BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR REPAIR OF NAM NGUM DAM POWER STATION UNIT NO.3 AND NO.4
IN
THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

APRIL 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

1903

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PREFACE

In response to a request of the Government of the Lao People's Democratic Republic, the Government of Japan decided to conduct a Basic Design study on the Project for Repair of Nam Ngum Dam Power Station Unit No. 3 and No. 4 and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Laos a survey team headed by Mr. Bunzo Sato, official of the Ministry of International Trading and Industry, from January 9 to 29, 1989.

The team exchanged views on the Project with the officials concerned of the Government of Laos and conducted a field survey in Vientiane. After the team returned to Japan, further studies were made and the present report has been prepared.

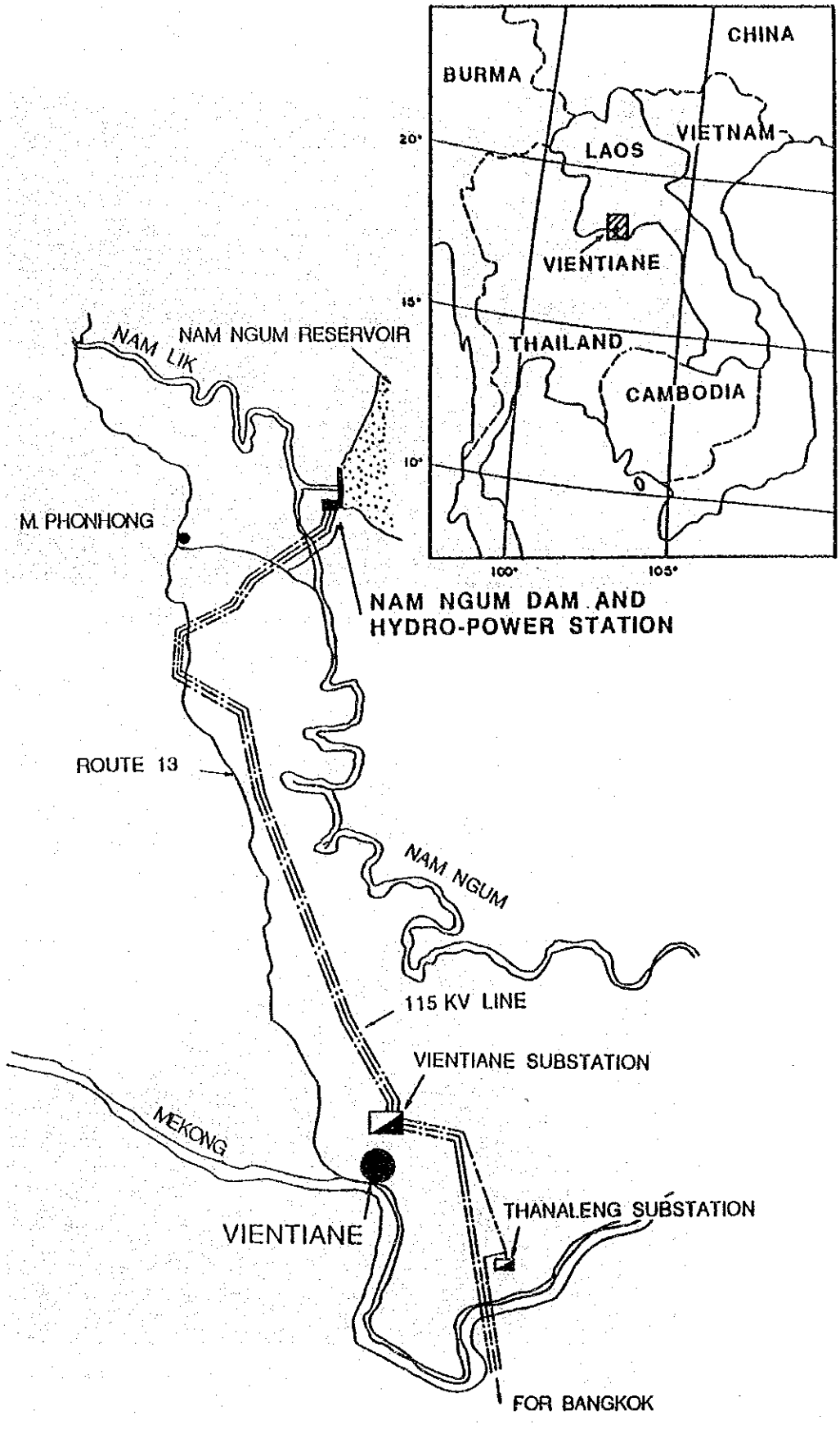
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Lao People's Democratic Republic for their close cooperation extended to the team.

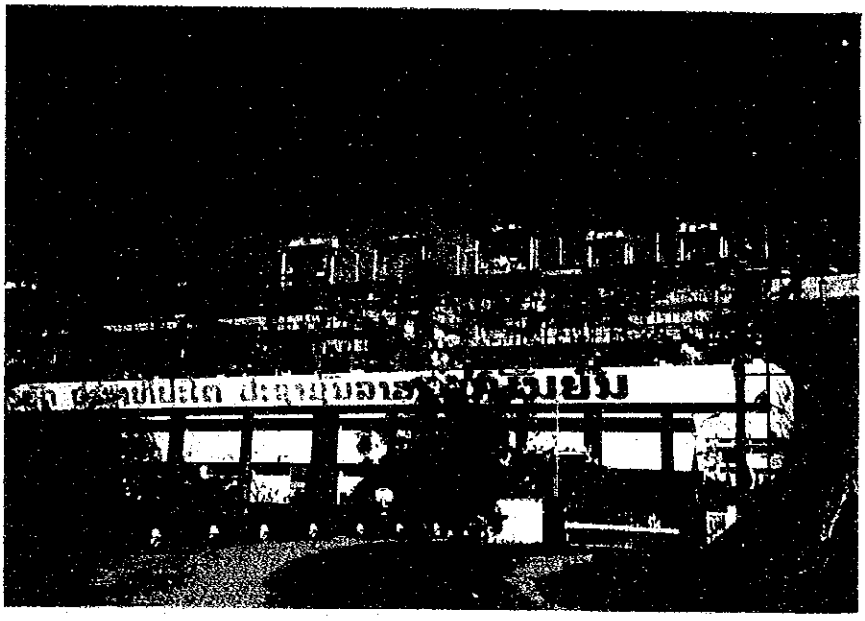
April, 1989

Kensuke Yanagiya

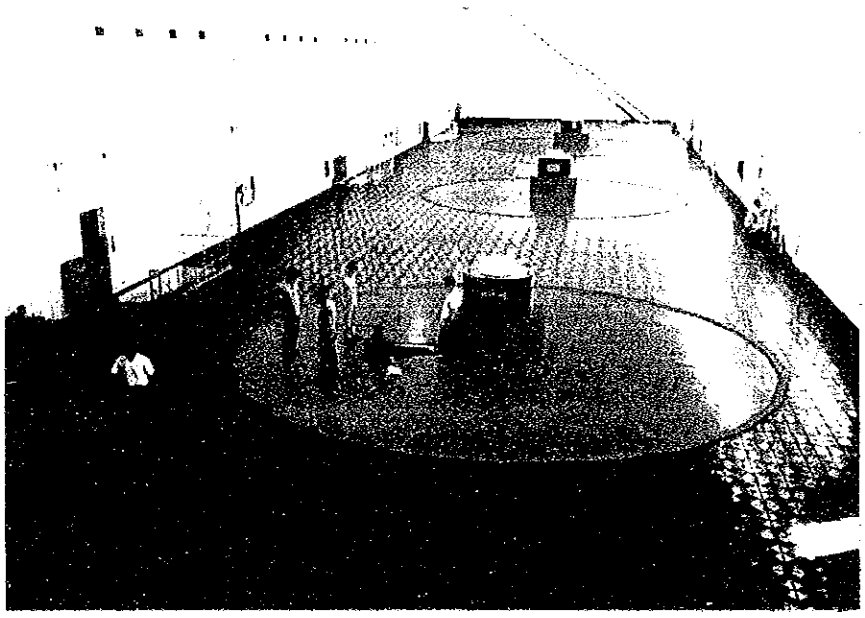
Kensuke Yanagiya
President
Japan International Cooperation Agency



LOCATION MAP



The Exterior Appearance of Nam Ngum Power Station



Generator Room (Units No.3 and No.4 from This Side)

SUMMARY

SUMMARY

The Lao People's Democratic Republic (Lao PDR) is a landlocked country bordering on China, Burma, Thailand and Vietnam. Its capital, Vientiane, is situated at the center of the country. The country is about 1,000 km long from north to south, and covers an area of 236,800 km^2. The population in 1986 was 3.7 million with a population density of 16 per km^2. Although the country has rich natural resources such as land, hydro potential, various kinds of minerals, etc., most of these resources have not been developed yet due to its inconvenient landlocked situation, underdeveloped infrastructures, low population, etc.

The principal industry of the country is agriculture which is engaged in by 85% people of its working population. Its main exports are electricity, raw lumber, timber products, coffee, and minerals such as tin, gypsum, etc., out of which the export of electricity held an average share of 44.9% of total national exports in the years 1984 to 1987. However, its balance of payments shows a chronic deficit, and its accumulated debt reached US$ 735.6 million as of the end of 1987. The deficit is made up by aid from foreign countries.

The Government of Lao PDR inaugurated its Second Five-Year Plan (1986 to 1990) to realize the following:

(a) increase food production to self-sufficiency,
(b) reduction of imports except foods,
(c) promotion of production and export of products to improve balance of payments, and
(d) improvement of existing infrastructures such as transportation and communication systems.

In the Plan, the power sector is designated to (a) decrease oil imports by replacing energy consumption of oil with electricity through rural electrification in the Vientiane plain, and in the southern provinces by developing mini hydro power plants, and (b) decrease electricity imports and promote electricity exports.

The Nam Ngum hydro power station is located 90 km north of Vientiane city and is operated by Electricite du Laos (EDL) which manages the power sector for the whole country. The station was developed in three (3) stages to a total of 150,000 kW with five (5) turbine-generator units and a total production of 890 million kWh per annum. The installed capacity of the station represents about 90% of the total capacity of the country and it will day a key role in achieving the target for the power sector in the Second Five-Year Plan. It is noteworthy that electricity is exported to Thailand and that all electricity exported is produced at the Nam Ngum power station.

During inspections carried out in 1986, EDL found that No.3 and No.4 turbine-generator units installed in the second development stage (1978) were damaged and that renovation of both units is required. However, the required renovation has not been achieved yet because of the present financial constraints in the country. In order to maintain a stable power supply to domestic consumers, to promote rural electrification and to continue electricity exports to Thailand, the Government of Lao PDR has requested the Government of Japan to renovate these units under a Grant Aid Program.

In response to this request, the Japan International Cooperation Agency (JICA) sent a basic study team headed by Mr. Bunzo Sato, official of the Ministry of International Trading and Industry, Japan, to Lao PDR from January 9, 1989 to January 29, 1989 to study justification of the renovation project, for confirmation of the project effects and for investigation of the appropriate scope of work for the project. During the study on site, the team investigated the equipment at the station, collected data, records and information necessary for basic design of the project, and had discussions with EDL, which had been appointed by the Government of Lao PDR to be the executing agency of the project. The results of these discussions are summarized in the minutes accompanying this report.

Through on site investigation by the team, the following were found;

(1) Accumulated operation times of No.3 and No.4 units have reached about 70,000 and 65,000 hours respectively in the 10.5 years since their commencement of operation. The standard time for overhaul and repair is acknowledged worldwide and in Japan to be every 40,000 operating hours or every 10 years for the equipment in a hydro power station. The operating times of No.3 and No.4 units in the station have therefore exceeded the standard time.

(2) Erosion was observed on the surfaces of runners and many parts of both turbines. Parts to be repaired or replaced with new materials were also found on other electrical and mechanical equipment.

(3) Power supply to Thailand is interruptible as occasion demands if prior notice is given. Accordingly, the renovation schedule can be arranged without restriction of electricity exports.

(4) Operators in the power station have been responsible for operation and maintenance of the equipment since operation of the station commenced. Therefore, there is no doubt that the present operators can carry out well routine operation and maintenance of the station after renovation of the equipment.,

(5) EDL is ready to arrange for appropriate persons to acquire the renovation skills and practices through execution of the project.

The basic design of the project done by the team in Japan shows that the following equipment and facilities should be renovated.

(1) No.3 and No.4 turbines and their auxiliaries
(2) No.3 and No.4 generators
(3) Other facilities
- overhead travelling crane
- air-conditioners and ventilation facilities
- water level indicating system
- cooling water supply system

(4) Operating system of intake gates for No.3 and No.4 turbines
(5) 115 kV switchgear

(6) Control, metering and protection system
(7) AC and DC auxiliary power supply equipment

It will take fifteen (15) months for manufacture of materials and equipment, transportation and site renovation work if the work is done for both units simultaneously. If the project is implemented under the Grant Aid Program of the Government of Japan, it will take nineteen (19) months including the detailed design and tender procedures after Exchange of Notes. Accordingly, it is proposed that the project be implemented in two (2) phases.

The first phase project would concentrate on renovation of No.3 unit in view of its longer running hours, followed by renovation of No.4 unit in the second phase. Each phase of the project will require twelve (12) months to complete after conclusion of the contract between EDL and the Contractor.

The project executing agency would be EDL, and the body in charge of the renovation work would be the Nam Ngum power station division. It is considered that these two organisations are well qualified to perform these functions.

If the project is implemented under the Grant Aid Program of the Government of Japan, the following work assignment will be set out.

(a) Japan would undertake manufacture of parts and equipment required for renovation of No.3 and No.4 units, transportation of the parts and equipment to the site, overhaul, renovation, testing and adjustment.

(b) Lao PDR would supply the electricity necessary for the work and provide working areas, site offices, etc.

Upon completion of the project, the generating equipment would be fully restored, which will result in improvement of operational reliability of the power station and stable supplies of electricity. It is also expected that annual energy production will increase by approximately 9,000,000 kWh over present production, which is

equivalent to increasing the installed capacity of the power station. Therefore, completion of the project will contribute to promotion of rural electrification as programed by the Government of Lao PDR and to increasing foreign currency earnings due to additional electricity export.

Operators in the power station, moreover, will gain experience in repair of equipment through the project.

Thus, substantial benefits are expected to result from implementation of the project and the project will have great significance if implemented under the Grant Aid Program of the Government of Japan.

In order to maintain proper functioning of the equipment after completion of the project, EDL will be required to train its personnel, especially young people, in maintenance of the station, and to execute a suitably programed maintenance scheme.

In addition, it will be necessary to establish a system in EDL to periodically procure consumables and spare parts necessary for maintenance of the power station.

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CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

The Nam Ngum Power Station in the Lao People's Democratic Republic (Lao PDR) has an output of 150,000 kW rated value (180,000 kW maximum value). The Power Station was completed as follows:

Phase	Installation	Year of Completion
First phase	30,000 kW with No. 1 and No. 2 units	1972
Second Phase	80,000 kW with No. 3 and No. 4 units	1978
Third phase (Final phase)	40,000 kW with No. 5 unit	1984

Since completion of the first phase development, the Nam Ngum Power Station has met all the electric power demands and the energy requirements of the capital of the Lao PDR, Vientiane, including its suburb. Since then, surplus energy has been exported to the northeastern area of Thailand.

It is a general practical rule that a detailed inspection of hydraulic turbines for electric power generation should be conducted once every ten (10) years in a thorough overhaul to confirm the degree of erosion and corrosion, and any need for repair and replacement of parts and components which have become worn.

Electricite du Laos (EDL) conducted a major inspection of No.3 and No.4 units in May 1986 after the elapse of eight (8) years from commencement of commercial operation. This inspection, however, did not include disassembly and overhaul. Temporary repairs were done to pitting on the runners due to the occurrence of cavitation to such an extent that such pitting had already reached a sufficiently serious level for repair to be needed.

EDL recognised from the condition of No.3 and No.4 units at Nam Ngum Power Station that thorough overhaul and repair of these units was required at the earliest possible time. At their request, therefore,

the Government of Lao PDR requested the Government of Japan to undertake the necessary work under the Grant Aid Program.

In response to the official request, the Government of Japan decided to propose a basic design for the repair work, and the Japan International Cooperation Agency sent a basic design survey team headed by Mr. B. Sato, official of the Ministry of International Trade and Industry of Japan, to the Lao PDR from January 9, 1989 to January 29, 1989 for this purpose.

During their stay in Lao PDR, the team undertook the following activities:

(1) Verification of the appropriateness of the said request for overhaul and repairs,

(2) A series of surveys on the existing condition of the generating equipment to confirm the object, contents and optimum scale of the request,

(3) Exchange of views with the Lao PDR authorities concerned, and

(4) Collection of relevant materials, data and information.

Details of the survey team, the team's schedule, Lao PDR officials with whom the survey team had interviews, details of discussions, etc. are given in the Appendixes.

Based on analysis of the results of the site survey, studies on the appropriateness and scale of the repair work, an estimate of the work required, operation and maintenance after completion of the work, an evaluation and recommendations were made, and these are all compiled in this basic design report.

CHAPTER 2

BACKGROUND OF THE PROJECT

CHAPTER 2 BACKGROUND OF THE PROJECT

2 - 1 Outline of Lao PDR

2 - 1 - 1 Land, Population and Climate

The Lao PDR is a landlocked country with an area of 236,800 sq.km and a population of 3.7 million, about 85% of which is engaged in agricultural activity.

The plains are limited to areas along the Mekong River and its tributary valleys. The cultivated acreage is only eight (8) percent of the whole land of the country.

The climate is of a tropical monsoon type having a wet season from May to October and a high temperature. The annual rainfall in Vientiane is around 1,600 millimeters. The dry season is from November to the following March while it is mild till February. The hottest period ranges from March to April when the temperature reaches as high as 40°C though the average atmospheric temperature is about 26°C.

The population density is very low and only 16 persons per kilometer. The growth rate of the population is believed to be 2.4 percent year. The Lao tribe accounts for about 60 percent of the total.

Country data are given in Appendix-7.

2 - 1 - 2 National Economy

According to information published by IBRD, Lao PDR is one of the least developed countries in the world with an estimated GNP per person of US$156 in 1987.

Lao PDR is blessed with abundant natural resources such as land, water and minerals. However, investment to elevate economic growth is very limited for the following reasons:

i) Isolation from world markets
ii) Shortage of skilled manpower
iii) Weak institutional capabilities
iv) Limited transportation and communication systems
v) Small and widely dispersed population

The country's export trade base is also so weak that foreign currency earnings of the country depend very largely on sales of electricity to Thailand as shown below:

Merchandise Export (Average 1984 - 87)

	Mil. US$	%
Hydroelectric power	25.0	44.9
Logs and wood products	14.2	25.5
Coffee	9.0	16.2
Tin and gypsum	3.5	6.3
Other	4.0	7.2
Total	55.7	100.0

(Source: EDL)

The country's balance of trade is in chronic deficit. The total outstanding external debt as of the end of 1987 was US$753.6 million (11.6% in debt service ratio). Import of goods was US$216.2 million, while export of goods was US$64.3 million in the same year.

2-1-3 Development Plan

Following two (2) consecutive Development Plans (1978-1980 and 1981-1985), the Second Five-Year Plan (1986-1990) is at present in force to achieve the following objectives:

i) Promotion of self-supply of food, and reduction of imports of goods other than foodstuffs, and acceleration of production and exports for more foreign currency earnings.
ii) Improvement of transportation and communication systems.
iii) Development of mainstay personnel and of human resources generally.

For this purpose, the following investment expenditures were allocated in the Second Five-Year Development Plan:

Allocation of Investment Expenditures
during the Second Five-Year Plan
(In million kip, 1986 prices)

	Foreign Resources	Domestic Resources	Total	%
Agriculture	6,569	7,500	14,069	18.5
Industry	11,851	3,750	15,601	20.5
Commerce	1,136	1,000	2,136	2.8
Transport	15,134	5,000	20,134	26.4
Construction	4,926	1,250	6,176	8.1
Other productive investment	-	1,250	1,250	1.6
Education	1,361	2,000	3,361	4.4
Health	1,293	1,250	2,543	3.3
Culture	1,137	750	1,887	2.5
Housing	768	1,250	2,018	2.7
Other	-	7,000	7,000	9.2
Total	44,175	32,000	76,175	100.0

(Source: EDL)

Foreign resources were converted to domestic currency by using an exchange rate of Kip 95 per US$.

Under the Second Five-Year Plan, the Government gave high priority to the improvement of electricity infrastructure and has the following development objectives:

i) to develop small and medium size hydropower stations within the country to reduce dependence on fuel imports for energy supplies to remote areas and thereby achieve foreign exchange savings,

ii) to export surplus power to Thailand as and whenever possible to earn additional foreign exchange,

iii) to increase food production with electric pump irrigation schemes and

iv) to promote development of agro-based industries such as rice mills, coffee processing industries and saw mills.

The power Development Plan under the Second Five-Year Plan is set out below:

Power Development Program (1987-1993)

	1987	1988	1989	1990	1991	1992	1993	Total
Southern Provinces Electrification	582	9,127	10,117	6,876	3,682	2,137	0	32,527
Xeset Hydropower	68	3,605	8,747	13,989	9,859	1,932	0	38,200
Other Hydro Projects	1,139	3,063	3,847	3,157	0	0	0	11,206
Thakhek-Phountiou 22 kV Feeder	228	2,805	2,267	2,886	585	0	0	8,771
Other Transmission Project	0	692	5,398	8,696	3,595	121	0	18,502
Nam Ngum III	1,506	343	0	0	0	0	0	1,852
Substation Rehabilitation	1,540	0	0	0	0	0	0	1,540
V.P.R.E. I	473	0	0	0	0	0	0	473
V.P.R.E. II	4,385	2,420	1,049	358	0	0	0	8,211
V.P.R.E. III	0	0	0	3,010	0	3,938	2,798	10,346
Vientiane Urban Rehabilitation	911	1,205	1,233	1,246	1,273	1,317	1,363	8,547
Nam Dong/Sclabam Rehabilitation	3,562	0	0	0	0	0	0	3,562
Other Capital Expenditures	1,937	4,488	3,397	661	0	0	0	10,483
Total	16,334	27,751	36,054	37,867	22,609	9,445	4,161	154,221

(Source: EDL)

2 - 2 Outline of the Power Sector in Lao PDR

2 - 2 - 1 Electricity Supply and Consumption

The per capita consumption of primary energy was equivalent to around 55 kg of oil in 1985. In this connection, per capita annual energy consumption in kg of oil for some other countries in the region in 1985 was: Bangladesh (44 kg), Sri Lanka (115 kg), Philippines (199 kg) and Pakistan (201 kg).

Indigenous fuel wood is the main source of energy and provided about 90 percent of the energy consumed in the country in 1985. Imported petroleum products and indigenous hydroelectric power each accounted for about five (5) percent of the remaining energy consumed.

The Lao PDR has a rich hydroelectric potential estimated at over 18,000 MW. However, only 153 MW has been developed and 150 MW of this is concentrated at the Nam Ngum Hydropower Project.

The present installed generating capacity in Lao PDR is 167 MW, consisting of 153.3 MW of hydro-generation and 13.7 MW of diesel plant. The following list gives details:

Existing Generation Facilities

Location	Type	Installed Capacity (MW)	Remarks
Vientiane Provinces			
Nam Ngum	Hydro	150.00	2 x 15 MW (1971) 2 x 40 MW (1978) and 1 x 40 (1984)
Sokpaluang	Diesel	8.00	4 x 2 MW (1971)
Luang Prabang Province			
Nam Dong	Hydro	1.00	3 x 336 kW (1970)
Luang Prabang	Diesel	0.68	2 x 100 kW (1971-83) 1 x 235 kW (1979) 1 x 240 kW (1960)
Champassak Province			
Selabam	Hydro	2.04	3 x 680 kW (1969)
Pakse	Diesel	0.24	1 x 240 kW (1970)
Champassak	Diesel	0.10	1 x 100 kW (1982)
Paksong	Hydro	0.04	1 x 40 kW (1985)
Savannakhet Province			
Savannakhet	Diesel	1.00	4 x 250 kW (1970)
Saravane Province			
Saravane	Diesel	0.40	2 x 200 kW (1985)
Houaphanh Province			
Houaphanh	Hydro	0.15	(1986)
Phongsaly Province			
Phongsaly	Hydro	0.05	(1986)
Others	Diesel	3.30	
Total		167.00	

(Source: EDL)

Actual and projected electricity export and import activities are as listed below:

	1984 actual	1985 actual	1986 actual	1987 est.	1988 plan	1989 plan	1990 plan
Production	891.0	906.6	867.3	566.0	716.7	870.0	870.0
Domestic consumption	129.8	130.4	124.9	125.5	146.2	157.9	173.7
Losses	51.5	60.0	58.9	53.8	54.8	56.6	60.0
Available for export	709.7	716.3	683.6	387.2	515.7	655.5	636.3
Import from Thailand	16.6	17.6	17.2	17.9	18.7	18.2	19.2

(Source: EDL)

Generated energy by power stations other than Nam Ngum Power Station is negligible. Losses are for system loss in transmission lines and distribution networks in the Lao PDR. Imported energy through underwater cables crossing the Mekong River was consumed in the Southern Provinces.

2-2-2 Outline of Electricite du Laos (EDL)

(1) Role and Organization

The executing agency for the project to repair the Nam Ngum Dam Power Station, Units No.3 and No.4 (hereinafter referred to as the "Project") will be Electricite du Laos (EDL), which is a wholly state-owned organization responsible for generation, transmission and distribution of electricity within Lao PDR. EDL was elevated to the status of State Enterprise under the Ministry of Industry and Handicrafts in 1980 by a resolution of Lao PDR Council of Ministers.

EDL is headed by a General Manager appointed by a decree of the Council of Ministers on the recommendation of the Ministry of Industry and Handicrafts. One Deputy General Manager of two is responsible for technical activities, while the other is responsible

for administrative activities. At present, EDL has about 931 employees, the organization of which is shown in Fig. 2.1.

Electricity outside the Vientiane Province is distributed and retailed by provincial electric power authorities, which conduct most of their activities independently of EDL. EDL often manages the acquisition and construction of new power facilities on their behalf.

(2) Finance and Accounts

Although operationally independent as a state enterprise, EDL's financial conduct is closely controlled by government financial policy. EDL prepares annual capital and operating budgets which are reviewed by the Government, but EDL has only nominal responsibility for realizing financial performance targets since the Government makes all decisions concerning tariffs, investment programs and financial resources management. EDL now pays a tax at 25 percent based on operating expenses including depreciation and interest, and dividends are passed on to the Government after reserves and provisions have been set aside for major repairs and capital investment.

The income statements for 1986 and 1987 are shown in Appendix-8.

(3) Tariffs

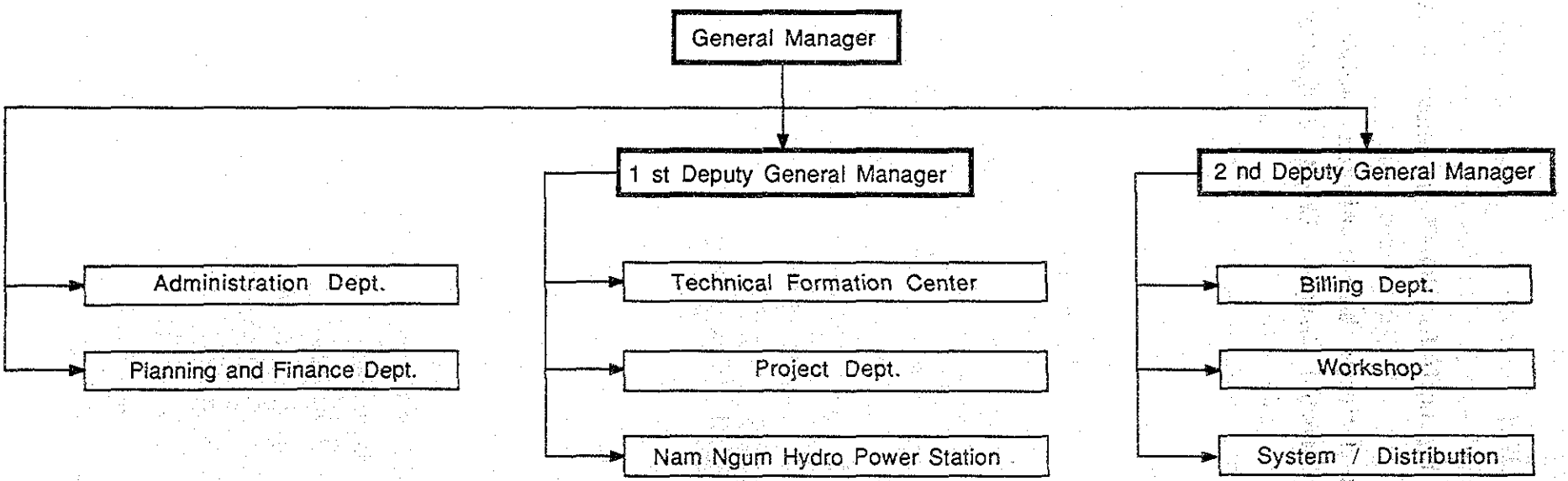
EDL has two tariffs at present. One is for the export and import of electricity to and from Thailand, and the other is for electricity supply to consumers within Lao PDR. At present, exports are only made to the Electricity Generating Authority of Thailand (EGAT) from the Nam Ngum Power Station. EGAT agreed with EDL on a price of US$0.0305 per kWh on September 21, 1987. Imports from EGAT to the Khanmouane and Savanakhet provinces at 22 kV are charged US$0.005 per kWh above the Nam Ngum export price to cover the cost of energy transmission through the EGAT system.

Charges of the tariff for EGAT are shown in Appendix-9.

EDL's local tariff is based only on energy charges and does not include any demand charges. Energy is sold at 7 Kip per kWh.

Fig. 2.1 ELECTRICITE DU LAOS

ORGANIZATION CHART



2-3 Outline of the Nam Ngum Power Station

2-3-1 Nam Ngum Hydroelectric Project

The Nam Ngum Hydroelectric Project was initiated in 1966 under the auspices of the United Nations Mekong Committee and was implemented in three phases ending in 1985. The project consists of a concrete gravity dam, a powerhouse with 150 MW installed capacity, and 115 kW transmission facilities to the country's capital, Vientiane, and across the Mekong River to interconnect with the EGAT system.

Phase I of the project was supported in part by multinational funds including Japanese funds, administered by IBRD, to construct a dam and a power station with two units of 15,000 kW each. Joint loans by a multinational fund, including Japanese funds, were provided and administered by ADB for Phase II to construct two new 40,000 kW/50,000 kVA units and to expand the power house to accommodate these two units and another unit. Joint loans from the Japanese funds and ADB funds were provided for Phase III to construct one new unit of 40,000 kW/50,000 kVA rating.

The principal facilities of the various phases were:

Phase I (The main construction period: 1967 to 1972)

- Concrete gravity dam including overflow chute spillway without radial gates;
- Nos. 1 and 2 units of generating equipment;
- Power station building for Nos. 1 and 2 units;
- Waterway facilities for Nos. 1 and 2 units;
- 115 kV single circuit transmission line from the Nam Ngum P.S. to Udon S.S.; and,
- Phontong S.S. and Nongkhai S.S.

(Fund required: Approx. US$24,000,000)

Phase II (The main construction period: 1975 to 1978)

- Nos. 3 and 4 units of generating equipment;
- Power station building for three units of generating equipment;
- Waterway facilities for Nos. 3 and 4 units including radial gates for spillway;
- 115 kV double-circuit transmission line from the Nam Ngum P.S. to Udon S.S.;
- Extension of the Phontong S.S. and,
- Thanaleng S.S.

(Fund required: Approx. US$49,000,000)

Phase III (The main construction period: 1982 to 1985)

- No. 5 unit of generating equipment; and,
- Waterway facilities for No. 5 unit

(Fund required: US$20,000,000)

The principal features of the completed project are:

- Concrete gravity dam, 75 m high and 468 m long;
- Overflow chute spillway with flip bucket and four radial gates, and a design discharge of 4,400 m^3/s;
- Power station building with 150,000 kW installed capacity and 115 kV roof switchyard;
- 115 kV three-circuit transmission lines to Vientiane and across the Mekong river to Thailand;
- 115/22 kV substation in Vientiane (Phontong) and Thanaleng;
- Electronic transmission line protection system and PLC telecommunication system; and,
- Operator's permanent quarters.

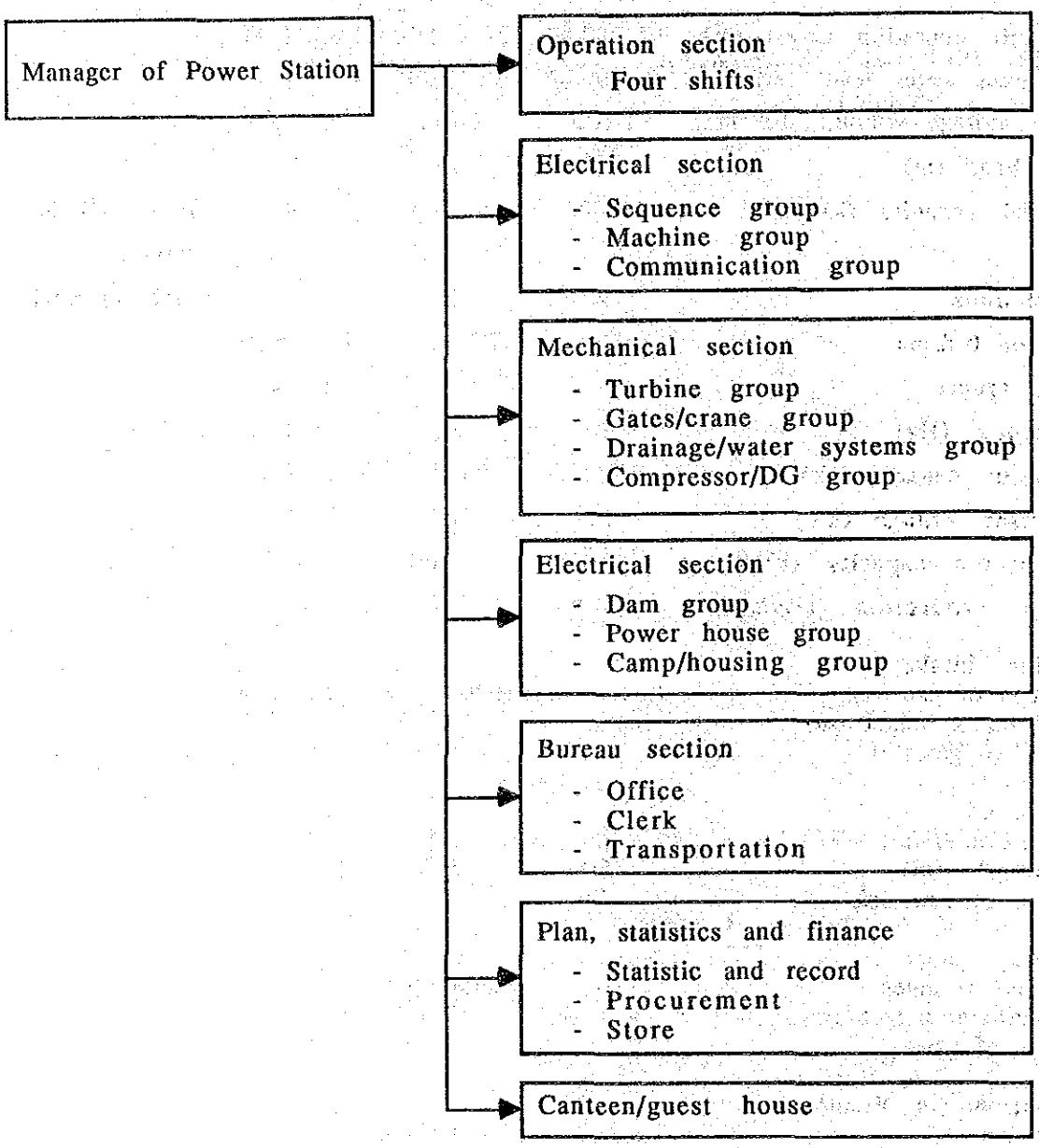
Main data of the Nam Ngum Project are as shown in Table 2.1.

Table 2.1 Main Data of the Nam Ngum Project

Description	Phase I	Phase II	Phase III	Remarks
Reservoir operation Level (m)	EL.202.50	EL.212.00	EL.212.00	
Drawdown water level (m)	EL.196.00	EL.196.00	EL.196.00	
Active storage volume (10^6 m^3)	1,600	4,700	4,700	
Rated head (m)	32	37	37	
Installed capacity (kW)	30,000	80,000	40,000	150,000 kW in total
No. of units	2	2	1	5-unit in total
Type of turbine	Francis	Francis	Francis	
Speed (rpm)	176.5	136.4	136.4	
Frequency (Hz)	50	50	50	
Generator capacity (kVA)	17,500	53,000	53,000	
Generator voltage (kV)	11	11	11	
Transformer capacity (kVA)	17,500	50,000	50,000	
Energy production (GWh/year)	240	890	890	
Turbine intake				
Type of gates	Roller type	Roller type	Roller type	
Width x height (m)	3.4 x 3.4	6.0 x 6.0	6.0 x 6.0	
No. of gates	2	2	1	
Penstocks				
Diameter (m)	3.4	6.0	6.0	
Length (m)	50	55	55	
No. of penstock	2	2	1	
Spillway gates				
Type of gates	-	Radial type	-	
Width x height (m)	-	12.5	-	
No. of gates	-	4	-	
Substations in Vientiane area				
Name	Phone Tong	Phone Tong		
Transformer capacity (kVA)	44,000	30,000	-	22,000 kVA x 2
Voltage ratio	110/22/15	110/22	-	in Phase I
Name	-	Thanaleng	-	
Transformer capacity (kVA)	-	10,000	-	
Voltage ratio	-	110/22	-	
115 kV transmission line				
No. of circuit	1	2	-	
Line route length (km)	140	140	-	

2-3-2 Personnel and Budgetary Arrangements at Nam Ngum Power Station

The personnel organization is as shown in the following chart:



Twenty operators consisting of four shifts with five operators each are assigned to the operation section. A technical staff of about 30 persons is assigned to maintenance sections for mechanical, electrical and civil purposes, etc.

In addition to the above, administrative personnel, drivers and supplementary members are working in the Power Station.

About 160 personnel in total are on the register of the Nam Ngum Power Station at present.

A comparative record of annual budget and actual expenditure in recent years for the Nam Ngum Power Station is tabulated below:

Year	Budget		Actual	
	Foreign Currency (US$)	Local Currency (Kip)	Foreign Currency (US$)	Local Currency (Kip)
1983	160,634	5,842,682	45,487	3,718,674
1984	125,000	10,402,434	-	4,210,478
1985	180,520	10,466,906	59,257	8,560,230
1986	120,375	36,438,260	101,256	24,900,400
1987	1,200,000	28,057,077	900,596	28,519,947

(Source: Nam Ngum P.S.)

The purpose of the foreign currency expenditure was mainly to import from Japan spare parts, consumables, apparatus and components which were not available on the market in Lao PDR.

Apart from the figures for foreign currency in 1987, the budgetary arrangements in the past were all very small in relation to the power station size and the number of generating units.

2-3-3 Energy Production of Nam Ngum Power Station and Energy Sales to EGAT

At present the integrated running hour meters for No.3 and No.4 units are both out of service. Thus, the accumulated operating hours are indistinct. However, the values actually recorded in May 1986 for both the No.3 and No.4 units were 60,846 hours and 56,021 hours, respectively. Since then, more than two years and half have elapsed. During 1987 and 1988, however, total energy production was limited to

only about 1,400 GWh, which was far less than the yearly average due to low rainfall.

In view of this low energy production, the operating hours were presumably around 9,000 hours to give about 70,000 hours and 65,000 hours for the total accumulated operating hours of No.3 and No.4 units, respectively.

In case of the Nam Ngum Power Station, the expected annual total was planned to be about 6,000 operating hours to generate 890 GWh by 150,000 kW installation (89,000,000 kWh/150,000 kW = 5,930 hr.)

It is ordinary practice for a hydroelectric power station with a large capacity reservoir to be planned as a peaking station with annual operating hours of around 3,000 hours (30 to 40 percent in terms of annual plant factor).

However, the Nam Ngum Power Station was planned to have its overall installed size to match the annual load factor of the power system to which the Power Station is connected rather than to be a peaking station. The annual operating hours of the Nam Ngum Power Station are thus longer than those of a peaking station.

As mentioned earlier the surplus energy after supply to consumers in Lao PDR is being sold to the EGAT. Energy sales, expressed in the form of US dollars, since commissioning of the Nam Ngum Power Station are listed below:

Year	Energy Sales ($)	Year	Energy Sales ($)
1972 (Nos. 1 and 2 commissioned)	0	1981	10,594,681.14
		1982	23,452,625.32
1973	20,777.44	1983	24,063,120.26
1974	281,397.46	1984 (No.5 commissioned)	26,150,107.25
1975	868,259.61		
1976	1,540,635.21	1985	28,615,952.96
1977	1,758,970.26	1986	26,976,899.55
1978 (Nos.3 and 4 commissioned)	2,229,362.19	1987	11,065,303.07
		1988 (Upto Oct.)	9,469,976.64
1979	8,165,125.17		
1980	7,918,816.77		

(Source: EDL)

The small figures for 1987 and 1988 were due to abnormally low rainfall as explained earlier.

2-3-4 Present Condition of No.3 and No.4 Units at Nam Ngum Power Station

The presumed accumulated operating hours for the No.3 and No.4 units are around 70,000 hours and 65,000 hours, respectively. But these units has not been overhauled thus far.

One of the known problems is corrosion by hydrogen sulphide which is produced in the reservoir water during the early stages of impoundment. This often occurs due to submergence of plants by impoundment of a reservoir in hydroelectric power development projects in tropical and subtropical zones. It results from chemical changes to chlorophyll in the plants and makes the reservoir water corrosive to ferrous materials.

In the first three years after completion of Nam Ngum Hydroelectric Power Project Phase I, hydrogen sulfide came out abundantly to corrode the interior of the hydraulic turbines of both No.1 and No.2 units remarkably.

Some corrosion due to chemical action of the reservoir water has also been observed in the interior of No.3 and No.4 turbines. Hydrogen sulfide was produced again when the reservoir water level rose by about 10 m and extended the circumference of the reservoir. It is noted, however, that the degree of corrosion observed in No.3 and No.4 turbines is less than that in No.1 and No.2 turbines.

The Preliminary Study Report, which had been prepared by EDL and was attached to the official request of the Lao PDR, mentions the results of EDL's inspection of No.3 and No.4 units. It was confirmed by the field survey that the contents of EDL's Report are generally correct. Also, it became clear that there is little difference in present condition of the No.3 and No.4 generating units.

The main items which are known to need repair are enumerated below.

Hydraulic Turbines

- Corrosion and cavitation pitting on the draft tube liners.
- Some corrosion on the stayring to the bottom ring.
- Painting on the spiral case is partially worn off.
- Upper and bottom gaps of the guide vanes were enlarged to twice their design values of 0.7 mm by development of corrosion.
- Cavitation pitting on the reaction side of vanes of runner outlet.
- Unevenness caused by corrosion over the surface just beneath the stainless plating on the discharge ring.
- A clear streak runs on the protective liner of No.3 turbine.
- The edge of the bottom ring facing the runner is corroded.
- The friction force of the regulating mechanism for guide vanes has increased.
- The manual locking device for the guide vane servomotor does not operate properly.
- The pressure gauge for the draft tube is out of order.
- The lubricating oil mist separator of the thrust bearing does not operate properly.
- Oil leaking from the manhole cover on the governor oil pressure tank.

Alternating Current Generators

- Insulating compound filled between the stator winding and the stator core has peeled off partially.
- Insulation treatment on the connection bars for the stator windings is incomplete.
- Scratches are observed on the surface of the collector range.
- The mechanical type speed sensor of No.4 unit does not function.
- Most of the temperature recorders are out of service.

Overhead Traveling Cranes

- Some strands of the wire rope for the 5-ton rope trolley of the No.1 crane are deformed.
- A joint in the control cable to the pendant switch for the crane in the cooling water treatment room is damaged.
- The upper and lower limit switches are both out of order.

Air Conditioning and Ventilation Systems

- The coolant pressure of the air conditioner is too low.
- V-belts for driving the ventilation fan are missing.

Fire Fighting Equipment

- Hoses and nozzles are not readily available.

Cooling Water Treatment System

- The check valve in the primary water system is out of service.

Water Level Indicating Device

- The water level transmitters are very rusty.
- Values indicated for reservoir water level and tailrace water levels are both incorrect.

Intake Gates

- The anti-corrosive effect of the paint coating has been lost.
- Greasing on the wire ropes is insufficient.
- The hoist brake mechanism is not sufficiently clean.
- Apparatuses and parts inside local control boxes have already deteriorated and have not been repaired or replaced.

115 kV Switchgear Equipment

- Operation of circuit breakers is unstable.
- Severe rusting is observed on the main contacts of the disconnecting switches.
- Oil leaks from the top of the coupling capacitor potential device must be insulated.
- The operation counter and discharge current recorder are seriously rusted.
- Door gaskets of control boxes have all deteriorated.

Control, Metering and Protective Systems

- Several components and apparatuses are out of order.

AD/DC Auxiliary Power Source

- Some circuit breakers have burnt down.
- Foreign bodies exist inside the storage battery units.
- Several storage battery terminals have corroded seriously.

2 - 4 Status of Related Plant

2 - 4 - 1 Status of Related Plant

The Asian Development Bank has extended five loans totalling US$16.32 million and two technical assistances totalling US$386,000 to the power sector in the LAO PDR as mentioned below:

Bank Loans and Technical Assistances to the Power Sector

Loans

Loan No.	Project	Amount	Date Approved
65-LAO (SF)	Vientiane Power Distribution	$3,370,000	6 May 1971
128-LAO (SF)	Vientiane Power Distribution (Supplementary)	$1,350,000	3 May 1987
501-LAO (SF)	Vientiane Plain Rural Electrification	$4,300,000	19 Dec. 1980
642-LAO (SF)	Vientiane Plain Rural Electrification (Ph II)	$6,300,000	11 Oct. 1983
698-LAO (SF)	Xeset Hydropower (TA Loan)	$1,000,000	23 Oct. 1984
	Subtotal	$16,320,000	

Technical Assistance (TA)

TA No.	Project	Amount	Date Approved
275-LAO	Vientiane Plain Rural Electrification (Project Preparatory)	$140,000	22 Dec. 1978
374-LAO	Xeset Hydropower (Project Preparatory)	$246,000	14 Nov. 1980
	Subtotal	$386,000	

Besides the above, the following projects have already been embodied in the power sector:

- Nam Ngum-Luang Prabang Power Transmission Project

The Asian Development Bank has approved a loan of US$12,700,000 to the Government of Lao PDR for financing a 115 kV single circuit power transmission line 208 km long from the Nam Ngum Power Station through Vang Vieng to Luang Prabang including substation facilities at the sending and receiving ends.

A feasibility study of this project has already been completed by Swed Power, a consultant firm of Sweden. This project, which is be executed by EDL and targeted for completion in 1992, will supply electricity generated at the Nam Ngum Power Station to meet industrial, commercial and domestic demand in the Luang Prabang Province.

- Tha Ngon Substation Project

Development of an industrial zone is being executed by the authorities concerned of the Government of Lao PDR in the Tha Ngon Area, which is located about 20 km northeast of Vientiane. A substation with an installed capacity of 10,000 kVA will be constructed and connected the existing 115 kV transmission line for power transformation from 115 kV to 22 kV.

The Asian Development Bank will provide funding for this project.

- Xeset Hydroelectric Power Project

The proposed 45 MW Xeset Hydroelectric Power Project, to be executed by EDL, will enhance the export earnings of Lao PDR through increased export of electricity to EGAT while supporting increased local electrification in the Saravane and Champassak Provinces. The project site is located 70 km southeast of Pakse.

The financing plan for this project is given below:

(in US$ million)

Source	Foreign Cost	Local Cost	Total Cost
ADB	15.50	-	15.50 (38.9%)
SIDA*	17.04	-	17.04 (42.7%)
UNDP	1.76	-	1.76 (4.4%)
EDL/Government	-	5.60	5.60 (14.0%)
Total	34.30	5.60	39.90 (100.0%)

SIDA: Swedish International Development Authority

The IDA Credit for the Southern Provinces Electrification Project, which will provide transmission/distribution facilities for this project, has been approved by the Government of Lao PDR.

2-4-2 Relationship to the Basic Plan on the Project for Repair of Nam Ngum Hydroelectric Power Station, Units No.3 and No.4

Supply of electricity generated at the Nam Ngum Power Station is at present limited to Vientiane, including its suburbs and to the neighborhood of the Nam Ngum Power Station. In order to enhance domestic electricity supplies, construction of 22 kV distribution lines is in progress by the Vientiane Plain Electrification Project. A substation for this project is nearing completion at a point 51 km from Vientiane.

Completion of the Nam Ngum-Luang Prabang Power Transmission Project will make it possible to extend electricity generated from indigenous hydropower resources to the constrained power market in the Luang Prabang Province in Northern Laos, thus promoting economic development and saving foreign exchange expenditure on imported fuel.

As shown above, measures are now being taken in Lao PDR to steadily increase electricity consumption. Nam Ngum Power Station will therefore be increasingly important for ensuring stability of electricity supply. The necessity for maintenance of the generating equipment is

all the more important because other major alternative energy sources are unavailable in Lao PDR.

2-5 Outline of the Request

2-5-1 Circumstance of the Request

Electricity consumption in the Vientiane area was about 25 GWh in 1970 and increased to about 130 GWh in 1985, showing an average annual increase rate of 11.6%. A rapid increase has occurred in recent years because tariffs were kept very low despite inflation. Electricity consumption decreased when tariffs were raised to their present level in March 1985, but a steady increase is again apparent at present. A major part of energy generation at the Nam Ngum Power Station is also exported to EGAT and as a result, it plays a key role in the economy as the nation's leading foreign exchange earner. Domestically, the Nam Ngum Power Station supplies electricity to an integrated urban and rural network operated by EDL in the Vientiane Province.

No.3 and No.4 units have now been in commercial operation for more than ten years without overhaul. It became clear through the field survey that overhauling was now urgently required in view of extent of corrosion and fatigue in these units. It would be very difficult, however, for EDL to execute the overhaul by themselves because of the present financial and technical limitations for both the Lao PDR and EDL.

In view of the above, the Government of Lao PDR requested the Government of Japan to repair No.3 and No.4 units under the grant aid program.

2-5-2 Outline of the Request

During the field survey, an outline of the request was confirmed and agreed upon between the JICA Survey Team and EDL, the executing Agency in the Lao PDR, as outlined below:

(1) The objective of the Project is to repair or replace components and parts which have become seriously worn in the hydromechanical and hydroelectrical equipment of the existing No.3 and/or No.4 units at the Nam Ngum Power Station.

(2) The relevant equipment of the No.3 and No.4 units will be as follows:

i) Hydraulic turbines
ii) Alternating current generators except excitation system
iii) Auxiliary mechanical equipment
iv) Intake gates
v) 115 kV switchgear equipment
vi) Unit control system
vii) AC/DC auxiliary power supplies

Items of equipment and jobs included in the request are as mentioned below:

i) Overhaul of main body and ancillaries of the hydraulic turbines
ii) Overhaul of main body of the alternating current generators
iii) Supervision of repair and supply of spare parts for the auxiliary equipment (powerhouse overhead cranes, air conditioning and ventilation systems, fire fighting system, water level indicating device, and cooling water supply system)
iv) Repair and replacement of faulty parts of the intake gates
v) Overhaul of the 115 kV circuit breaker and repair of other 115 kV switchgear equipment
vi) Repair and replacement of faulty parts of the control, metering and protective devices.
vii) Repair and replacement of faulty parts of the AC/DC auxiliary power supplies

CHAPTER 3

OUTLINE OF THE PROJECT

CHAPTER 3 OUTLINE OF THE PROJECT

3-1 Objective

The purpose of this project is to improve the deteriorated performance of the generating equipment units No. 3 and No. 4 in the Nam Ngum power station due to long hours operation, of which units have already been operated for more 10 years after commissioning, and to restore the equipment to the original condition by overhauling the equipment. By increasing the reliability of the power supply, it will be expected to keep a stable power supply to the domestic network in the Lao PDR and to continue the power exports to Thailand. The said power exports is the nation's leading foreign exchange income.

To achieve this purpose, the grant aid from the Japanese government was requested for the procurement and delivery of the required components and materials for the overhaul, repairing work and test after completion of the repair work.

As a site survey result, the pitting damage due to cavitation was observed on the runner vanes of both the unit No. 3 and unit No. 4, and it was judged that, considering the degree of the damage, the repair should be necessary. While the gap between bottom ring and guide vane has been enlarged to three times the design value due to local corrosion on the guide vanes, which was caused by the long time operation, and not caused by the property of the material and the water condition of the reservoir.

Viewed from the turbine, the following technical problems will arise if the turbine should be operated under this condition:-

(1) Uneven surface on the runner vanes due to cavitation pitting will cause further development of the erosion acceleratedly. This will cause lowering turbine efficiency, and make the repairing work more difficult, consequently.

(2) At the Nam Ngum power station, considering the effective head and penstock length, no inlet valve was provided to all the units. Then, the stop control of the turbine depends on the closing guide vane. Increase of the guide vane gap will arise the condition that the turbine could not be stopped due to leakage water from the gap. This condition had really occurred on unit No. 1 and unit No. 2.

Besides the turbine, repair of the following items shall be required urgently:-

(1) The indication and recording instruments of temperature do not function properly due to bad order of the said equipment.

(2) Mechanical speed detector was out of order. So, the speed control is forced to rely on the electrical device only.

(3) Due to improper insulation treatment of the connection bars between stator coils, there have high possibility to occur the ground or short circuit fault on the coils.

By taking an effective measure to the above, the further progress of the problem will be stopped, and the generating equipment will be also prevented from serious accident a damage, as possibility of occurrence will become surely less.

3-2 Study and Examination on the Request

3-2-1 Study of Repairing Schedule

The actual status of the request items was checked carefully and in detail at the site. Check items were summarized in the Table 3.1.

The basic design for the repair was based on analysis of the survey results of the generating equipment. The causes why the repair of the machine was required were categorized in the six items as below:

Cause A : Wear, fatigue or stain due to long hour operation

Cause B : Improper application of the equipment and material, or defect in design and manufacture or installation

Cause C : Unforeseen factors such as water conditions and corrosive atmosphere.

Cause D : Improper operation or maintenance

Cause E : Non-fulfillment of periodical maintenance work

Cause F : Others

Items \ Cause	A	B	C	D	E	F
1. Hydraulic Turbine						
(1) Draft tube liner	O		O			
(2) Stayring			O			
(3) Spiral care			O			
(4) Guide vane	O					
(5) Runner	O					
(6) Discharge ring			O			
(7) Protect liner						Damage due to biting foreign matters
(8) Top cover and it's drainage system			O		O	
(9) Bottom ring			O			
(10) Link mechanism of guide vane					O	
(11) Guide vane servomotor						Looseness of mannual locking device
(12) Draft tube pressure gauge				O		
(13) Oil vapour filtering device of thrust bearing oil		O				
(14) Governor and pressure oil system	O					
(15) Guide bearing	O					
(16) Lubricating oil and pressure oil	O					
2. A.C. Generator						
2.1 Stator						
(1) Stator winding	O	O				
(2) Joint of stator winding	O					
2.2 Rotor						
(1) Rotor	O					
(2) Collector ring				O	O	
(3) Brush and brush holder						
2.3 Brake and oil jack	O					
2.4 Mechanical speed detective device		O				
2.5 Recording thermometer	O				O	
2.6 Air cooler	O		O			
2.7 Guide bearing	O					

Items \ Cause	A	B	C	D	E	F
3. Ancillary Equipment						
(1) Wire rope of overhead traveling crane (OHTC)				O		
(2) Pendant control switches of OHTC					O	
4. Air Conditioning and ventilation equipment						
(1) Fan driving belt					O	
(2) Coolant pressure					O	
5. Fire Extinguisher	O				O	
6. Cooling Water Supply System	O		O			
7. Water Level Indicator	O		O			
8. Intake Gate Facility						
(1) Hoist brake		O				
(2) Local control panel		O	O			
(3) Operating system					O	
(4) Distribution panel located on the dam crest			O		O	
9. 115 kV Switchgear						
(1) Circuit breaker	O					
(2) Disconnecting switch	O		O			
(3) Current transformer	O					
(4) Potential transformer	O	O				
(5) Lightning arrester	O		O			
(6) Earthing mesh			O		O	
(7) Lighting fixture					O	
(8) Operation box		O			O	

Items \ Cause	A	B	C	D	E	F
10. Control, Measuring and Protective Device						
(1) Temperature indicators on main control boards	O					
(2) Recording wattmeter	O					Consumables such as recording pen and etc. were not replenished.
(3) Recording frequency meter	O					
(4) Recording voltage meter	O					
(5) Watthour meter	O					
(6) Sequential indicator	O					
(7) Protective relays						Sign of aging on the device shall be checked.
(8) Automatic synchronizer						There is possibility that some component is out of order.
(9) Recording thermo meter	O					
(10) Operating hour counter	O					
(11) Instruments						
(12) Sound arrester for telephone box near local control boards	O					
(13) Flow meter for turbine discharge			O			
(14) Caulking for cable hole					O	
(15) Connection cable for thermo-sensor					O	
(16) Lighting fixture for fluorescent lamp					O	
11. Auxiliary Power Supply Equipment						
(1) Storage batteries	O					
(2) Electrolyte					O	
(3) Battery charger	O					
(4) Circuit breaker for DC main circuit		O				

As itemized in the above table, the cause of damage was due to natural fatigue or deterioration after long time operation and corrosion suffered from a hydrogen sulfide solubled in the reservoir water.

In connection with the repairing on the turbine which is major item of the repair, the cause was mainly due to water conditions and secular deterioration.

After installing the spillway gates at the second stage development, the reservoir water level increased by about 10 m higher than the previous level. Hydrogen sulfide generated from the submerged plant breeding at circumferential zone of the reservoir. It is consequently judged that the corrosion observed in the turbine was caused by the sulfided water. However, no corrosion due to water condition will be predicted since the generation of hydrogen sulfide has already ceased at this moment.

Equipment other than the turbine, procurement of the consumables and spare parts was not arranged in time. Due to this difficulty of spare parts procurement, the generating equipment could not be maintained physically, and then progress of wear and tear could not be prevented.

3-2-2 Additional Requests

Additional requirements proposed by EDL during the survey at the site are as referred to attached memorandum are classified as follows:

Additional Requested Items	Included in this Project	Excluded in this Project
A. Power House Drainage System		
(1) Inspection of drainage pump control and water level instrument	O	
(2) Inspection and repair of pump	O	
B. Intake gates (except for Unit No. 3 and No. 4)		
(1) Inspection of local control box, limit switches and brake		O
(2) Inspection of water level measuring instrument		O

Additional Requested Items	Included in this Project	Excluded in this Project
(3) Inspection of transmitter for gate position indicator		O
C. Control, Measuring and Protective Device		
(1) Replacement of cut signal lamps	O	
(2) Supply of governor control motors as spare	O	
D. 115 kV Switchgear Equipment (except for Units No. 3 and No. 4)		
(1) Disassemble inspection of 115 kV transmission line circuit breaker	O	
(2) Inspections of 115 kV bus potential transformers and lightning arresters	O	
(3) Supply of spare parts		O
(4) Circuit breaker for 115 kV side of 3,000kVA local service transformer		O
E. 11 kV Switchgear Equipment		
(1) Inspections of switchgear	O	
(2) Replacement of exciting transformer for units No.3 and No.4		O
(3) Inspection of operating solenoid valve for circuit breaker	O	
(4) Supply of supporting insulator for 11 kV side main transformer bus bar		O
F. 22 kV Switchgear		
(1) Inspection, repair or replacement of component	O	
G. Auxiliary Power Supply Equipment		
(1) Replacement of storage batteries for Units No. 1 and No. 2		O
(2) Inspection of low tension cubicles	O	
(3) Supply of diluted sulfuric acid	O	
(4) Supply of DC voltmeter	O	
(5) Supply of gravity meter	O	

H. Field Circuit Breaker (1) Supply of spare field circuit breaker for Units No. 1 and No. 2	O	
I. Main Control Board (1) Watthour meter for No.1 115 kV transmission line (2) Fault locater	O	O

The classification as tabulated above was made based on the following consideration:-

I. Items to be included in the Project

(1) Inspection work can be executed by the power station staff under supervision of the contractor since this is closely concerned with operation of the units No. 3 and No. 4.

[Item A.(1), Item A(2,), Items D.(1) and D.(2), Item I.(1)]

(2) Total amount for the repair work doesn't increase since the power station staff can perform these items under instruction of the supervisor despatched by the contractor.

[Items E.(1) and E.(2), G.(2)]

(3) These are required for usual maintenance work. It is difficult, however, to procure because of necessity of special order in the local market of Laos which takes very long time till acquisition.

[Item C.(1), Items G.(3), G.(4) and G.(5)]

(4) No spare parts are available at present, while those are considerably worn out now.

[Item C.(1), Item H.(1)]

(5) Although the relevant equipment had previously used for construction power supply purpose at the first stage development, they are at present used for the power supply to the power station, permanent quarters and neighbouring areas on the power station. However, they are considerably worn out because of longer than 17 years in the time elapsed after having put into service.

[Item F.(1)]

II. Items to be excluded from the Project

(1) These mean substantial improvement of the original condition.

[Item D.(4), Item E.(2), Item I.(2)]

(2) These should be included in the usual maintenance work. And it is not required to inspect or repair them urgently.

[Items B.(1), B.(2) and B.(3)]

(3) Considering substantial character of the request, these should be procured by the budget, if the Nam Ngum Power Station.

[Item D.(3), Item E.(4), Item G.(1)]

3-3 Project Description

3-3-1 Executing Agency and Operational Structure

The executing agency of the Project in Laos is EDL. The Project Control Center will be located at the Vientiane Head Office to take charge of the required management and communication with other authorities concerned during execution of this Project. The Site Executing Agency for the repairing work will be the Nam Ngum Power Station. During working period, the manager of the Power Station will take a post as the Superintendent to deal mainly with technical matters.

Working group for repair will be organized by members of electrical and mechanical maintenance teams, and the leading members of these teams will play key roles for the respective works. But, the number of maintenance members are not enough for this job, some of operators will also join to this job for reinforcing the repairing staff. Total number of the working group will be approximately 30 persons. This reinforcement can be realized considering the present arrangement of operators at the Power Station.

It is noted that there be no fundamental problem related to the maintenance after completion of the Project since the Nam Ngum Power Station staff will continue executing the operation and maintenance.

3-3-2 Plan of Operation

The Project will be executed with the shortest working period and the least cost under the terms and conditions of the grant aid program.

Scope of work is as follows:-

(1) Manufacture of components and parts, procurement of materials, transportation and installation works
Example: Replacement of the guide vane.
Insulation treatment of the generator stator windings.

(2) Despatch of workers for site work
Example: Overlay of the runner and welding repair of main body of the turbine.

(3) Despatch of guidance staff for site work
Example: Calibration, repair and adjustment of devices and apparatuses on cubicles and panel boards.
Inspection and repair for the switchgear equipment.

(4) Supply of materials and parts for repair

Example: Supply of spare parts for the cooling water supply system.

Supply of equipment and materials for repair of the intake gate.

Table 3.1 Comments on Request Items

Request Items	Comments on Actual Conditions
1. Hydraulic Turbine	
(1) Repairing corrosion and pitting of the draft tube liner	Paint coat applied to surface of the liner remains in sound condition, but the corrosion and pitting were observed on the following parts:- Corrosion on top parts of downstream surface of the draft tube fins:- The corrosion which looks like a crater was observed on 1/3 of 2,500 mm draft tube fins from the top, but touch-up painting remains in good condition. No damage was observed on the stainless clad plate welded on the lower parts of the draft fins, but on Unit No. 3, the wave shaped corrosion with 1-2 mm in depth was observed on the upstream side of the draft fins. See Photo-1 and 2. Refer to attached Figs.-3 ~ -7.
(2) Repairing the stayring	The local corrosion with 1 to 2 mm in depth and 10 to 50 cm2 in area were distributed either horizontally or vertically on the edge parts of stayring facing to the bottom ring. The gap designed by 3.5mm has enlarged by 4.0 to 4.5mm for the unit No. 4 with slight corrosion volume, but that of unit 3 has reached 4 to 6 mm with rather big corrosion volume. See Photo-3. Refer to attached Fig.-22. Refer to attached Table-1.
(3) Repairing the spiral case	Anti-corrosive paint coat on surface of the spiral case remains in sound condition, but some parts have been peeled off locally.
(4) Repairing side gap the guide vane	The corrosion around lower gap of the guide vane was rather big, especially for toe parts of down-stream gap. The average values of gap are 1.62 mm for the unit No. 3 and 2.2 mm for the unit No. 4 respectively, and the maximum value reached 3 to 4 mm against the design value of 0.7 mm.

Request Items	Comments on Actual Condition
	Upper gaps of the guide vanes measured are mostly within tolerance. Comparing with the data measured in 1986, the corrosion is slightly progressed in both the unit No. 3 and No. 4, and the degree of progress for the unit No. 4 is bigger than the unit No. 3. Partial damage was observed on the surface of the guide vanes, but no damage was observed on the shutter surface, lower and upper edge parts. Paint coat also remains in sound condition. Refer to attached Figs.-1 and -2.
(5) Welding repairing cavitation pitting on the runner vane	Total area of the damage by cavitation pitting on the outlet part of the suction side is approximately estimated at 6,400 cm2 for the unit No. 3, and 9,200 cm2 for the unit No. 4. And, average areas per vane are 320 cm2 for the unit No. 3 and 460 cm2 for the unit No. 4. Depth of the pitting on the vane is 1 to 4.5 mm for the unit No. 3 and is 1 to 7 mm for the unit No. 4. The progress of the pitting for the unit No. 4 is slightly faster than the unit No. 3. Previous repaired part of the cavitation pitting could hardly be distinct from the present cavitation area. It seems, however, that the present cavitation is distributed in the almost same part of the previous repairing as the boundary parts of the runner crown. Interval of repair is estimated at about seven years based on the present pitting condition which had elapsed about five years and half since the previous repair. See Photo-4. Refer to attached Figs.-8 ~ -15.
(6) Repairing the discharge ring	No damage was observed on the stainless steel made wearing ring, but the rough corrosive damage with 4 to 5 mm in depth was observed on the circumference area just below the wearing ring. Damage were observed on the lower wearing ring with 400 mm in width for the unit No. 3 and 100 mm for the unit No. 4. Anti-corrosive paint coat on the unit No. 3 for repairing purpose remains in good condition. Then, application of the protective paint was proved to be effective.

Request Items	Comments on Actual Condition
	See Photo-5. Refer to attached Figs.-16 ~ -19.
(7) Repairing the protect liner	Noticeable damage was not generally observed on the protect liner, but one scratched damage with 1 to 2 mm in depth, 13 mm in width and 170 mm in length was observed on the protect liner between No.11 and No.12 guide vanes See Photo-6. Refer to attached Fig.-23.
(8) Overhaul of the top cover and the drainage system	According to visual inspection, both surfaces of the top cover remain in good condition. No corrosion nor pitting due to the cavitation was observed, but it is necessary to replace several rusted stud bolts with new ones at the time of overhaul. No water leakage from the seal packing nor unusual condition on the top cover drainage system was observed on both the unit No. 3 and the unit No. 4.
(9) Repairing the bottom ring	The corrosion was observed on the horizontal parts of the bottom ring edge and the gap portion. The degree of the corrosion on the horizontal parts reached to 1 to 4 mm in depth, and the corrosion was progressing on the whole mild steel portion. The gap was developing to 4 to 5 mm against the design value of 3.5 mm. See Photo-7. Refer to attached Figs.-20 and -21.
(10) Overhaul of the guide vane operating mechanism	Friction force of the operating mechanism increased. It is recommended to clean the mechanism and replace the oil-less bearing with new one.
(11) Internal inspection of the guide vane servo-motor	Adjustment of the servomotor stroke for the unit No. 3 is required because one mechanical locking plate could not be positioned due to the short closing stroke of the guide vane. The shortage value is 2 mm.
(12) Repairing the draft tube pressure gauge	The pressure gauge was out of the mounting plate. Water leakage from the tapping point of the gauge, the stop valve and other parts was observed.

Request Items	Comments on Actual Condition
(13) Overhaul of the oil mist separator	A part of the exhaust air to the oil mist separator leaks and spreads into the turbine pit to wet the pit wall.
(14) Overhaul of the governor and pressure oil system	The function of the governor system is in a normal operating condition. Oil leakage from the man-hole provided on the oil tank was observed.
(15) Guide bearing	Abnormal condition was not observed on the both the unit No. 3 and the unit No. 4. Temperature of the guide metal and the gap were also within the specified range.
(16) Oil analysis for turbine, thrust metal and governor system	Sample oils for analysis were taken from pressure oil system and lubricating system of the unit No. 4.
(17) Spare parts	
2. <u>Generator</u>	
2.1 Stator (1) Stator winding, wedges, vanishing for supporting part of connection points	Winding: No deformation, damage nor displacement was observed on the stator winding. Irregularities of the coil edge order: Irregularities of the coil edge were checked. As a measuring result, the maximum value is 10mm in tangential direction of the stator coil, and the minimum value 13 mm and the maximum value 29mm were measured between adjacent winding at the lower end portion on the unit No. 4. This seemed to be caused during erection stage, not caused by the mechanical unbalanced force during operation condition. No oil contamination on the upper end side of the winding was observed, and the surface of the winding was not covered with dust so much. Slight oil contamination was observed on the lower winding end due to oil mist coming out from the oil pan adjacent to the winding. However, the degree of the contamination is negligible small.

Request Items	Comments on Actual Condition
(2) Inspection of the stator winding connection cap and replacement, if any	Blasted finishing vanish was completely adhered on the surface of the winding, while the vanish was locally peeled off on the compound surface between coils and caps . Connection cap: The number of winding slot is 420 per unit and its required cap is 858 numbers. 75 caps out of 858 caps were checked on both the unit No. 3 and unit No. 4. As a result of check, the damage with 10mm in length and 1 mm in width was observed, which seems to be injured by the screw driver and other 75 mm in length was also observed, which seems to be injured by the knife edge. Numbers of damage and dent are as follows:- damage dent unit No. 3 2 11 unit No. 4 3 14 It is noted that the maximum depth of dent reached to 2 mm was observed in two caps. But those deformation was not due to deterioration by operation, but had appeared during installation. Abnormal swelling was not observed. Cores: No looseness of the iron cores was observed. Slight oil contamination due to oil mist was observed on the lower portion of the core, but dust deposit in the cooling air duct is negligible scare. Wedges: Hammering check was done on 75 slots per unit. No looseness was observed. Insulation of connection bars: Red varnish impregnated in the glass fiber tape used for insulating of the connection bar had not hardened and dropped down on the fastening plate of the cores, which was seen on both the unit No. 3 and unit No. 4. See Photo-8. Insulation level has a tendency to reduce due to dropping of varnish gradually since the varnish have not yet hardened.

Request Items	Comments on Actual Condition
	Bind-rings: Bind-rings were fastened firmly. Binding the winding: No looseness, deformation nor cutting was observed on binding the winding at the straight portion, the adjacent winding end portion and the bind-rings portion which were bound with the glass fiber tape and were fastened firmly. End-bell cover: Though the end-bell cover made of fiber reinforced plastic (FRP) was chipped off in the edge slightly, but no distortion nor looseness was observed. Space between the winding and the cover was kept at 15 to 25 mm, and that of the fans and the cover was also kept with 6 to 13mm. These figures were judged to be proper value. Oil contamination was observed on the mating surface of the lower cover due to oil mist.
2.2 Rotor	
(1) Inspection and clearing of the rotor	Coils and cores: Slight oil contamination was observed on the lower surface of the rotor, which was seen on both the unit No. 3 and unit No. 4, but adhesion of dust was slight. No looseness nor damage was observed on the winding and the insulation collar. Connections between windings: The connection was made by two copper bars; one bar arranged inner side was bent with right-angle and another arranged outer side was bent diagonally and connected with the bolts. Connection copper bars without silver plating were fastened with bolts, and no insulation was provided. No corrosion due to hydrogen sulfide was observed. Copper bars between coils and collector ring: As red varnish impregnated in the glass fiber tape used for insulation of bars had oozed out, but the insulation was already repaired with new tapes.

Request Items	Comments on Actual Condition
	See Photo-9. The copper bars fixed to the spider were in good condition without any looseness and deformation. Damper: Damper bars and damper rings were kept in good condition. No sign of the overheating nor corrosion was observed on the connecting portion of the ring made of non-plating copper bars and fastened with bolts. Fans: Fixing of the fans was kept in good condition. Slight oil contamination was observed on the lower parts of the fans.
(2) Maintenance of the collector ring	Collector ring: No spiral groove is provided to the sliding surface, and the rings were kept in good condition. Some scratches were observed at the lower side ring on both the unit No. 3 and unit No. 4.
(3) Replacement of the brush	Brushes and brush holders: Brushes were maintained in good condition with no sign of the overheating on the lead wire of the brush and no spark from the sliding surface. Brush holders were also maintained in good condition. Spider and yoke: Abnormal condition was not observed. Measurement of insulation resistance (unit No. 3 and unit No. 4) Stator windings (by 1,000 V megger, 1 minute) U - E more than 2,000 Mohms V - E - ditto - W - E - ditto - U - V - ditto - V - W - ditto - U - W - ditto - Rotor winding (by 500 V megger, 1 minute) Winding - E more than 1,000 Mohms
2.3 Overhaul of the brake and jacking device, and replacement of the brake liners	Brakes and jacking up device: A little oil leakage was observed at the pressure oil pump filter for the unit No. 3.

Request Items	Comments on Actual Condition
	The functional problem of the unit No. 4 pressure oil system was already solved. Brake operating system of both the unit No. 3 and unit No. 4 were maintained in good condition. Brake liners of both the units were not so worn off. Brake rings of both the units were kept in smooth condition.
2.4 Repairing the jointer between the permanent magnetic generator (PMG) and the mechanical speed detective device	PMG and speed detective device: Mechanical type speed switch of the unit No. 4 doesn't functions properly. Photo type switch of the unit No. 3 doesn't function properly.
2.5 Repairing the recording thermometers	Thermometers: (1) For generator winding Recording thermometer does not function properly. 8 numbers of the embedded resistant type detector per unit were in good condition for both the units. (Actual measured value; 110 to 120 ohms by Pt 100 ohms at 0°C) (2) For thrust bearing and turbine guide bearing metals: Recording thermometer does not function properly. Unit No. 3: Indication showed correct value, but the paper feeding mechanism does not operate correctly. Unit No. 4: Both indication and paper feeding mechanism don't operate correctly.
2.6 Checking the air cooler	Air coolers: The air coolers for both the unit No. 3 and unit No. 4 were maintained in good condition. Temperature indicator of the unit No. 4 for air cooler outlet show 30 to 34°C by dial thermometer provided 8 numbers per unit.
2.7 Overhaul of the guide bearing	Thrust bearing: A little oil leakage was observed from the packing seal portion of the cooling water pipe fixing plate for the unit No. 3.

Request Items	Comments on Actual Condition
	A little oil contamination was observed due to oil mist coming out from the air blower mechanism on the generator lower end bell, lower parts of coil ends and lower parts of the cores. Bearing temperature was 56°C See Photo-10.
2.8 Spare parts	Spare parts to be delivered: Brake shoes 8 sheets Insulation caps 123 pieces Brushes for collector ring Approx. 100 pieces Gasket for generator air cooler 1 lot Dial thermometer 1 piece Flow meter for air cooler 1 piece
2.9 Fire extinguisher	There is no problem to be noted on the piping system.
2.10 Static type excitation system	Excitation system had been repaired and was maintained in good condition.
3. Ancillary Equipment	
3.1 Overhead travelling crane	
(1) Inspection prior to commencement of the repair work	There was the repair mark on the power cable supports on girder of the No. 2 crane. Fixing part of the power cable with the pendant type control switch box was damaged.
(2) Replacement of 5-ton rope trolley on the No. 1 crane	The deformation of strand was observed on the 5-ton hoist wire rope. Automatic stop of traversing could not function due to the limit switch trouble. Good condition was observed under no-load operating, but it was reported that, sometimes, the crane could not be operated due to loss of power supply cut by decrease in current collecting capability of the trolley wheels.
3.2 Overhead crane in the cooling water supply room Replacement of power supply and control cables	Connection part of the power cable to pendant type control switch box was damaged.

Request Items	Comments on Actual Condition
3.3 Overhead crane in warehouse	The crane could not be operated due to trouble of upper and lower limit switches.
4. Air Ventilation System (1) Fitting the V-shape belt of the ventilation system (2) Supplying the bearing, the V-belt and the coolant	Exhaust fans could not be checked because of direct connection with driving motor. Ventilation fan was driven by the motor with three driving belts. Elongation and wearing were observed on each belt.
5. Fire Extinguisher Inspection and Repair	Eight fire hydrants were provided: two for the erection bay and six for the generator room. It was doubtful whether the rubber hose have the specified strength or not because no periodical inspection record was found. Missing or damage was observed on each hydrant nozzle. A quick hose connection with a hydrant could not be expected in the emergency case because of damage of the connecting adaptor.
6. Cooling Water Supply System (1) Overhaul and procurement of spare parts (2) Improper operation of secondary check valve	Check valve for the primary cooling water system was out of service intentionally. Normal operating condition was observed on the packing seal and other parts.
7. Water Level Indicator	Indications of the receivers for both reservoir and tailrace are incorrect.

Request Items	Comments on Actual Condition
8. Intake Gates and Others	
8.1 Intake gates	External appearance and corrosion of the gate leaf: There is found damage on paint coat of both the No.3 and No.4 units. The anti-corrosive function has already lost. But, a remarkable rust is not observed on the structural members of gate leaves. Sheave: The sheave rotates smoothly by movement of the wire rope. No damage is found on the sheave grove and the sheave itself. Main roller: While wheel tread of the main roller is in rust, a deep flaw is not found out. The roller shaft which is of stainless steel is in sound condition. The main roller rotates smoothly by hand. Then, it is judged that the bearing condition is very good. Water tightness: Function of the existing rubber seal is good enough because the elasticity is appropriate and no flaw nor damage is observed. Although a very slight water leakage is seen in the corner portion, it is unnecessary to rectify this problem. Wire rope: No cut is observed on the strand of the wire rope. However, grease application on the wire rope is insufficient. Then, wire rope of the No.3 unit is in rust partially.
(1) Inspection of the hoist brake	The condition of the hoist brake is generally good, while cleaning is not done properly. The rope groove on the rope drum is in rust, and lubrication is not well done.
(2) Replacement of faulty electrical parts	Electrical components and parts mounted inside local control boxes are mostly deteriorated due probably to high temperature and high humidity. Weatherproof function of the door gaskets of the local control boxes has been lost.
(3) Inspection and test of the limit switches	Limit switches for upper and lower positions do not function. Wire slack protection does not operate.

Request Items	Comments on Actual Condition
(4) Distribution panel on the dam crest	Moulded case circuit breakers (MCCB) mounted inside the distribution panel on the dam crest are very dirty, and are very rusty on their terminals.
8.2 Gantry cranes	
(1) Intake gate gantry	Limit switches for upper and lower positions do not operate, and wire slack detection does not operate also. Cabtyre cable for power supply is damaged partially on the sheath.
(2) Tailrace gantry crane	Limit switches for upper and lower positions do not operate, and wire slack detection does not operate also.
9. 115 kV Switchgear	
(1) Overhaul of circuit breaker	
(2) Inspection of the disconnecting switch	
(3) Inspection of the instrument transformer	Oil leakage is seen on the top of the capacitance type potential device.
(4) Repair of the operation counter	Corrosion on discharge current recorder is very severe.
(5) Improvement of the jointer to earthing network	
(6) Replacement of door gasket of the local control boxes	
10. Control, Metering and Protective Systems	There are several items to be repaired or replaced with new ones because of their inoperative condition and incorrect function.
(1) Inspection and calibration of the temperature indicators	
(2) Repair or replacement of the recording wattmeter	

Request Items	Comments on Actual Condition
(3) Repair or replacement of the recording frequency meter (4) Repair or replacement of the recording voltmeter (5) Calibration of the watthour meter (7) Operation test of the protective relays (8) Inspection of the automatic synchronizer (9) Repair or replacement of the recording thermometer (10) Replacement of the running hour meter (11) Calibration of other indicating meters (12) Soundproof measure in telephone boxes near local control boards (13) Caulking of cable hole (14) Cleaning special cables for temperature sensors (15) Inspection and repair of the flow meter (16) Replacement of the fluorescent lamp	

Request Items	Comments on Actual Condition
11. AC/CD Auxiliary Power Supplies (1) Inspection and replacement of the faulty battery (2) Correction of electrolyte level (3) Inspection of the battery charger (4) Replacement of faulty MCCB in DC main circuit	Black colored foreign substance is observed inside of the most of unit storage battery containers.

CHAPTER 4

BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4 - 1 Design Policy

In accordance with results of the field survey, the components and parts on generating equipment which were included in the official request are classified into the following categories to establish the design policy.

A. Components and parts which will be repaired (including touch-up paint and readjustment) to use from now on
B. Components and parts which will be replaced with new ones though they are in service at present
C. Components and part which will be overhauled for detailed inspection and be repaired if necessary
D. Components and parts which will be supplied as spare because no spares are available at present

Classification of these equipment and machinery is as listed below:

	A	B	C	D
Turbine	- Runner - Upper draft liner - Stayring - Discharge ring - Protect liner - Bottom ring - Oil cooler for bearing of No.3 unit	- Guide vane - Packings - Mechanical speed switch - Bushes in guide vane regulating ring - Bolts, nuts and washers	- Oil mist separator in thrust bearing - Governor and pressure oil systems	- Governor motor
Generator	- Phase connecting bar insulation - Collector ring - Temperature indicator	- Wedges for fixing winding - Packings - Bolts, nuts and washers	- Stator winding - Rotor winding - Air cooler units	- Insulating materials - Brake liners
Auxiliary Mechanical Equipment		- Faulty components and parts		- Packings - Spare pump sets with accessories

	A	B	C	D
Intake Gate		- Faulty electrical components and parts	- Hosit brake	
115 kV Switch gear		- Coupling capacitor potential device - Packings	- Circuit breaker - Disconnecting switch - Instrument transformer - Lightning arrester	
Control, Metering and Protective Devices	- Automatic synchronizer - Meters indicating incorrect value	- Faulty meters and annunciators - Broken lamps		
Auxiliary Power Supplies		- Storage - Faulty components and parts	- Battery charger	

4 - 2 Establishment of Basic Design

The following particulars were examined in establishing the basic design:

(1) Machining process is needed for fabrication and repair of turbines to keep accuracy within tolerable limits. Comparative study was done between execution of field repair and delivery of new products from the factory to ascertain which way will be justifiable technically and economically taking into account of transportation of necessary machine tools to the project site and re-export after repair and probable length of working hours for the field repair as well.

(2) In order to determine the objective for the repair, occurrence of defacement and fatigue along with its progress were estimated for the respective machines just after completion of the repair to the next opportunity of repair in the future.

(3) Cause of wear and tear and the influence of such wear and tear upon performance of the generating equipment were considered.

(4) Present level of capability on maintenance technique of the Nam Ngum Power Station staff and possible raise of the said capability were examined.

Table 4-1 shows key points of the basic Design for the respective items in request.

Table 4-1 Basic Design for Repair Work

Request Items	Basic Design for Repair Work
1. Hydraulic Turbine	
(1) Repair of corrosion and cavitation pitting on the upper draft tube liner	It is unnecessary to repair the stainless steel plated portion just below the runner outlet because no corrosion is found. However, anti-corrosive paint is applied to the top portion of the steel liner beneath the stainless plating where partial corrosion exists. Downstream of whirl suppressing fins is repaired by building up method.
(2) Repair of the stayring	As degree of the corrosion is very slight, no repair by welding will be done. However, anti-corrosive paint is applied to the stayring after smoothing unevenness. While the gap between the stayring and the bottom ring has already widened due to corrosion, turbine performance will not be influenced by this gap directly. However, in order to stop progress of this corrosion, a suitable caulking material is filled up in the gap.
(3) Repair of the spiral case	There is no portion that necessitates repair. However, touch-up paint is applied to parts where the original paint peeled off partially.
(4) Repair of the guide vane gap	One unit of the turbine is provided with 20 Nos. of the guide vane. Machining is required for restoration of the gap to designed value. Therefore, necessary machine tools will have to be brought to the project site including despatch of qualified technicians for machining. Because a longer period will be needed for the field machining, new guide vanes are transported to the site from the manufacturer's shop to replace the existing ones with them.
(5) Repair of the runner vanes	After having taken out to outside by overhaul, welding is done to build up the cavitation pitting. Quality control of welding and heat treatment should be done strictly because of stainless steel in the runner material.
(6) Repair of the discharge ring	After cleaning, prime coat and finish coat of anti-corrosive paint are applied.
(7) Repair of the protective liner	A streak with a depth of 1 to 2 mm running on the protective liner of the No.3 unit is repaired by building up weld.

Request Items	Basic Design for Repair Work
(8) Overhaul of the head cover and drainage system	After cleaning, wear and tear on the head cover are repaired including application of anti-corrosive paint. The drainage system on the head cover is very soiled, and is then to be cleaned completely.
(9) Repair of the bottom ring	In view of extent of the corrosion, welding repair is unnecessary. Anti-corrosive paint is applied to it.
(10) Repair of the regulating mechanism	To replace oilless bearing with new one, overhaul is done. The bushes are also renewed.
(11) Repair of the servomotor	The servomotors are overhauled to rectify abnormal condition on manual locking device.
(12) Repair of the pressure gauge	The piping system is repaired to stop water-leakage. The stop valve for the pressure gauge is renewed.
(13) Repair of the oil mist separator for thrust bearing	This system is overhauled, and pipeline of this system is extended to outside of turbine pit to avoid lubricating oil condensation.
(14) Overhaul of the governor and the pressure oil system	Cleaning and repair are done. Manhole gasket is replaced with new one to stop oil leakage.
(15) Repair of the guide bearing	Bearing is overhauled. Packing for water seal are renewed.
(16) Cleaning of the governor and the lubricating oils	It was confirmed that these oils are sound in quality after composition analysis at laboratory in Japan. Filtration treatment is done.
(17) Spare parts	Governor motors for speed changer and for load limiter are supplied.
2. <u>Alternating Current Generator</u>	
2.1 Stator	
(1) Cleaning of the winding wedges and the winding supporter, and varnishing	Overhaul is done. Varnish spraying is done on winding insulation surface.
(2) Repair of the winding joint	Defective joint caps are replaced with new ones. Insulation treatment is done once again on phase joint bars, insulation of which is defective.

Request Items	Basic Design for Repair Work
(3) Treatment of the core	Varnishing is done on the core surface.
2.2 Rotor	
(1) Repair of the rotor	The rotor is overhauled, and varnished on the surface.
(2) Repair of the collector ring	Scratch on the surface is smoothed.
(3) Replacement of the brush	Brashes worn off are replaced with new ones.
2.3 Repair of the brake and the jack-up equipment	Air brake and high pressure oil pump are overhauled. Gaskets are all renewed.
2.4 Repair of joint of the PMG(permanent magnet generator) and the mechanical speed switches	While a temporary measure was taken in the No.3 unit, no joint is provided to the No.4 unit. Permanent measures are taken for both the units.
2.5 Repair of the recording thermometers	Both the temperature sensor and recorder are repaired, or replaced with new ones.
2.6 Repair of the air cooler	All the cooler units are overhauled. Gaskets are also replaced with new ones.
2.7 Repair of the bearing	The bearing is overhauled to repair oil leaky portions. Gaskets are renewed.
3. Auxiliary Mechanical Equipment	
3.1 Overhead traveling crane at the generator room	
(1) Inspection prior to use	Mechanical and electrical inspections are to be done before commencement of the repair works of No.3 units. Faulty parts are to be replaced with new ones.
(2) Replacement of the rope of 5-ton hoist for No.1 crane	Though the strands of rope trolley hoist have deformed partially, the rope itself is in a good condition. Then, this is not replaced.
3.2 Overhead traveling crane at cooling water treatment room	The repair of the pendant switch can be done by the power station staff as one item of routine maintenance. Then, this is excluded from the Project.

Request Items	Basic Design for Repair Work
4. Air Conditioning and Ventilation Systems	
(1) Renewal of the V-belts of ventilation system	This item is excluded from the Project because procurement of the V-belts is to done by the power station staff in the routine maintenance.
(2) Replenishment of the coolant	This item is excluded from the Project because the said repair is to be done by the power station staff in the routine maintenance.
5. Fire Fighting System	This item is excluded from the Project because inspection and repair of the fire fighting system is to be done by the power station staff as one item of the routine maintenance works.
6. Cooling Water Supply System	
(1) Overhaul	In view of the present operating condition of the system, the overhaul is unnecessary.
(2) Supply of the spare parts	At present, no spare parts are available. Then, items requested are supplied as spares.
(3) Repair of the check valves	As no check valve is needed technically in the primary pipeline of the heat exchanger, the existing check valve which is out of service is not restored.
7. Water Level Indicator	The water level transmitting device is in rust remarkably. It is judged that the field repair be so difficult. Then, the said device is renewed. Indication of receiver is also incorrect. Then, the receivers are repaired or replaced.
8. Intake Gate	
(1) Adjustment of the hoist brake	While spring of the electromagnetic brake has to be adjusted to avoid lack of stability. However, the said adjustment can be done by the power station staff easily. Then, this item is excluded from the Project.

Request Items	Basic Design for Repair Work
(2) Replacement of faulty electrical apparatuses in control boxes or in distribution panel on dam crest	In view of difficulty of replacement of apparatuses only at the site, new control box or new distribution panel are to be delivered.
(3) Inspection of the control system and replacement of limit switches	Limit switches are renewed. The renewal work and the inspection are to be done by the power station staff.
9. <u>115 kV Switchgear Equipment</u>	
(1) Overhaul of the circuit breaker	The circuit breaker is overhauled. And the control circuits are inspected and readjusted.
(2) Inspection of the disconnecting switch	The main contacts are cleaned to remove the rust.
(3) Instrument transformers	Inspection of terminal box and cleaning of the bushings are carried out.
(4) Coupling capacitor potential device	As it is very difficult to repair oil leakage at the site, a new device is delivered.
(5) Lightning arrester	Cleaning of the bushing is done. Discharge current recorder which is not always indispensable for operation is removed.
(6) Jointer to grounding network	Corroded jointers are replaced with new ones.
(7) Lighting fixture	Defective fixture is replaced with new one.
(8) Gasket for control box door	Inferior gaskets are replaced with good ones.
10. <u>Control, metering and Protective devices</u>	
(1) Temperature indicator on main control boards	This item is repaired or replaced depending on degree of badness.
(2) Recording wattmeter	- ditto -

Request Items	Basic Design for Repair Work
(3) Recording frequency meter	- ditto -
(4) Recording voltmeter	- ditto -
(5) Integrating watthour meter	- ditto -
(6) Sequence indicator	- ditto -
(7) Temperature recorder	- ditto -
(8) Running hour meter	- ditto -
(9) Calibration of the meters	Calibration is done.
(10) Operation test of the protective relays	Operation test is done to confirm setting value.
(11) Automatic synchronizer	- ditto -
(12) Sound absorber in the telephone box near local control boards	A new material is provided to the telephone box door.
(13) Turbine flow meter	The transducer and indicator are checked and repaired.
(14) Cable hole of cubicles	Caulking material is supplied. And, filling the holes with the said material is to be done by the power station staff.
(15) Cables connecting to temperature sensors	Special cable is supplied for cabling work by the power station staff.
(16) Interior lighting at the battery room	Fluorescent lamps are supplied. And. lighting fixtures are inspected.
11. AC/DC Auxiliary Power Supplies	
(1) Inspection and replacement of the storage battery	Cause on eduction of black colored foreign substance inside the storage battery units is unknown. All the battery units are replaced with new ones.
(2) Correction of level of electrolyte of the storage battery	The electrolyte (sulfuric acid) is supplied.

Request Items	Basic Design for Repair Work
(3) Inspection of the battery charger	No abnormal condition was observed during operation. Then, visual inspection only is done.
(4) Replacement of bad circuit breaker (Mould Case Circuit Breaker) in DC main circuit	The said MCCB is replaced with new one because the existing MCCB has already burnt down.
(5) Ventilation fan for battery room	The fan is replaced with new one to keep a good ventilation.

CHAPTER 5

EXECUTION OF THE PROJECT

CHAPTER 5 EXECUTION OF THE PROJECT

5 - 1 Organization of Project Execution

The Electricite du Laos (EDL) will undertake the Project as the execution agency of the Government of Lao PDR.

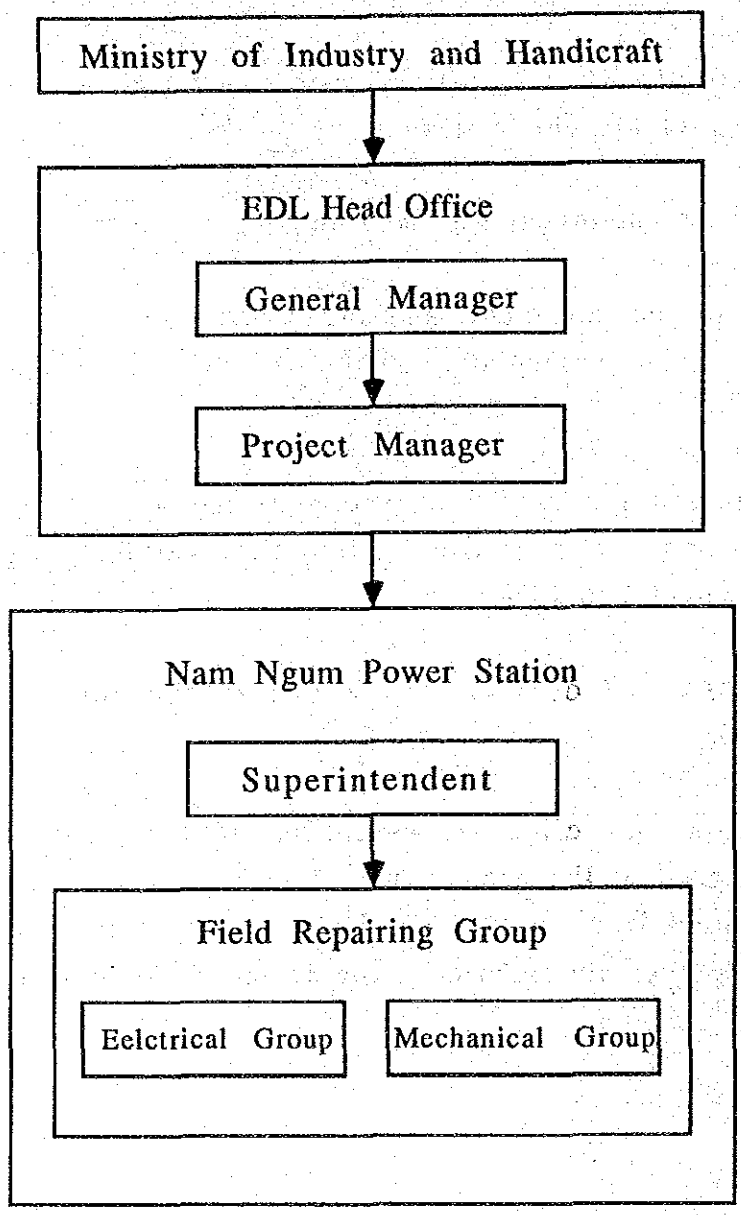
EDL will be authorized for the following services;

(1) Contract to the consultant and the contractor;
(2) Approval of implementation planning and tender document;
(3) Tender and tender evaluation;
(4) Approval of payment;
(5) Supervision of the overall execution of the Project; and
(6) Contact and coordination with the related parties of the Government of Lao PDR.

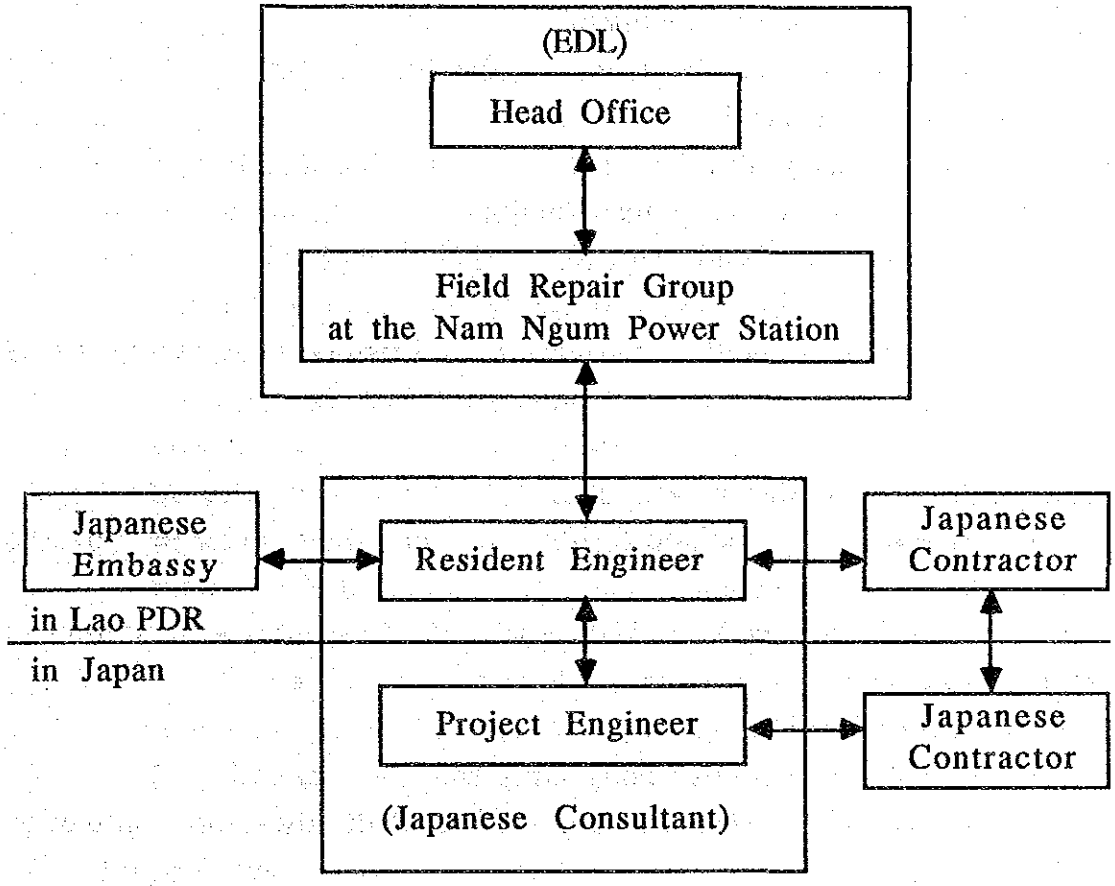
General Manager of EDL has a full responsibility for the above mentioned duties.

For smooth and effective execution of the Project, the Project Manager is assigned at the head office of EDL in Vientiane, and the field repair group which is controlled by the manager of the power station as the Superintendent of the Project is organized at the Nam Ngum Power Station.

The organization of the Government of Lao PDR for the project execution is illustrated as follows:



The organization for the project execution under the grant aid of Japan is illustrated as follows:



Scope of the service performed by the Government of Lao PDR, Japanese consultant and Japanese contractor is outlined as follows:

EDL as the representative of the Government of Lao PDR performs the following duties from a standpoint of the Employer:

(1) Supervision of the overall execution;
(2) Order of engineering services for the Project;
(3) Payment; and,
(4) Taking over after the completion of the Project.

Japanese consultant takes charge for the following works on behalf of the Government of Lao PDR.

(1) Detailed design;
(2) Preparation of tender document;
(3) Cooperation with EDL for tender evaluation;
(4) Construction supervision;
(5) Approval of payment;
(6) Witness of commissioning test; and,
(7) Reporting to the related parties.

Japanese contractor will carry out the following undertaking based on the Contract.

(1) Fabrication of replacement parts;
(2) Procurement and transportation of materials related to the Project;
(3) Execution of the overhaul and repair of the generating equipment requested;
(4) Despatch of technical guidance staff;
(5) Execution of the commissioning test; and,
(6) Handing over to the Government of Lao PDR after the completion of the Project.

5 - 2 Apportion of Project Cost

The Government of Lao PDR would bear only the charge of electric power supply during the implementation stage which costs about 210,000 Kips for the repair of the respective units.

5 - 3 Implementation Plan

5 - 3 - 1 Implementation Method

The study for the implementation method was made for two cases; one unit out of No. 3 or No. 4 units is implemented in the first phase

and another is implemented in the second phase (phase-wise method), or two units are implemented simultaneously. The detailed study is described below. As a result of study, it is recommended to implement this project by the phase-wise method.

(1) Implementation schedule

- Manufacturing period of the turbine parts takes 7 months for one units and 10 months for two units.
- Transportation period is assumed as 2 months.
- For the preliminary works, it takes about 1 month.
  Field work period per unit is required for 5.5 months at a standstill of the generating equipment.
- Overall period is 12 months until completion of one unit, because it is possible to proceed to execute the repair work of generator before arrival of the turbine parts at site.
- Field work period for two units implementation is reduced to 7 months, provided that the field work of No. 3 and No. 4 unit is performed in parallel and overlapping period of field work of two units in 4 months. Overall period is eventually 15 months for simultaneous execution of two units.

(2) Project cost

- This Project aims at overhaul and repair work of equipment. Therefore, the proportion of personal expenses in the total cost is high as compared with that of installation project of new machine. In addition to the above, required number of personnel despatched from Japan for two units implementation is almost same as that of one unit implementation.
- In case of the phase-wise method, total field work cost including both the first phase and second phase works is higher in price than that of two units simultaneous implementation.
- In case of the phase-wise method, common equipment and materials costs of both No. 3 and No. 4 unit are included in the first phase cost. Therefore, equipment and material costs for repair work in the first phase are much more than those for the second phase.

(3) Spilling out

- If the reservoir water level will be lowered down to the low water level (EL. 196.00) prior to the commencement of field work, the spilling out from the reservoir will not occur in any case in drought or average year. It will be, however, expected to occur the spilling out in case the repair works for two units are implemented simultaneously in wet year.

The following should be considered during the implementation stage since overhaul and repair of the generating units will be carried out under operation of other units.

(a) Safety at the Power Station

The generating equipment are arranged in order No. 1 unit to No. 5 unit from side of the erection bay.

It would take a sufficient working area by utilizing the generator floor as well as the erection bay because the top elevations of the housing of No. 3, No. 4 and No. 5 units are identical to the generator floor level.

However, prudential safety countermeasures should be taken to divide areas at the power station into the access for daily works and the working area completely.

(b) Variation of water level in the reservoir and the tailrace

The water levels in the reservoir and the tailrace change considerably from high in wet season to low in dry season.

The maximum difference between high and low water levels reaches 16 m in the reservoir, while 12 m in the tailrace.

Considering the above, a correct installation of the stoplogs in the tailrace is required to minimize a leakage during such high water

level season since no gates are installed, while nothing in the tailrace side is needed for water stoppage in the reservoir because both the intake gates and the stoplogs can be used.

5-3-2 Precaution During Implementation

Considering the nature of the Project that the overhaul and repair are done for the generating equipment inside the power station building, for 115 kV switchgear equipment on the roof of the power station building and for the intake gate facilities, it was confirmed that there be no special precaution for many and unspecified person in the third party, regional characteristics and rules.

5-3-3 Detailed Design and The Supervising Plan

(1) Detailed design

Soon after concluding the Exchange Note, the consultant shall make consulting contract with EDL, and shall start design works in Japan after discussion about detailed design. Detailed design and the tender documents shall be obtained approval by EDL before tender.

The respective works for the repair can be classified into the following three items according to the responsibility concerning the work. The tender documents are necessary to be prepared considering differences of responsibility laying under the works:

Work I The items which the contractor completes all the work on his responsibility.

Work II The items which are completed by EDL under supervision of the contractor. The contractor, however, has a responsibility for the problem caused by incomplete supervision.

Work III The items which are completed by EDL by themselves. The contractor has no responsibility for the work.

Although spare parts supply involves no work, the quality should be guaranteed for one year after handing over.

Major works classified in the above categories are as shown below:

Work I
(1) Work for the turbine including the ancillary equipment
(2) Work for the generator except excitation system
(3) Work for the 115 kV switchgear
(4) Operational test for automatic synchronizer

Work II
(1) Calibration, repair and replacement of the switchboard apparatuses
(2) Operational test for the protective and control relays
(3) Replacement of the lead acid storage batteries
(4) Work for 11 kV and low voltage switchgears

Work II
(1) Work for the auxiliary machinery equipment
(2) Work for the intake gate
(3) Work for the distribution panel installed top on the dam
(4) Work for the 22 kV switchgear

(2) Supervising plan

Although the work contains various items such as disassembly check, cleaning, repair, replacement, welding, finishing, painting, assembly and readjustment of the equipment and so on, the repair works do not interfere with each other in view of the scopes of work. And, power station cranes can be used and large temporary facilities are not required. Progress control, however, should be made in parallel with keeping quality control and safety control.

It is necessary that one (1) consultant who has a thorough knowledge of electrical and mechanical facilities stays at the site for the engineering services.

5-3-4 Procurement Plan for Equipment and Materials

Equipment and materials necessary for the Project are all procured in Japan except wooden materials and so on which will be procured in Laos for temporary facility use.

Since the generator was manufactured by AEG in West Germany, parts which have no interchangeability with Japanese made parts have to be imported from AEG.

For the works of disassembly, check and assembly of the generator, dispatch of an instructor from AEG may be needed to facilitate these works.

Electrical parts mounted on the operation box for the intake gate deteriorate remarkably and are to be repaired. Because the control boxes had been manufactured by Zschokke Wartmann AG, Switzerland, the repair of troubles was left undone for a long time due to unavailableness of spare parts.

Repair cost for these boxes would become higher than cost for manufacturing new boxes. Therefore, the existing boxes will be replaced with new control boxes instead of repair. And the control boxes manufactured in Japan will make it easy to procure spare parts for them in the future.

5-4 Implementation Schedule

Implementation schedule after concluding the Exchange Note is shown in Fig. 5.1.

(1) Consultant contract and detailed design

Work period for the detailed design including preparation of the tender document can be shortened to 1.5 months, because the contents of the Project are clear.

(2) Tender and contract award

A term of bidding and the evaluation would supposedly be one (1) month. A term necessary for the contract award including negotiation would be 0.5 month with reference to past examples for the grant aid project relating to EDL.

(3) Manufacture of replacement parts

Period necessary for manufacture of the replacement parts will give a large influence to the overall schedule. The major item of replacement parts is the guide vane of the turbine, numbers of which are 20 per one turbine. A term the manufacturing period for the guide vane is considered as 7 months per one turbine.

(4) Transportation

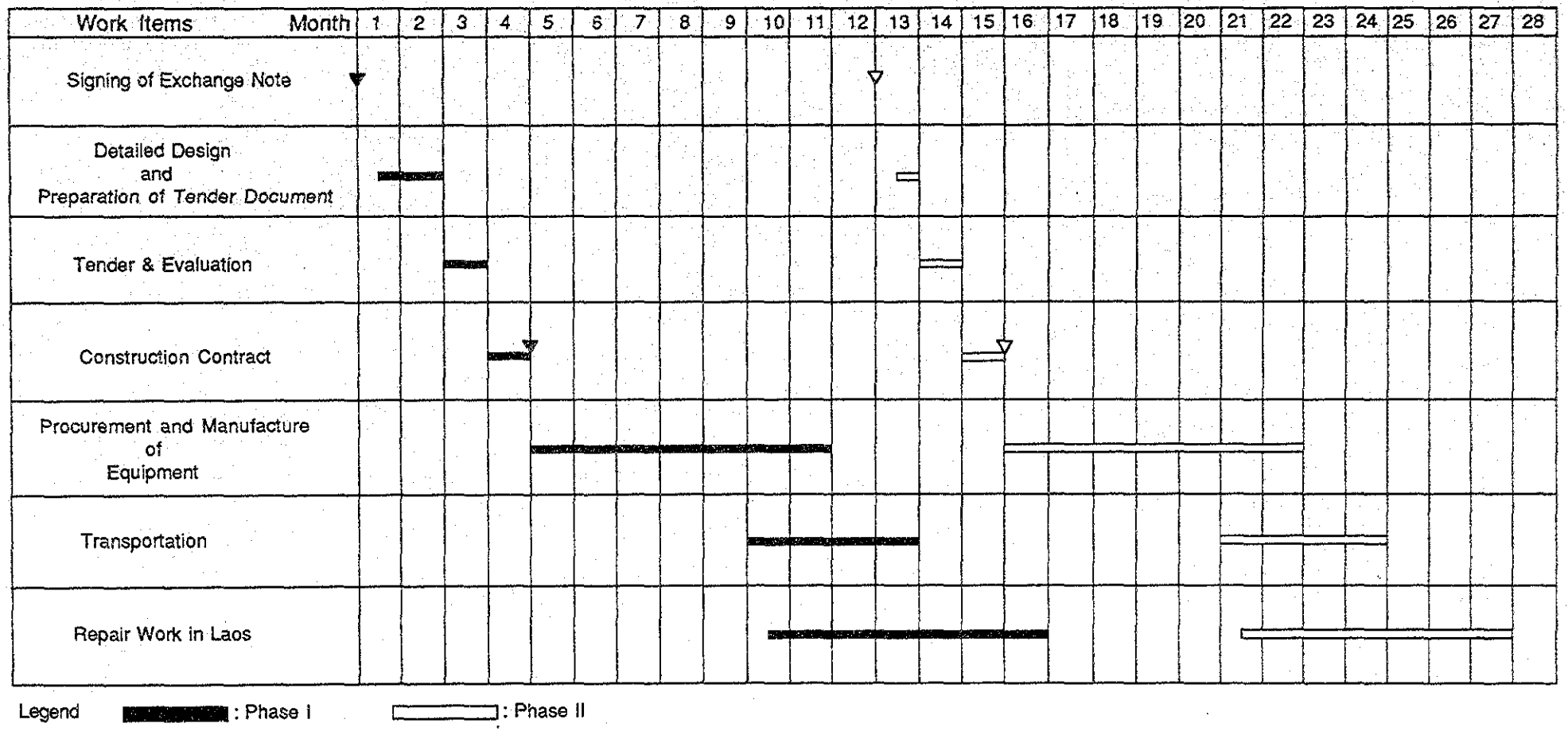
Transportation of equipment and material for the repair from Japan will take a period of two (2) months by marine transportation to Bangkok and by inland transportation through Thailand to Laos.

Items to be procured from West Germany are not considered in a term of transportation, because they can be transported by air in view of the contents and quantities of them.

(5) Repair work at site

Preparatory work period is one (1) month. A term of the repair work at site which is carried out under a standstill of the generating unit is 5.5 months for each unit.

Fig. 5.1 Work Schedule



CHAPTER 6

OPERATION
AND
MAINTENANCE PLAN

CHAPTER 6 OPERATION AND MAINTENANCE PLAN

6 - 1 Organization of Operation and Maintenance

The Nam Ngum Power Station has been operated and maintained by EDL. The operation and maintenance works will be conducted successively by the existing staffs working at the power station even after this plan will be completed. The existing organization of Nam Ngum Power Station is as described in clause 2-3-2 hereinbefore.

There is no necessity for substantial changes on the existing organization and assignment of the operation and maintenance personnel for the power station because the existing staffs have had much experiences on operation of the power station since 1972 and be well acquainted with their functions. There is no remarkable problem to be pointed out within the scope of ordinary operation and maintenance works as the operation and maintenance works have been carried out by the experienced and skilled key personnel in the respective group who have taken their post since the completion of the first stage construction work of the Nam Ngum Power Station.

As a result of site survey following technical matters were found:

A. Technical Works executed by the Manager of the Power Station

During execution of the field survey, the technical works which include information to and arrangement of the important matters with the EDL Head Office, and plan, approval and instructions of technical activities at the power station, were executed promptly and no delayed works were found by mis-judgement by the manager of the Power Station. He was very busy to attend many visitors by himself because there was no position of sub-manager (acting manager).

B. Operation Division

Operation division had been constituted by 4 groups which include five staffs in the respective groups. Duty by three (3) shifts for eight (8) hours working system, which is the standard system in southeast Asia, had been taken. Data logging system was manual because automatic operation data logging device was not provided. Judging from such work volume as daily patrol time and records of data on indicators, it seems to be reasonable to arrange five (5) staffs per groups.

Operation and control of generating equipment, information to the Vientiane Substation, operation data logging works and ordinal operation works have been carried out smoothly. The indicated data were recorded precisely and recorded sheets had been well preserved.

Shut down of main unit due to mal-operation has never arisen.

C. Maintenance Division

(1) Electrical Section

At the time of site survey, reservoir water level was very low because rainfall in this year was remarkably small, and three (3) units of generators were often stopped except peak hours in the evening. Availing of this resting time, cleaning of such electrical equipment as generator, transformer, etc. had been made. However, the stain was observed partly on the switchgear equipment installed at the roof of building as the cleaning works of the equipment had not been carried out systematically. It seems that more frequent maintenance work of the outdoor equipment is required than that of the indoor equipment. Moreover, formulation of a plan is required for the equipment and instruments which will be used practically for the maintenance use purpose.

(2) Mechanical Section

It seems that most staffs have a capability of execution of ordinary maintenance work, judging from their activity of preparatory works for inspection performed actually at the time of the site survey. The existing order and instruction flow system was in a satisfactory condition. However, maintenance tools and machines were insufficient for the maintenance works. Therefore, it is supposed to be slow working efficiency by the reason above. In future, the increase of the working efficiency and quality can be expected, if adequate maintenance tools and machines will be available as occasion demands.

In the event that the large scaled maintenance work should be required incidentally, the maintenance work will have to be done by help of the operation staffs. However, considering future maintenance work, it should be considered to increase maintenance staff by about ten (10) persons in the mechanical section.

It is required to improve the items and quantity of consumable materials and repairing parts which are insufficient and not met with the actual work.

6 - 2 Operation and Maintenance Costs

As for the Nam Ngum Power Station, the actual expenditure in Kip currency was about 28.52 million Kip in 1987, and most of expenditure was disbursed for personal expenses. On the other hand, foreign currency was provided for procurement of spare parts and repairing parts. The actual expenditures of the foreign currency were US$101,256 in 1986 and US$900,596 in 1987 which included in the cost of pumps for emergency procurement, and US$148,918 in 1988.

Due to the variation of Kip currency, amount of annual budget for operation and maintenance works has been increasing, and it would exceed 30 million Kip in 1988.

Annual budget of foreign currency is about US$150,000. However, considering the scale and operation conditions of the Nam Ngum Power Station and items of goods and quantities to be procured, the present budget will have to be increased to a level of five times the present figure.

6 - 3 Necessity of Training and Education of Operation and Maintenance Staff

Ever since the first stage construction work of the Nam Ngum Power Station had been completed, number of experienced senior staff is decreased year by year in course of time and contrarily number of junior staff is increasing gradually. All generating units of the Nam Ngum Power Station are operated continuously with the rated load except such occasion as the stoppage for inspection and the abnormal drought season as that in 1987/1988. Therefore, as the staff have few chance of adjustment of output power or start/stop operation of the units, it is supposed that the training during actual operation (on-the-job-training, abridged as OJT) for technical improvement of operation is hard to be carried out. Moreover, frequency of maintenance work is few as deterioration of equipment is low on condition that unit is operated continuously with a rated load, and this means that the chance for OJT of maintenance is few. It is judged that necessity of technical guidance is emphasized for settlement of such problem that junior staff have few chance for learning the operation and maintenance technique.

CHAPTER 7

EVALUATION OF THE PROJECT

CHAPTER 7 EVALUATION OF THE PROJECT

7 - 1 Direct Effects of Project Implementation

(1) Improvement in Reliability of Power Generating Equipment

Secular deterioration within power generating equipment, especially turbines, appears as fatigue and damage. Those parts in contact with running water suffer erosion due to cavitation and corrosion due to acids, silt and oxygen in the water. Since turbine secular deterioration cannot be averted, it is important in the operation and maintenance of a hydroelectric power plant that provision must be made for occasional repair to control advancing deterioration. Although it is difficult to define a standard, it is a recognized guideline in Japan and many other countries is that thorough overhaul and internal inspection should be done generally after 40,000 running hours or 10 years after installation.

Erosion by cavitation is one of the most frequent causes of damage to turbine runners. Erosion has apparently been observed on the runners of No.3 and No.4 turbines of Nam Ngum Power Station. Their total running hours are about 70,000 and 65,000 hours respectively, both being much over the standard value of 40,000 hours.

The following particular problems will be eliminated from turbines by repairs covered by this project.

i) Unevenness caused by erosion accelerates cavitation damage and the accelerating erosion can lead to serious accidents and breakage of a runner.

ii) Enlargement of the gap between guide vanes and the bottom ring owing to corrosion makes leakage of water increase even when the guide vanes are closed: this makes it difficult to stop turbines when, as at Nam Ngum Power Station, no main inlet valve is installed.