transmitted from Aimeliik Substation will be reduced from 34.5 KV to 13.8 KV by main 10MVA transformer to be located in the Malakal Substation and distributed to consumers in Koror State. The electricity generated at Malakal Power Plant will be boosted from 4.16 KV to 13.8 KV at Malakal Substation and is planned for distribution in Koror State. This will make power transmission and distribution from Aimeliik and Malakal Power Plants possible in Koror State, where electricity demand is large. At the same time, the reliability of the electricity system will significantly improve. Furthermore, with the application of 34.5 KV power transmission voltage and adoption of transformers equipped with on-load tap changer, we can expect decreased voltage fluctuations, voltage drops and power loss.

Malakal Substation will be constructed at a site that neighbors existing substation. Main 10MVA transformer, 3.5 MVA unit transformers, circuit breakers, disconnectors and lightning arrestors, and 13.8 KV switchgear will also be installed.

The basic specifications of the principal equipment to be installed at the substation are as follows. The Basic Design Drawing (Section 4.3.4) shows the arrangement of the equipment and a one-line diagram for the entire substation.

1) Transformers

		Main transformer	Unit transformer
Type	:	Outdoor installation, oil filled self cooled	Outdoor installation, oil filled self cooled
Capacity	:	10 MVA	3.5 MVA
Number of phases	:	3	3
Rated voltage	:	13.8 KV/34.5 KV	4.16 KV/13.8 KV
Tap	:	Equipped with on-load tap changer	No-voltage tap changer
		17 taps between 36.22 KV and 29.33 KV on the secondary side	5 taps between 13.11 and 14.49 KV on the secondary side
Frequency	:	60 Hz	60 Hz
Connection	:	Y-Y-Δ connection	Δ-Y connection
		Neutral directly grounded at primary and secondary sides Tertiary stabilizing winding	Directly grounded at secondary side

2) Circuit Breaker

		34.5 KV side	13.8 KV side (Incorporated intoswitchgear)
Type	:	Gas (SF6) type	Vacuum type
Rated voltage	:	36 KV	24 KV
Rated current	:	600 A	600 A

Rated rupturing current	:	12.5 KA	12.5 KA
Rated breaking time	:	5 cycle	5 cycle
Insulation class	:	30 A	20 A
Rated closing and tripping voltage	:	DC 100 V	DC 100 V
Operation method	:	Electric operation	Electric operation

3) Disconnecting Switch

		34.5KV side
Rated voltage	:	36 KV
Rated current	:	600 A
Rated current of short duration	:	12.5 KA
Operation method	:	Manual, 3 phase simultaneous closing operation
Grounding method	:	Equipped with grounding switch on the line side

4) Lightning Arrestor

		34.5KV side	13.8KV side
Rated voltage	:	30 KV	12 KV
Rated discharge current	:	10,000 A	10,000 A

5) Main Lines

		Primary side	Secondary side
Main transformer	:	2 x 22 KV CVT - 100 mm^2	AAC 150 mm^2
Unit transformer	:	2 x 6.6 KV CVT - 150 mm^2	22 KV CVT - 100 mm^2
Switch gear	:	-	2 x 22 KV CVT - 100 mm^2 (Koror Line)
			22 KV CVT - 100 mm^2 (MCDC line)
(Note) CVT	:	Triplex crosslinked polyethelene insulated vinyl sheathed cable (copper conductor)	

6) Control Panel

A control panel with the functions to operate, control and supervise substation will be built into the 13.8KV switch gear.

7) Direct current power source device

As a power source to implement closing and tripping of breakers as well as control and alarm functions, a DC110 V power source device will be installed in the substation.

Battery : Alkali type 100 AH 5 hours
Charger : 25 A

8) Grounding Method

Assuming the buried grounding network located in the existing substation has a maximum 1 ohm grounding resistance, the grounding network will be installed in the ground of the new substation by extending the existing grounding network from the connection point.

9) Peripheral facilities

Unauthorized access will be prevented by building fences to surround the substation. At the same time, outdoor illumination should be installed for operations and surveillance. Furthermore, oil protection banks should be built so that oil leaks at the time of accidents in the transformer will not affect the surrounding environment.

10) Operation of Substation

a. Operation of Major Equipment

Closing and tripping of breakers, opening and closing of disconnecting switches, monitoring of measuring instruments and other tasks will be carried out at the new substation. As the condition of equipment at the substation can be monitored at a 13.8 KV switchgear, only alarms of abnormal situations will be indicated in the existing control/monitor panel at Malakal Power Plant. Furthermore, taking into account a future shift to a centralized monitoring system, auxiliary contacts should be installed in breakers and other major equipment.

b. Parallel Operations

Aimeliik and Malakal Power Plants are expected to carry out parallel operations. This will be achieved by monitoring the voltage using synchronizing check circuits located in the control panel, and by closing circuit breakers for generators.

c. Interlock mechanism

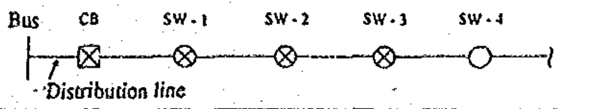
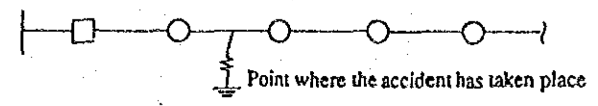
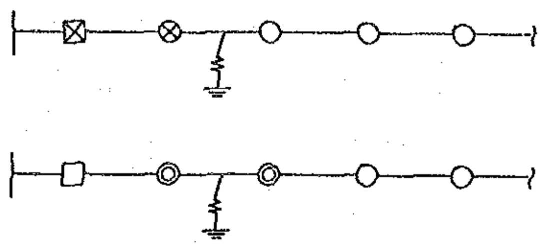
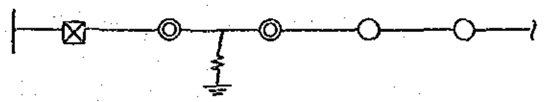
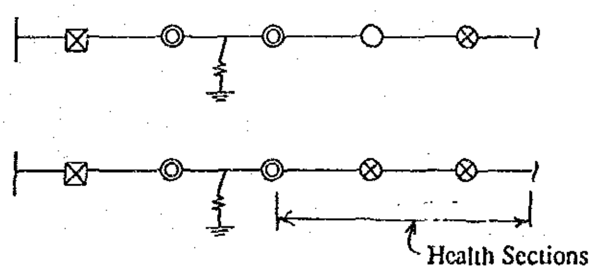
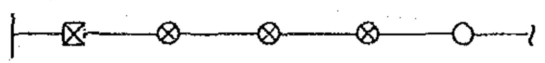
An interlock mechanism should be installed so that the disconnecting switch will not open while the transmission line circuit breaker remains closed.

(4) Design Specifications of Automatic Section Switch

Given the current situation, with power blackouts a frequent occurrence, an automatic section switch is vital as it quickly detects the point where the accident has happened, automatically isolates that section and shortens the duration of the power blackout. The installation of an automatic section switch will significantly improve the stability of the supply of electricity in Koror State. Based on the present maintenance and control conditions of the power distribution facilities, the widely used time delayed automatic section switch to be installed under this project is believed appropriate for improving the power distribution network because of its high reliability and easy operation and maintenance features. In the future, as a means to improve the power distribution quality, a further shift to a remote control system is possible by advancing the degree of automation. A system that uses an automatic section switch to enable this improvement in the grade will be designed.

Figure 4.2 shows such an automatic section switch. A fault section indicator for monitoring and control will be installed in the control room of the Malakal Power Plant. The fault section indicator will indicate the section where accidents have taken place by counting the time lapse between the reclosing of the circuit breaker (CB) of (3) and the time when it trips again. When the time is seven seconds, it is judged that the location of the accident is between SW-1 (SW:section switch) and SW-2. When the time is 14 seconds, it is judged that the accident has taken place between SW-2 and SW-3.

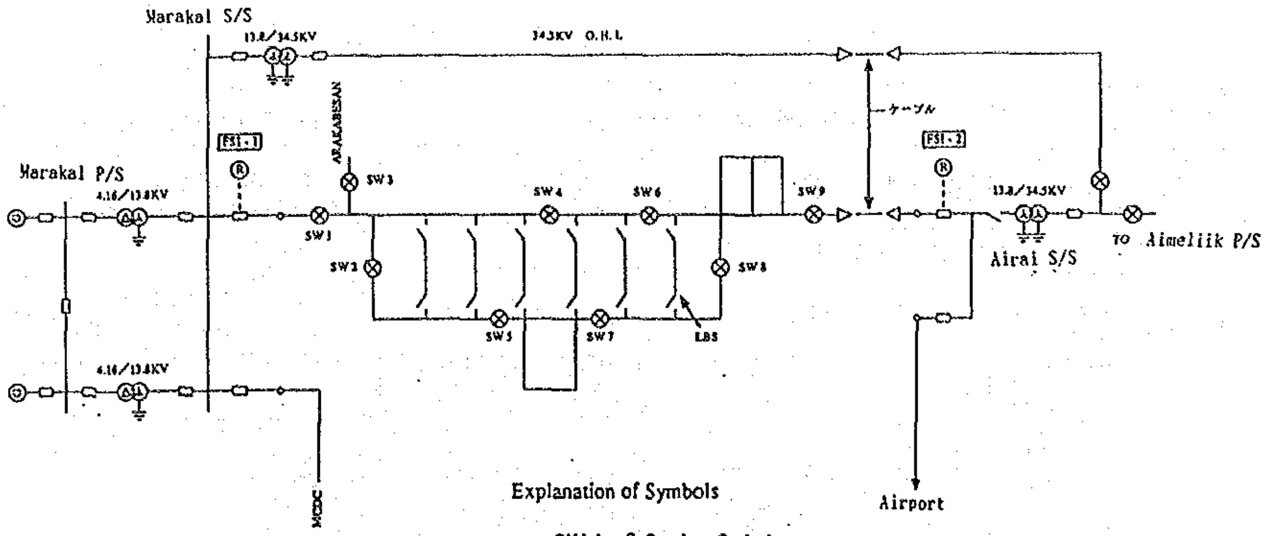
Based on the results of a site survey and analysis in Japan, the adoption of this automatic section switch is planned as per Figure 4.3. In the Figure, SW-1 ~ SW-9 show the vacuum type automatic section switch and vacuum switch, and these are installed on the poles. If SW-1 and SW-2 are left as open point (constantly open), electricity is distributed in one direction from Airai Substation to Koror State (operation mode (1)). When SW-4 and SW-5 are switched to open point, electricity will be distributed in both directions from Malakal and Airai Substations (operation mode (2)). These are the same as for operation modes (3) and (4). The opening and closing of SW will enable power distribution by section. Combined with the installation of a loop circuit, this will improve the system operations, which will be more flexible.

Event	CB and SW operation conditions	Explanation of operations
(1) Normal		Normal condition. SW-4 remains constantly open at open point.
(2) When an accident has taken place		CB trips and SW-1, SW--2 and SW-3, which normally remain closed, become open.
(3) Reclosing		With reclosing of CB, voltage is generated on the primary side of SW-1. Seven seconds later, SW-1 will automatically close. As the secondary side of SW-1 contains the epoint where the accident has happened, CB will trip again because of the fault current. At this moment, SW-1 and SW-2 lock in open status.
(4) CB reclosing		As CB is closed, voltage is generated on the primary side of SW-1. However, SW-1 remains locked and open and maintains open status.
(5) Supply of electricity to sound sections		SW-4 judges that there is no voltage for a certain period of time, and automatically closes. Voltage is generated on the right side of SW-3. Seven seconds later, SW-3 closes. Electricity is supplied up to the right hand side of SW-2.
(6) Recovery from accident		After recovering from the accident that occurred between SW-1 and SW-2, SW-4 is opened and SW-1 and SW-2 are closed manually.

Explanation of signals : CB : circuit breaker SW : section switch

CB	SW
□ Open	○ Open
⊠ Close	⊗ Close
	◎ Locked Open

Figure 4.2 Operations of Automatic Section Switch



Explanation of Symbols

- ⊗ SW-1 ~ 9 Section Switch
- Ⓡ FDR fault detection relay
- ▭ Circuit breaker
- [FSI] FSI-1, 2 Fault section indicator
- Load break switch

Sequency of Operation (Example)

Operation mode	FDR set up, FSI indication	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9
(1) SW1 & SW2 Open	Set up/lapse (seconds)	Open	Open	7/28	7/21	7/49	7/14	7/42	28/35	7/7
	FSI-1	-	-	-	-	-	-	-	-	-
	FSI-2	-	-	4	3	7	2	6	5	1
SW 1 and SW 2 remain constantly open at the open point, while SW 3 ~ SW 9 remain closed. From Airai Substation, electricity is distributed to places in Koror State where there is demand. When an accident has taken place, the circuit breaker trips and SW 3 ~ SW 9 open. However, when the circuit breaker is reclosed , the switches will close at seven second intervals in the order of SW 9, SW 6, SW 4, SW 3, SW 8, SW 7 and SW 5,. This operation mode lasts 49 seconds, from SW 9 to SW 5.										
(2) SW4 & SW5 Open	Set up/lapse (seconds)	7/7	7/14	7/14	Open	Open	7/14	7/28	21/21	7/7
	FSI-1	1	3	2	-	-	-	-	-	-
	FSI-2	-	-	-	-	-	2	4	3	1
(3) SW6 & SW7 Open	Set up/lapse (seconds)	7/7	21/28	14/21	7/14	7/35	Open	Open	7/14	7/7
	FSI-1	1	4	3	2	5	-	-	-	-
	FSI-2	-	-	-	-	-	-	-	2	1
(4) SW8 & SW9 Open	Set up/lapse (seconds)	7/7	28/35	21/28	7/14	7/42	7/21	7/49	Open	Open
	FSI-1	1	5	4	2	6	3	7	-	-
	FSI-2	-	-	-	-	-	-	-	-	-

Figure 4.3 Operations of Automatic Section Switch

In order to avoid a situation where protection devices become too complex, one of two load switches for branch circuits located in the loop circuit should remain open constantly. A plan should be made for these to be switched manually during inspection or accidents.

(5) Electrification Plan in Non Electrified Areas

For the four non electrified states on Babelthaup Island, based on the electricity demand forecast in (3) of 3.2.1, a plan has been made for transmission and distribution lines. The contents of the plan are as follows. Furthermore, the Basic Design Drawing (Section 4.3.4) shows the plan for the lines.

1) Outline

Based on the examinations made in Design Criteria (Section 4.2), 34.5 KV transmission lines and 13.8 KV distribution lines will be installed and 13.8 KV will be distributed to the four non electrified states. Furthermore, 34.5 KV transmission lines will be constructed from Nekken district in Aimeliik State to Ngeremiengui State, via Kokusai district. These will be the power transmission system running north to south, connecting Babelthaup Island in the north and Koror Island in the south. Depending on the progress of the development projects on Babelthaup Island, flexible transmission lines will be planned, so that the lines will be extended further to the north from Ngeremiengui State and the lines will be linked up to Melekeok State, which is the potential site for the future capital under the First National Development Project.

2) Point Where 34.5 KV Transmission Lines Will be Drawn Out

At the pole mounted substation in Nekken district, 34.5 KV transmission lines will be installed, which will branch out in the shape of a T from 34.5 KV transmission lines (line connecting Imelsbech and Nekken) on the primary side, and electricity will be transmitted to non electrified areas. At Nekken Substation, there are two circuits; one connecting Aimeliik and Airai and the other connecting Imelsbech and Nekken. After examinations are made on the excess transmission capacity of the lines, the effects of power outage at the time of construction at the T branch and other factors, a T branch is planned to be installed from the line connecting Imelsbech and Nekken. Furthermore, in order to minimize the duration of power outage, load switches will be installed at the part which branches out in the shape of a T.