No.

Ministry of Energy and Mines
Lao People's Democratic Republic

PREPARATORY SURVEY

ON

NAM NGUM 1 HYDROPOWER STATION EXPANSION

IN

LAO PEOPLE’S DEMOCRATIC REPUBLIC

FINAL REPORT

January 2010

Japan International Cooperation Agency

NIPPON KOEI

J-POWER

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JR
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Ministry of Energy and Mines of Lao PDR

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Preface

In response to the request from the Government of Lao PDR, the Government of Japan decided to conduct the Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion, and entrusted the Survey to the Japan International Cooperation Agency (JICA).

JICA dispatched the Survey Team, headed by Mr. Takuji KATAOKA of the joint venture, composed of Nippon Koei and J-Power, to Lao PDR five times from February 2009 to November 2009. The Survey Team consisted of experts of hydropower expansion plan, power demand and supply analysis, hydrology and reservoir operation, geology, electric power civil engineering, electrical equipment, mechanical equipment, power system analysis, economic and financial analysis, and environmental and social consideration.

The Survey Team had a series of discussions with the organizations concerned such as the Electricite du Laos and the Ministry of Energy and Mines etc., and conducted the field surveys. The Study Team conducted further studies also in Japan to complete the Final Report.

I hope that this report will contribute to the reinforcement of power supply capacity for the country as well as to enhancement of the amity between our two countries.

I wish to express my sincere appreciation to the officials concerned for their cooperation and supports provided throughout the Survey.

January 2010

Atsuo Kuroda
Vice President
Japan International Cooperation Agency

January 2010

Mr. Atsuo Kuroda
Vice President,
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We have the pleasure of submitting to you herewith the Final Report upon completion of the Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion in Lao PDR. The joint venture, composed of Nippon Koei and J-Power, executed the Study under an agreement with your Agency over a period of about 13 months from January 2009 through to January 2010.

The Survey has been conducted in accordance with the Scope of Works concluded in February 2009. Power demand forecast, power development plan and basic design for the optimum expansion plan were conducted to prepare the expansion plan of the existing Nam Ngum 1 Hydropower Station.

In course of the Survey, particular efforts were made on technology transfer through various joint works with the counterparts from the Electricite du Laos and the Ministry of Energy and Mines etc., and the steering committee meetings. The related technologies to expansion projects, that shall be useful for the future implementation of expansion project, were also introduced by holding the seminar.

We hope this report would contribute to developing the socio-economy of the Lao PDR through the stable supply of electricity.

We would like to note that we have received the sincere cooperation and supports from the relevant organizations such as the Electricite du Laos and the Ministry of Energy and Mines etc. We also would like to express our deep appreciation to the valuable advices and cooperation provided by the staff and experts of the Embassy of Japan in the Lao PDR, the JICA Headquarter, and the JICA Laos Office.

Very truly yours,

The Study Team of Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion
Leader Takuji KATAOKA

Location Map of the Project Area

Nam Ngum 1 Dam and Power Station (February 2009)

Downstream View from Nam Ngum 1 Dam (February 2009)

Salient Features of Nam Ngum 1 Hydropower Station Expansion Project

Descriptions			Dimensions
1.	Reservoir (Existing)	River System	Nam Ngum river
		Catchment Area	8,460 km^2 (Completion Report 1972)
		Max. Flood Level	El. 215.0 m
		Full Supply Level (FSL)	El. 212.0 m
		Minimum Operation Level (MOL)	El. 196.0 m
		Gross Storage Capacity at FSL	7,030 x 10^6 m^3
		Active Storage Capacity	4,700 x 10^6 m^3
		Annual Average Inflow	375 m^3/s (*)
		Flood Inflow Peak (PMF)	8,800 m^3/s
2.	Dam (Existing)	Type	Concrete gravity dam
		Dam Crest Level	El. 215.0 m
		Max. Height of Dam	75 m
		Length of Dam Crest	468 m
		Volume of Dam	358,000 m^3
3.	Spillway (Existing)	Type	Open channel with flip bucket
		Width of Chute Channel	57.5 m
		Length of Chute Channel	95.2 m
		Overflow Crest Level	El. 202.5 m
		Gates (radial type)	4 nos. @W12.5 m x H10.0 m
4.	Intake (Existing Units)	Type	Horizontal bell-mouth
		Diameter of Penstock	3.4 m (for Units 1 & 2) 6.0 m (for Units 3, 4 & 5)
		Center Elevation of Penstock	El. 189.0 m (for Units 1 & 2) El. 186.0 m (for Units 3, 4 & 5)
		Trashrack	Removable type
		Staoplogs	Inserted in trashrack slot
		Type of gate	Rope-hoisted fixed wheel gate
	(Expansion)	Type	Horizontal bell-mouth installed in a hole excavated in dam
		Diameter of Penstock	5.5 m
		Center Elevation of Penstock	El. 185.25 m
		Trashrack	Removable type
		Staoplogs	Inserted in trashrack slot
		Type of gate	Bonnnet type (with hydraulic hoist)
5.	Powerhouse (Existing Units)	Type	Surface type concrete building
		Height (Bottom to Roof)	42.1 m
		Width x Length	43.95 m x 138.4 m
	(Expansion)	Type	Surface type concrete building
		Height (Bottom to Roof)	42.1 m
		Width x Length	42.45 m x 25.74 m
6.	Tailrace	Type	Open Channel
		Water Level (no flow)	El. 164.0 m
		Water Level (Units 1 to 5)	El. 168.0 m
		Water Level (Units 1 to 6)	El. 168.4 m (after expansion)

Descriptions			Dimensions
7.	Turbine (Expansion)	Type	Vertical Shaft Francis Type
		Number	1
		Rated Output	40.90 MW
		Revolving Speed	142.9 rpm
		Rated Net Head	40.0 m
		Rated Dischrage	111.2 m^3/s
8.	Generator (Expansion)	Type	Umbrella Type
		Rated Output	50.00 MVA
		Frequency	50 Hz
		Voltage	11 kV
		Power Fcator	0.8
9.	Transformer (Expansion)	Type	Single-phase, oil-immersed type
		Capacity	50 kVA (for three phase)
		Voltage	11kV / 115kV
		Cooling	ONAF
10.	Switchyard (Expansion)	Type	Conventional type on roof
		Voltage	115 kV
		Bus	HDCC 725 mm^2
11.	Generation (Expansion)	Incremental Capacity	35 MW (95% dependable)
		Incremental Energy Production	56 GWh/year
12.	Project Cost for Expansion		US$ 7,006 million (**)
	Construction Period (including Bid Preparation)		5 years

(*): Including inflow from Nam Song and Nam Luek diversions

(**): US$ 1.0 = JPY 95.0 = Kip 8,510

THE PREPARATORY SURVEY
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Terms

Abbreviations	English
Lao PDR Agencies	**Lao PDR Agencies**
DMH	Department of Meteorology and Hydrology
CDEP	Committee for Development of Electric Power
CPC	Committee for Planning and Cooperation
DOE	Department of Electricity, MEM
EdL	Electricite du Laos
FIMC	Foreign Investment Management Committee
GOL	Government of Lao PDR
LNCE	Lao National Committee for Energy
LWU	Lao Women's Union
MEM	Ministry of Energy & Mines
NN1	Nam Ngum No.1 Poser Station
STEA	Science, Technology & Environment Agency
WREA	Water Resources and Environment Agency
Foreign Organizations	**Foreign Organizations**
ADB	Asian Development Bank
EGAT	Electricity Generation Authority of Thailand
EVN	Electricity of Vietnam
IMF	International Monetary Fund
IUCN	World Conservation Union (Switzerland)
JICA	Japan International Cooperation Agency (Japan)
MOI	Ministry of Industry of Vietnam
MPI	Ministry of Planning and Investment of Vietnam
NEPO	National Energy Policy Office of Thailand
NTEC	Nam Theun 2(NT2) Electricity Company
NTPC	Nam Theun 2(NT2) Power Company
PEA	Provincial Electricity Authority in Thailand
PRGF	Poverty Reduction and Growth Fund
UNDP	United Nations Development Program
WCD	World Commission on Dams
Others	**Others**
AAU	Assigned Amount Unit
B.	"Ban" Village in Laotian language
BOT	Built-Operate-Transfer
CA	Concession Agreement
CDM	Clean Development Mechanism
CER	Certified Emission reduction
COD	Commercial Operation Date
DPRA	Development Project Responsible Agency
ECA	Export Credit Agencies
ECC	Environmental Compliance Certificate
ESIA	Environmental and Social Impact Assessment
EMMU	Environmental Management & Monitoring Unit
EPC	Engineering, Procurement and Construction
EPMs	Environmental Protection Measures
ERU	Emission Reduction Unit
ESMP	Environmental and Social Management Plan
FS	Feasibility Study
FARD	Focal Area for Rural Development
GHG	Green House Gas
GIS	Geographic Information System
GMS	Greater Mekong Sub-region
GPS	Global Positioning System
HEPP	Hydroelectric Power Project
ICB	International Competitive Bidding
IEE	Initial Environmental Examination
IPDP	Indigenous Peoples Development Plan
IPP	Independent Power Producer
IWRM	Integrated Water Resources Management

Terms

Abbreviations	English
JI	Joint Implementation
LA	Loan Agreement
LEPTS	Lao Electric Power Technical Standard
LLDC	Least Less-Developed Countries
MOU	Memorandum of Understanding
NBCA	National Biodiversity Conservation Area
NEM	New Economic Mechanism
NGOs	Non Governmental Organizations
NN1	Nam Ngum 1 Hydropower Station
NNRB	Nam Ngum River Basin
O&M	Operation and Maintenance
ODA	Official Development Assistance
PDA	Project Development Agreement
PDP	Power Development Plan
PO	Project Owner
PPA	Power Purchase Agreement
S/W	Scope of Works
SIA	Social Impact Assessment
SPC	Special Purpose Company
SPP	Small Power Producer
TOR	Terms of Reference

Unit/Technical Terms	Unit/Technical Terms
B-C, B/C	B: Benefit and C: Cost
EIRR, FIRR	Economic/Financial Internal Rate of Return
EL.( ) m	Meters above Sea level
FSL.	Full Supply Level of Reservoir
GDP	Gross Domestic Product
GWh	Giga Watt Hour (one billion watt hour)
IRR	Internal Rates of Return
LWL	Low Water Level of Reservoir
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MCM	Million Cubic Meter
MOL.	Minimum Operation Level of Reservoir
MW	Mega Watt (one million watt)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
US$	US Dollar
Kip	Kip
THB	Thai Baht
JPY	Japanese Yen

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE SURVEY

In Laos, the domestic peak power and energy demand requirements are increasing at an average rate of 10% from 2000 up to 2006. The Government of Lao PDR is aiming to increase the rate of household electrification and the development of mine production such as copper and bauxite. Consequently, it is expected that the domestic power and energy demand will increase significantly in the future. Existing power sources in Laos are not enough to cover the rapid increase of power demand, thus installation of additional power sources is necessary.

Export of power from Laos to the neighboring countries is an effective means for acquisition of foreign exchange. The amount of power export, excluding those of the independent power plants (IPP), was more than the power import up to 2005. However, the amount of power import exceeded the power export in 2006 due to the increase in domestic power demand. The unit rate of the power import is set up to be higher than the power export. Furthermore, in the case that total amount of annual import energy from Thailand is higher than the annual export energy, the unit rate of the excess power import is set up to be at a higher level. Therefore, development of additional power sources is important from the viewpoint of the improvement of national government finance.

The Government of Lao PDR has prepared the power development plan (PDP 2007-2016) in 2006 aiming at social development founded on sufficient power supply and acquisition of foreign exchange through the power export. In the PDP 2007-16, hydropower development with the practical use of high hydropower potential in Laos, through the positive introduction of IPP, is emphasized. However, power demand is increasing more than the expected especially in the metropolitan area. The implementation of power development projects tend to be got behind the PDP project schedule. Therefore, the urgent reinforcement of power supply capacity for metropolitan area (C1 area) is required. The present power supply to the C1 area relies on the Nam Ngum 1 (NN1) Power Station (155 MW), Nam Leuk Power Station (60 MW) and Nam Mang 3 Power Station (40 MW), and surplus power is exported to the Thailand. However, the peak power supply of Laos during the dry season partially relies on the power import from Thailand, and it is expected that the peak power demand in 2010, even during the rainy season, would rely on power imports.

Source: EdL

Figure 1.1.1 Category of Electricity Demand Areas in Lao PDR

Because of these conditions, the Government of Lao PDR has requested the cooperation of the Japanese Government, who has a lot of previous experience on hydropower development in Laos, for the Nam Ngum 1 Hydropower Station Expansion. In response to the request, the Japan International Cooperation Agency (JICA) confirmed and signed on the scope of the preparatory survey of the Nam Ngum 1 Hydropower Station Expansion on 10 February 2009. This preparatory survey was carried out based on the scope of work agreed between JICA and the Lao PDR government.

In the latest power development plan (PDP 2007-16), the expansion plan for the NN1 Hydropower Station was not mentioned. However, EdL intends to add to the PDP the NN1 expansion plan with optimum scale after this preparatory survey. Considering the feasibility study that had been carried out by IDA in 1995, and the rapid increase in power demand of Laos, the priority of this expansion plan near the huge power demand center is high.

1.2 PURPOSE OF THE SURVEY

The purpose of the preparatory survey is to study the viability of the expansion of the NN1 power station which is located in the Nam Ngum River Basin (NNRB), about 65 km north of Vientiane. In the survey, the policy of the Government of Lao PDR on the implementation of the expansion of NN1 will be confirmed, and the implementation of expansion plan will be taken shape with source of Japanese fund.

1.3 SURVEY AREA

The study area consists of Lao PDR, Vientiane Province, NNRB, NN1 Hydropower Station and its surrounding areas, and the whole of the NNRB. The existing and planned substation(s) around Vientiane City are also included in the survey area.

1.4 COUNTERPART FOR THE SURVEY

The main counterpart for the preparatory survey is the Electricite du Laos (EdL), with technical support from the Department of Electricity (DOE) of MEM. The NN1 Hydropower Station is under the control of EdL.

1.5 TEAM MEMBER

In order to assess the various work items such as power demand forecast, power development plan and basic design for optimum expansion plan, the team for the survey was organized with the corresponding members as shown in Table 1.1.2 below. In particular, the knowledge on dam piercing method, which is quite effective for expansion of power generation capacity, is transferred to the Laos technical staff by well-experienced survey team engineers.

Table 1.1.2 Survey Team Staff Composition

No.	Name	Position/Field of Expertise
1	Takuji KATAOKA	Team Leader/Hydropower Planner
2	Masayuki SHINZAWA	Hydropower Expansion Plan
3	Hitoshi EGAWA	Power Demand and Supply Analysis
4	Sohei UEMATSU	Hydrology and Reservoir Operation
5	Tadashi Amano	Geology
6	Yuichi UEDA	Electric Power Civil Engineering A (Power Plant Equipment)
7	Noriyuki IKEDA	Electric Power Civil Engineering B (Hydraulic Structure)
8	Kiyohito YAMAZAKI	Electric Power Civil Engineering C (Cost Estimate, Construction Schedule)
9	Naoji NAKATO	Electrical Equipment
10	Kenji SETO	Mechanical Equipment
11	Ryosuke TOKUNAGA	Power System Analysis
12	Yusaku MAKITA	Economic and Financial Analysis
13	Yuka NAKAGAWA	Environmental And Social Consideration
14	Masahiko EBARA	Coordinator

Prepared by the JICA Survey Team

1.6 LOCAL SUB-LETTING WORKS

In order to select the optimum expansion plan and implement the basic design for the selected plan, the topographic survey for surrounding areas of NN1 Hydropower Station and boring investigations along the waterways of each alternative expansion plan have been carried out during the survey. Regarding the downstream river stretch, the daily water level fluctuation due to peak operation by additional power generation may affect the water users in the downstream area. In order to confirm the scale of the impact of expansion of the power generation facilities, the river cross section survey and environmental investigation (IEE) were carried out. These surveys were conducted by sub-letting them to local firms in accordance with the scope of works as discussed below:

(1) Topographic Survey

The topographic survey was conducted for the selection of optimum expansion plan and basic design of selected plan. The work items and scopes for the surveys include the following:

(i) Topographic survey for studying the expansion alternatives,

- Survey area：13.5 ha (134,200 m^2)
- Dam crest alignment survey, Total length：0.5 km

(ii) Preparation of topographic map in AutoCAD (Scale 1:500, Contour interval 1 m）

(iii) River cross section survey (25 sections) and river bank alignment survey (total length 23.5 km) in the downstream stretches

(iv) Additional river cross section survey in the area of downstream rock outcrop (15 sections)

(v) Installation of staff gauge (one set at downstream of NN1 Hydropower Station)

(2) Geological Investigation

The drilling works and laboratory tests were conducted for the selection of the optimum expansion plan and basic design of the selected plan. The items for the drilling works and tests are as enumerated below:

(i) Drilling of 25 m deep boreholes for the assessment and confirmation of rocky soil bearing capacity for the foundation of the aboveground powerhouse for both tunnel plans in the right and left banks (A4, B2 and D2 plan): total of 2 boreholes, and drilling of 25 m deep borehole for the assessment and confirmation of the depth of the tunnel in the left bank: 1 borehole.

(ii) Drilling of a 20 m deep borehole for the assessment and confirmation of the soil permeability for the tailrace outlet in the expansion plan between existing power house and spillway (A1 and A2): 1 borehole; 3 permeability tests at 5 m intervals.

(iv) Drilling works of a 55 m deep borehole for the assessment and confirmation of depth of the intake tower and the permeability of rocks in the tunnel route in the right bank (Plan D): 1 borehole, bottom at EL.160 m, and 4 permeability tests at 5m intervals

・The permeability test (Lugeon test), standard penetration test, and the laboratory test of drilled cores to include specific gravity, water absorption rate, uni-axis compression test and pressure crack test, were carried out as required.

(3) Environmental Study

The Survey Team supported the implementation of the survey for environmental and social considerations at IEE level that was conducted by Lao PDR side for the environmental assessment of this project. The survey was based on the “JICA Environmental Guidelines” and “JBIC Guidelines for Confirmation of Environmental and Social Considerations (2004)”.

Main scope of the IEE study, through local subletting work, is as follows:

(i) Collection and analysis of existing data,

(ii) Interview survey in Nam Ngum River Basin,

(iii) Field reconnaissance to confirm environmental and social conditions possibly affected by the NN1 expansion project and water level measurement at three sites of downstream of NN1

(iv) Conduct of public consultation,

(v) Preparation of the draft Environmental Management Plan and Environment Monitoring Plan, including assessment of alternatives, and

(vi) Preparation of the IEE Report

Specifically, it is important to confirm the environmental and social impact on the downstream catchment area of NN1, and assess the impact of water level fluctuation to the downstream residents.

1.7 STEERING COMMITTEE MEETING

In order to disclose information and achieve leveling of opinions on the scope of the preparatory works, processes and results of the survey, the steering committee was organized. The steering committee meetings were held to discuss the important issues and disseminate information. Members of steering committee are shown in following list:

1	Electricite du Laos
2	Department of Energy, Ministry of Energy and Mines
3	Department of Environmental and Social Impact Assessment, WREA
4	Department of Water Resources, WREA
5	Ministry of Public Works and Transport
6	Vientiane Provincial Office

The three times meetings of steering committee have been held as follows.

1st meeting	Presentation of Inception Report	February 2009
2nd meeting	Presentation of Selected Optimum Expansion Plan	June 2009
3rd meeting	Presentation of Draft Final Report	November 2009

CHAPTER 2 PRESENT SITUATION OF POWER SECTOR

2.1 OUTLINE OF POWER SECTOR IN LAO PDR

2.1.1 OUTLINE

Electricite du Laos (EdL) is a national power entity under the Department of Electricity (DOE) of the Ministry for Energy and Mines (MEM), which owns and operates the main generation, transmission and distribution assets in Lao PDR, and manages electricity imports into its grids and exports from its power stations.

EdL was established in 1959 and it started with only a small unit for small-scale power generation and electric power supply to part of Vientiane City and the French base. From 1966 to 1971, EdL was expanded. In the same period, Nam Ngum 1 hydropower station (NN1) was constructed under the Nam Ngum Development Fund Agreement concluded in 1966 and started operation with supply capacity of 30 MW of electric power. The Sokpaluang Training Center with a capacity of 10 MW was built at the same time. Afterwards, the transmission line facilities in Thakek, Luangprabang, Savanaket and Pakse areas have been successively improved. Transmission line facilities in the capital Vientiane area were also rehabilitated from 1973 to 1975.

At the time just after the political regime was transferred to Lao PDR in 1975, the whole Lao PDR had only been supplying a capacity of 42 MW in total. Vientiane Capital is dependent on the power supply of 30 MW from NN1 and 10 MW from diesel generators of the training center in Vientiane. In other areas, Xelabam hydropower station with 2.0 MW was distributing power around Pakse, and in the northern area, Namdong hydropower station with 0.9 MW was distributing power mainly to Luang Prabang. As of 1975, EdL had customers of 19,000 houses only and the net system energy demand recorded was 241 million kWh.

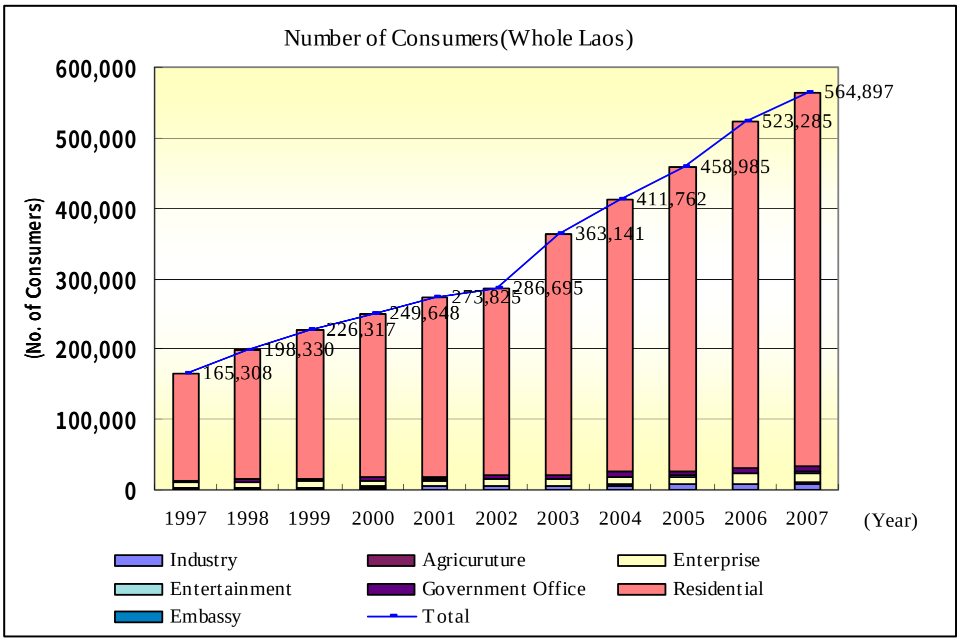
From 1976 to 1979, the generation capacity of NN1 was upgraded from 30 MW to 110 MW, and the total power generation capacity of the country became 122 MW. Afterwards, in 1983 to 1990, NN1 upgraded its generation capacity to a total of 150 MW. In 2004, units No.1 and No.2 were overhauled and the total capacity was upgraded to 155 MW through the assistance of Japan’s Grant Aid.

At present, the electric power of the capital region is being supplied from NN1 (155 MW), Nam Leuk (60 MW) and Nam Mang 3 (40 MW).

2.1.2 PRESENT STATUS AND ORGANIZATION OF EdL

As of June 2009, the power supply in the four areas: northern, C1, C2 and southern, is separately operated due to insufficient transmission network linkage. In the case of electrical power shortage, EdL imports power from Thailand, Vietnam or China. The power interchange with Thailand (EGAT) records the largest volume of power transaction.

As of 2007, there are about 560,000 customers in Lao PDR being served by EdL. Recent data over the past ten years shows that the number of customers has drastically increased to about 2.5 times (Figure2.1.1). The household connections that form 94% of the total users have the most significant rate of increase, among others.



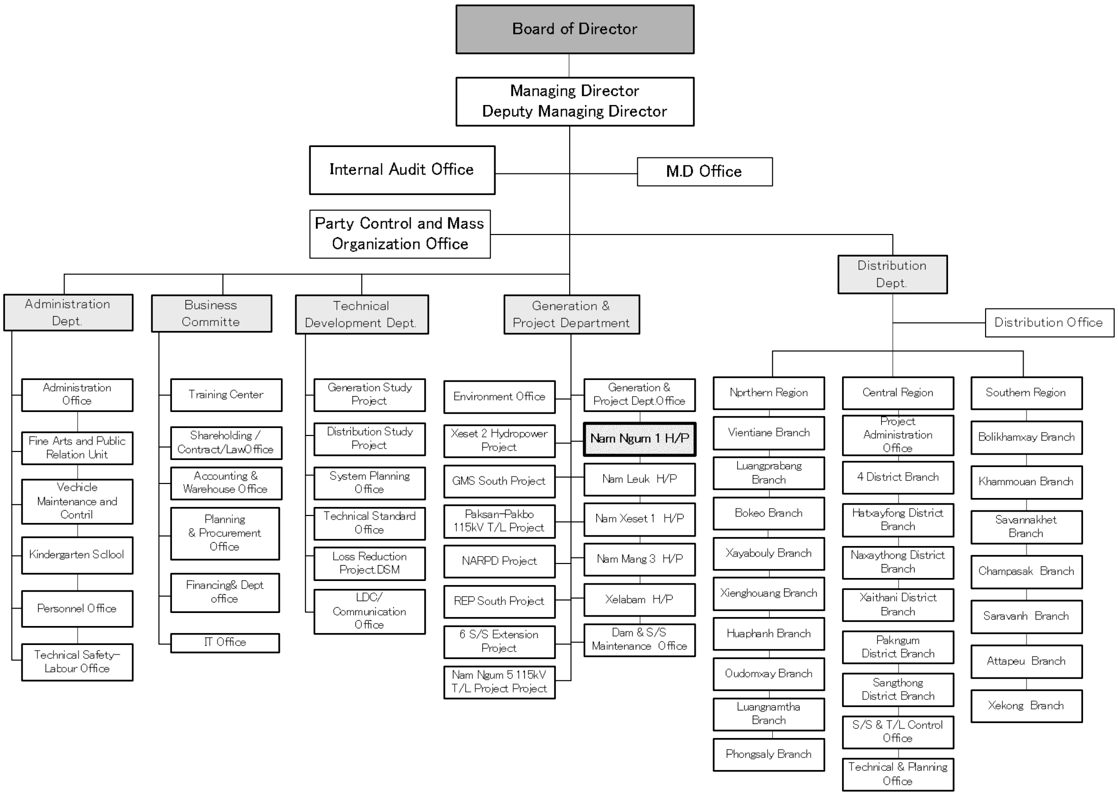
Prepared by JICA Survey Team

Figure 2.1.1 Number of Customers

As of 2008, it is reported that EdL has 3,008 employees composed of 2.537 male staff and 471 female. Educational attainments of the staff are shown as follows:

Education degree	persons
Master Degree	145
Bachelors Degree	307
High Diplomas	555
Medium Diplomas	1118
Primaries	533
Others	350

Figure 2.1.2 shows the organizational setup of EdL. Operation and maintenance of the existing power stations, including the NN1 power station, are being carried out by the Generation & Project Department of EdL.

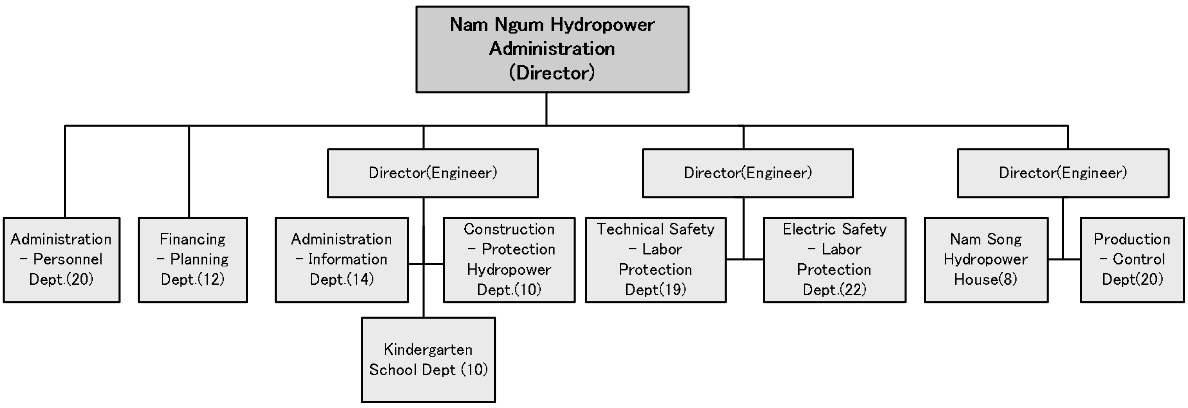


Source: EdL

Figure 2.1.2 Organizational Chart of EdL

2.1.3 ORGANIZATION OF NAM NGUM 1 HYDROPOWER STATION

Figure 2.1.3 shows the organizational setup of NN1. The administration system consists of nine departments under the three directors. One of the nine departments is in charge of the works related to NN1 operation. The department for the Nam Son Diversion Station in NN1 has eight staff members. A total of 124 staff is working under the NN1.



Source: EdL

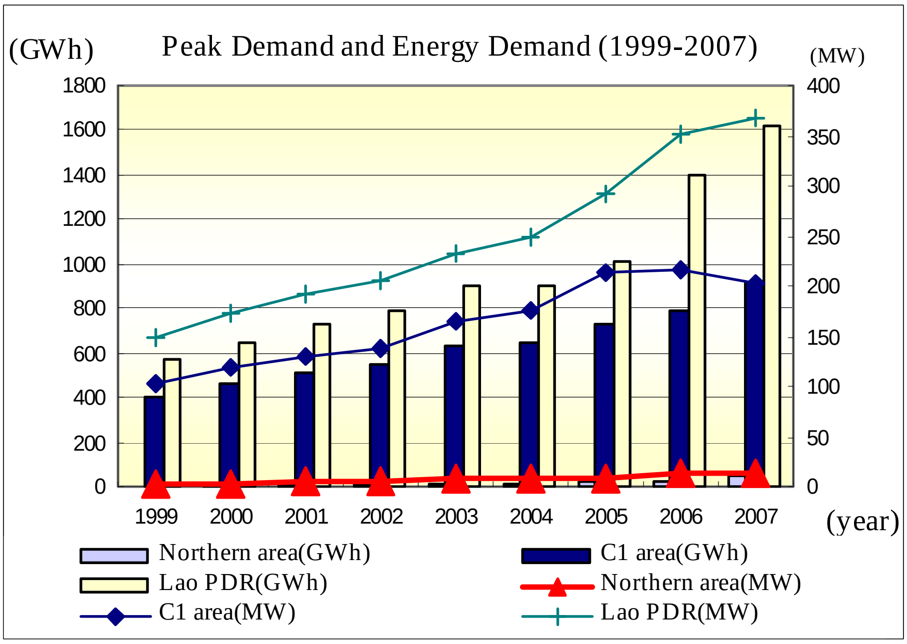
Figure 2.1.3 Organizational Chart of the NN1 Hydropower Station

2.2 PRESENT SITUATION OF ELECTRICAL POWER SUPPLY AND DEMAND

2.2.1 TOTAL ENERGY DEMAND AND PEAK DEMAND IN LAO PDR

In Lao PDR, the average annual growth rate of domestic energy consumption and peak power demand has recorded more than 10% from 2000 to 2007, because of the rapid increase of power demand.

As of 2007, the peak power demand in Lao PDR has reached 369 MW. This consists of the 203 MW in C1 area with an installed capacity of 259 MW, 14 MW in the northern area, 116 MW in C2 area, and 36 MW in the southern area (see Figure 2.2.1). Although the peak demand in 2007 in C1 area decreased a little from the 217 MW recorded in 2006, the growth rate from 1999 to 2007 showed almost 2.5 times increase and the average growth rate is over 12% in terms of peak demand.



Prepared by JICA Survey Team

Figure 2.2.1 Peak Demand and Energy Demand

In the same years, the total annual generated energy recorded was 3,935 GWh. Expecting IPP generation, the total installed capacity was 330 MW and the yearly generated energy was 1,640 GWh. Power import exceeded export in gross energy in 2007. According to an interview at the NN1 power station, the peak demand in C1 area has reached about 263 MW in April 2009.

The installed capacity, including that of the IPPs in Lao PDR, amounts to 691.9 MW (Table 2.2.1). It is estimated that comparatively large-scale hydropower stations for the supply to C1 and northern areas are 258.7 MW in total with the capacity of 155 MW in NN1.

Table 2.2.1 Existing Power Plants

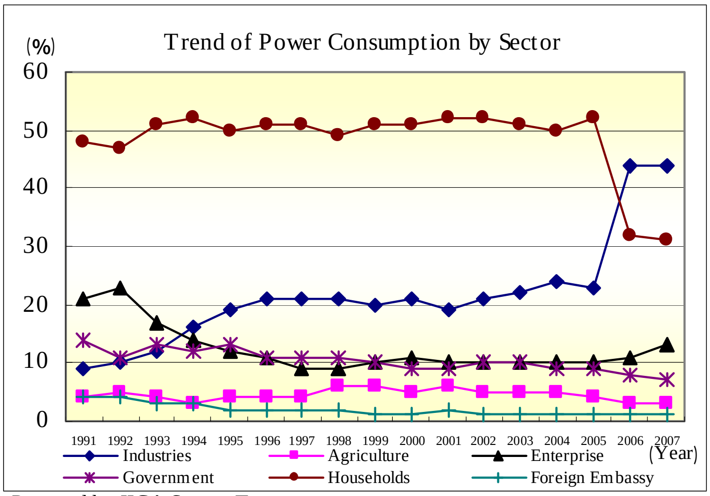
Power Plants	Location (province)	Installed Capacity (MW)	Energy Production (GWh p.a.)	Owners	Year of comm.
Selabam(H)	Champasak(S)	5.0	21.5	EDL	1969
NamDong(H)	Luangprabang(C1)	1.0	5.0	EDL	1970
Nam Ngum 1(H)	Vientiane(C1)	155.0	1002.0	EDL	1971
Xset1(H)	Saravan(S)	45.0	133.9	EDL	1971
Nam Ko	Oudomxay(N)	1.5	7.9	EDL	1996
Thuen Hinboun(H)	Khammouane(C2)	210.0	1620.0	IPP	1998
Houay HO	Attapeu(S)	152.1	617.0	IPP	1999
Nam Leuk(H)	Vientiane(C1)	60.0	218.0	EDL	2000
Nam Mang3(H)	Vientiane(C1)	40.0	150.0	EDL	2005
Nam Ngay(H)	Phonsaly(N)	1.2	2.0	EDL	2006
Micro-hydro	(37 locations)	6.6		Provincial	
Solar	(106 locations)	0.2		Provincial	
Diesel	(48 locations)	14.3		Provincial	
Total		691.9	3,777.3		

Note: hatching lines indicate power station existing in C1 and northern areas
Source: EdL

2.2.2 POWER CONSUMPTION BY SECTORS

In the 2007 records, the power consumption of the industries is 44%, which records the highest portion in total consumption, followed by households with 31%, which is the second highest,, 13% for enterprises as the third, and followed by that of government offices and foreign embassies.

Power consumption in households, which accounts for the largest in contracted number by sector, also accounted for the largest consumption in the total demand consumption. However, in 2007, the demand consumption of industries has exceeded that of households and became the top in the list.



Prepared by JICA Survey Team

Figure 2.2.2 Trend of Power Consumption by Sectors

2.2.3 PRESENT SITUATION OF POWER INTERCHANGE

In Lao PDR, power export was used to be one of the significant means to earn foreign money, and the gross amount of export, except for IPP, was larger than that of the import until 2005. Hence, the import amount has exceeded the export amount in the yearly gross amount since 2006 (Figure2.2.3).

Power interchange is being carried out with Thailand, China and Vietnam, and the power interchange with Thailand accounts for the largest volume among the transactions.

Future power demand is expected to drastically increase because of the new developments on copper and bauxite mining, and on the rate of increase in the expansion of household electrification that has been planned by the government. It is presumed that this trend will continue as of this time. However, the interchange tariff in import from Thailand is set at a much higher rate than the export from Lao PDR. In addition, in the agreement with EGAT, the escalation of fuel cost is supposed to be annually reviewed as to the excess portion of the import tariff. Over power import from EGAT could be a financial predicament of EdL. However, the existing power stations in the Lao PDR are not sufficient to cater to growing domestic power demand. Accordingly, the development of new power sources is urgently needed.

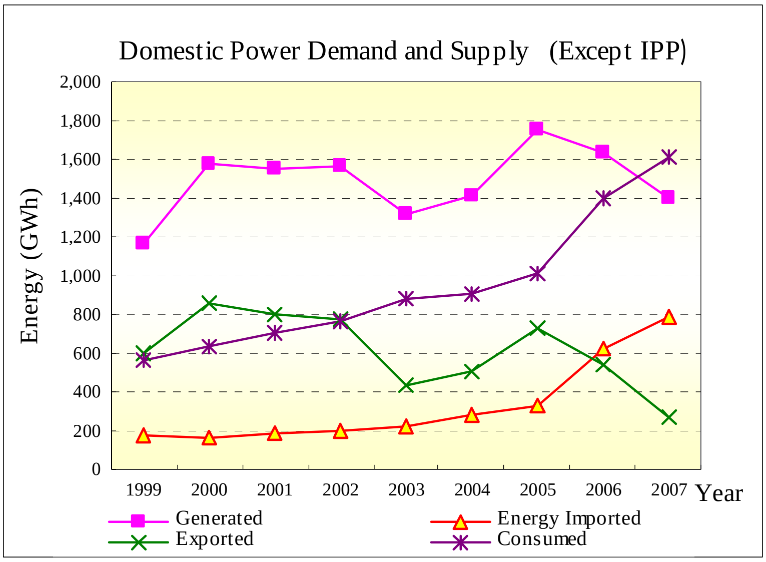


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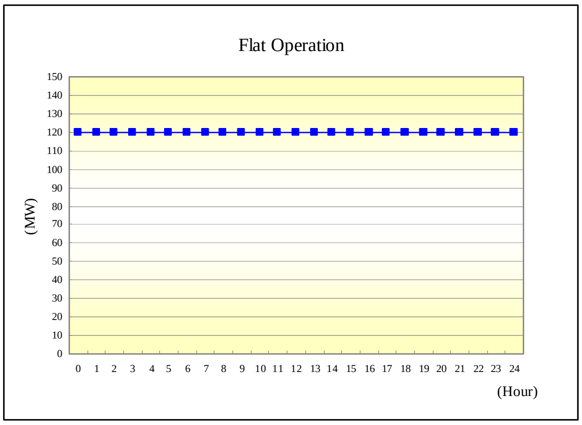
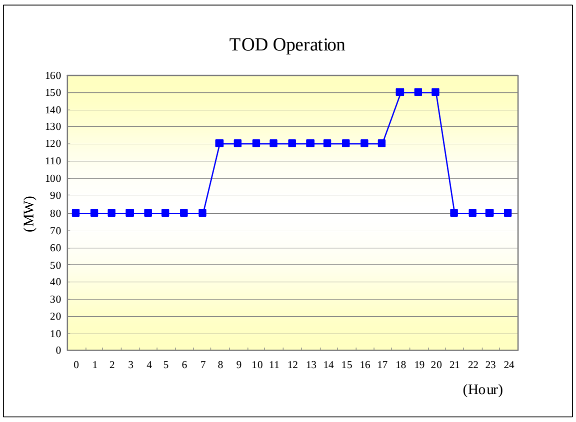
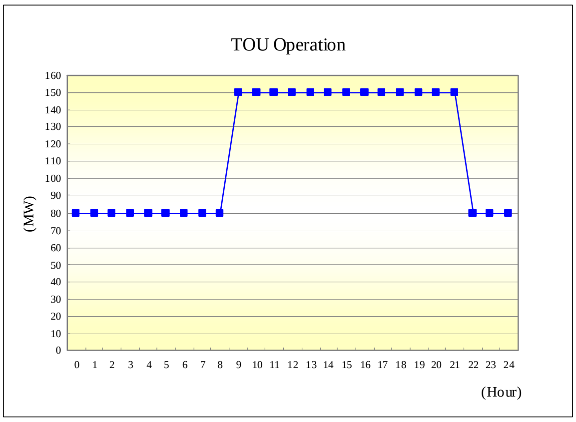
Figure 2.2.3 Domestic Power Demand and Supply

International power interchange with Thailand for the northern, C1, C2 and southern areas is conducted by EdL. EdL is virtually advancing Sepon mining, which is situated in the C2 area, to pay money for purchasing power from EGAT, and EdL collects the same power rates as that of the charge rate by EGAT from the mining. EdL also charges them with actual expenses for the use of the EdL's electrical facilities for their maintenance cost every year.

Figure 2.2.4 shows the history of basic operational pattern of NN1 to date. Since March 2, 2006, NN1 has been operating based on the TOU (Time of Use) operation pattern which is divided into two ranges of peak and off-peak time. although it is reported that NN1 is currently operated based on a pattern nearer to TOD (Time of Day) operation, since the Rule Curve serves as the basis for the reservoir operation and has not been revised as of to date.

Year and Operation Name	Operation
Before 1990 **Flat Operation**	
1990-2000 **TOD Operation** (Peak 18:00～21:00h、Partial Peak 7:30～18:00h、Off Peak 21:00～7:30h)	
2000-2005 **TOD Operation** (Peak 18:00～21:30h、Off Peak 21:30～18:00h)	
Present *(From March 2006)* **TOU Operation** (Peak 9:00～22:00h、Off Peak 22:00～9:00h)	

Prepared by JICA Survey Team

Figure 2.2.4 History ofNN1 Operation

Table 2.2.2 shows that the different tariffs for import and export in the power interchange with EGAT that have been applied for peak and off-peak time, respectively. In regular power interchange with EGAT, the unit price per kWh is set to about 0.19 THB higher for imports than that for export, even though the same volume between import and export is interchanged in total yearly. Provided that import exceeds export in yearly total of interchanged volume, another excess tariff shown in Table 2.2.3 will be applied for the calculation, and the retail prices of power in Thailand, which is generated through thermal power stations, is taken into consideration in the calculation of the excess charge. The excess charge during the year is then, calculated using the induced unit excess tariff. In the present method for power charge calculation, it is suggested to supply the surplus power to domestic consumers when the transmission networks are improved, since no merit in exports can be seen under the current agreement.

Table 2.2.2 TOU Tariff Rate

(Baht/kWh)

Time	EGAT imported from EdL	EGAT exported to EdL	
		Regular	Emergency
Peak	1.60	1.79	1.60
Off Peak	1.20	1.39	1.20

Source: EdL

Table 2.2.3 Excess Charge Tariff

Voltage Level	Peak Demand Charge (Baht/kW)	Energy Charge (Bart/kWh)		Service Charge (Bart/month)
		Peak	Off Peak	
115 kV	74.14	2.7595	1.3185	228.17

Source: EdL

「**TOU(Time of Use) Range**」
- Peak 09:00-22.00(Monday-Friday)
- Off peak 22:00-09:00(Monday-Friday)
  00:00-24:00(Saturday, Sunday)

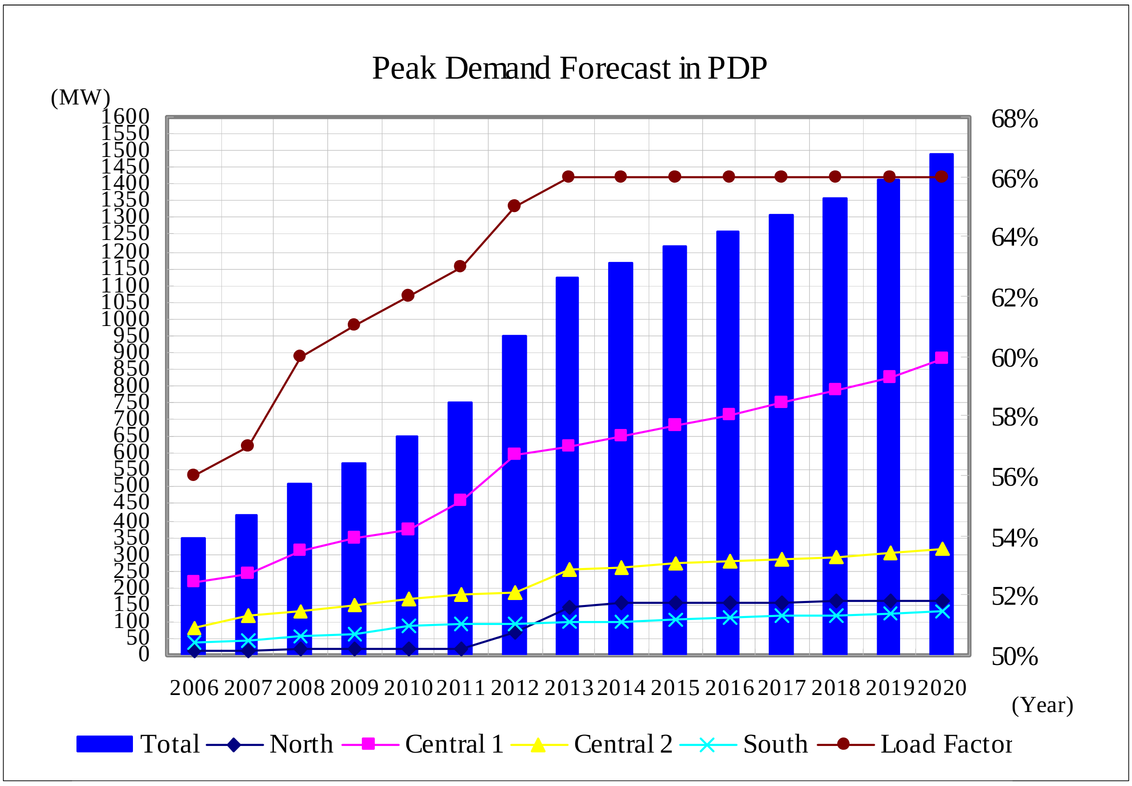
2.3 POWER DEMAND FORECAST

2.3.1 POWER DEMAND FORECAST IN PDP

EdL finalizes the future power demand projection and power supply plan for the whole Lao PDR service areas and these are presented in the Power Development Plan (PDP). The latest official PDP is the PDP 2007-16. In the plan, the records of the power consumption and development plans are summarized and finalized for the whole Lao PDR and specifically, also for the northern, C1, C2, and southern areas.

In the latest PDP, EdL projects the overall future power demand from 2007 up to year 2020 based on the provincial demands at substation points, along with future large-scale loads of plants and mining activities. The applied method for the demand projection is the same as that introduced in the previous study conducted by JICA in 2002. The total power demand projection applied was the sum of the projection for each province and as per user such as households, industries, agriculture and services.

If there is any change in the operation plans of large-scale consumers, EdL updates the demand projection accordingly. The projection tends to be revised increasingly. The graph below shows the latest demand projection made by EdL.



Prepared by JICA Survey Team

Figure 2.3.1 Peak Demand Forecast in PDP

According to the result of EdL's demand projection, the peak power demand as of 2020 in the whole Lao PDR is forecasted at 1486.8 MW, which shows the peak power demand to be about 3.5 times the demand as of 2007. In the peak demand by area, the peak demand forecasts in 2020 are shown for C1, northern, C2, and southern area as 880.6 MW, 163.0 MW, 313.7 MW, and 129.5 MW, respectively. The load factor is projected to be kept at 66% from 2012 to 2020. EdL has added the newly identified loads to the projection in the near future such as new mining industries, and therefore, the demand growth is anticipated to increase.

2.3.2 POWER DEVELOPMENT PLAN IN PDP

Table 2.3.1 shows the power development plan as of June 2009, which has been updated from the PDP (2007-2016) for the northern and C1 areas that are being supplied from NN1. The plan indicates that by 2030, the installed capacity of the power stations, except from the IPP for export, will reach to 2,375 MW from the present 258.7 MW in northern and C1 areas. Most of the future development plan takes into account the IPP plans. This means that these are very susceptible to changes in economic conditions and thus, will have uncertain factors for realization.

Table 2.3.1 Power Development Plan (2030)

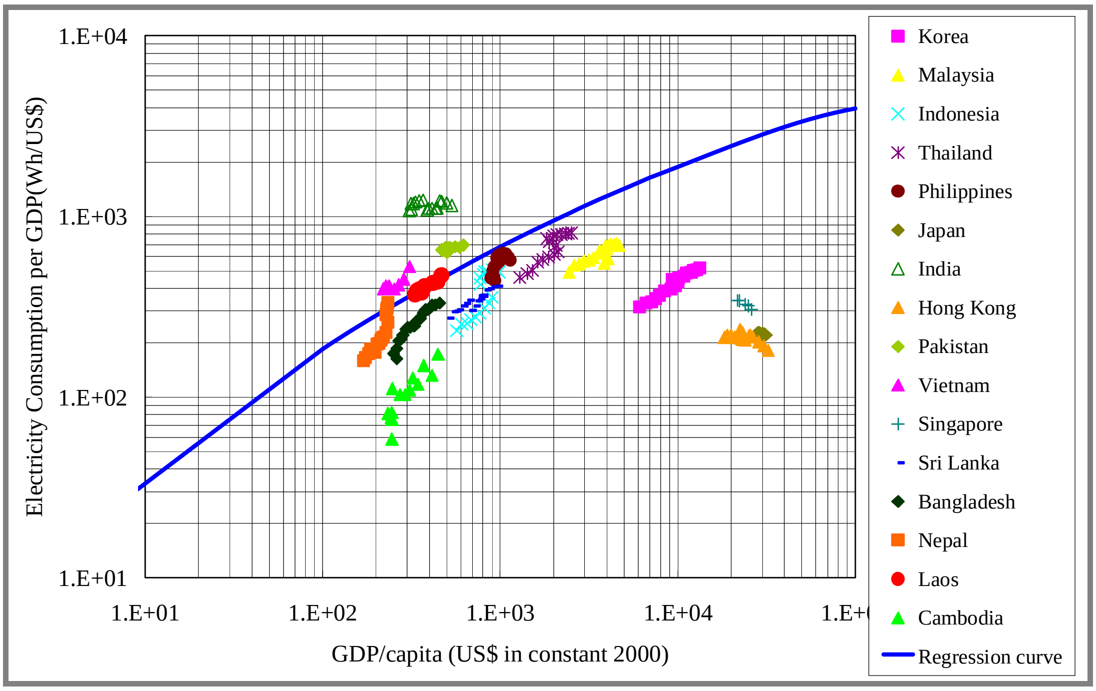
No.	Power Plant	Installed Capacity(MW)	Plant Factor(%)	Com.Year	Type	Status
1	Nam Ko	1.5	60.0	1966	Run of river	Existing
2	Nam Ngay	1.2	18.7	2006	Run of river	Existing
3	Nam Dong	1.0	53.7	1961	Run of river	Existing
4	**Nam Ngum1**	**155.0**	**74.0**	**1971**	**Reservoir**	**Existing**
5	Nam Leuk	60.0	41.5	2000	Reservoir	Existing
6	Nam Mang 3	40.0	42.8	2005	Reservoir	Existing
7	Nam Nhon	2.4	43.8	2010	Run of river	Under Construction
8	Nam Ham 2	3.5	60.3	2010	Run of river	Prepare for Construction
9	Nam Lik1/2	100.0	49.7	2010	Reservoir	Under Construction
10	Nam Ngum 5	120.0	47.6	2011	Reservoir	Under Construction
11	Nam lik 1	60.0	47.3	2011	Reservoir	MOU
12	Nam Sim	8.0	49.9	2012	Run of river	PDA
13	Nam tha 1	168.0	49.0	2012	Reservoir	PDA
14	**Nam Ngum1 ext**					
15	Nam Mang 1	50.0	44.7	2015	Reservoir	Planned
16	**Hongsa Lignite TPP**	**100.0**	**80.0**	**2015**	**Thermal**	**Planned**
17	Nam Boun	8.0		2015	Run of river	Planned
18	Nam Long	5.0	51.3	2016	Run of river	MOU
19	Nam Bak 2	80.0	47.0	2016	Reservoir	Planned
20	Mekong Luangpravang	140.0		2016	Run of river	Planned
21	Nam Ma 1	60.0	52.5	2016	Run of river	Planned
22	Nam San3	48.0	75.2	2016	Reservoir	MOU
23	Nam Ma 2	24.0	52.5	2016	Run of river	Planned
24	Nam Ma 3	36.0	52.5	2016	Run of river	Planned
25	Nam Ngiep Regulating	20.0		2017	Reservoir	PPA
26	Nam Theun 1(Local)	13.0	42.0	2017	Reservoir	Planned
27	Nam Ou 6(Local)	90.0	50.0	2017	Reservoir	Planned
28	Nam Ngiep 2	180.0	56.3	2017	Reservoir	MOU
29	Nam Khan 2	145.0	51.1	2018	Reservoir	MOU
30	Nam Khan 3	66.0	53.9	2018	Reservoir	Planned
31	Nam Ngum 4	50.0	34.9	2019	Run of river	Planned
32	Nam Beng	45.0	43.2	2020	Run of river	MOU
33	Nam Nga	60.0	49.9	2020	Reservoir	MOU
34	Nam Mo 1	60.0	44.7	2020	Reservoir	Planned
35	Nam Phay	50.0		2021	Reservoir	Planned
36	Nam Peun 1,2	70.0	60.0	2021	Reservoir	Planned
37	Nam Souang 1	31.0		2026	Run of river	MOU
38	Nam Feung 1	28.0	46.1	2026	Run of river	Planned
39	Nam Feung 2	25.0	50.2	2027	Run of river	Planned
40	Nam Feung 3	20.0	50.2	2028	Run of river	Planned
41	**Viengphukha Lignite**	**60.0**	**99.9**	**2030**	**Thermal**	**Planned**
42	Nam Phouan	90.0		2030	Reservoir	Planned

Prepared by JICA Survey Team

2.3.3 POWER DEMAND PROJECTION FOR LAO PDR

In another on-going study, "The Study on Power Network System Plan in Lao People's Democratic Republic" (by JICA Network System Team), macro-analysis is the method used in the projection for power demand for the whole Lao PDR. This method considers the relation between the economic growth rate and electricity demand intensity, and a regression curve is induced based on the relationship between electricity demand intensity and GDP/capita. Macro-analysis is regarded as reasonable in power demand projection. In this survey, the same method is applied for the verification of existing power demand projection.

Figure 2.3.2 shows the relationship between GDP/capita and electricity demand intensity of neighboring Asian countries. The GDP is a net value based on the price index and exchange rate in 2000. As the economy of a country develops, the GDP/capita increases. There is a tendency that the electricity intensity also increases to a certain level. However, if the growth has been saturated, electricity intensity sometimes decreases, similar to the level in Japan. In this survey, the same regression curve will be adopted for power demand projection. The same regression curve has been induced by analyzing the relationship shown below.

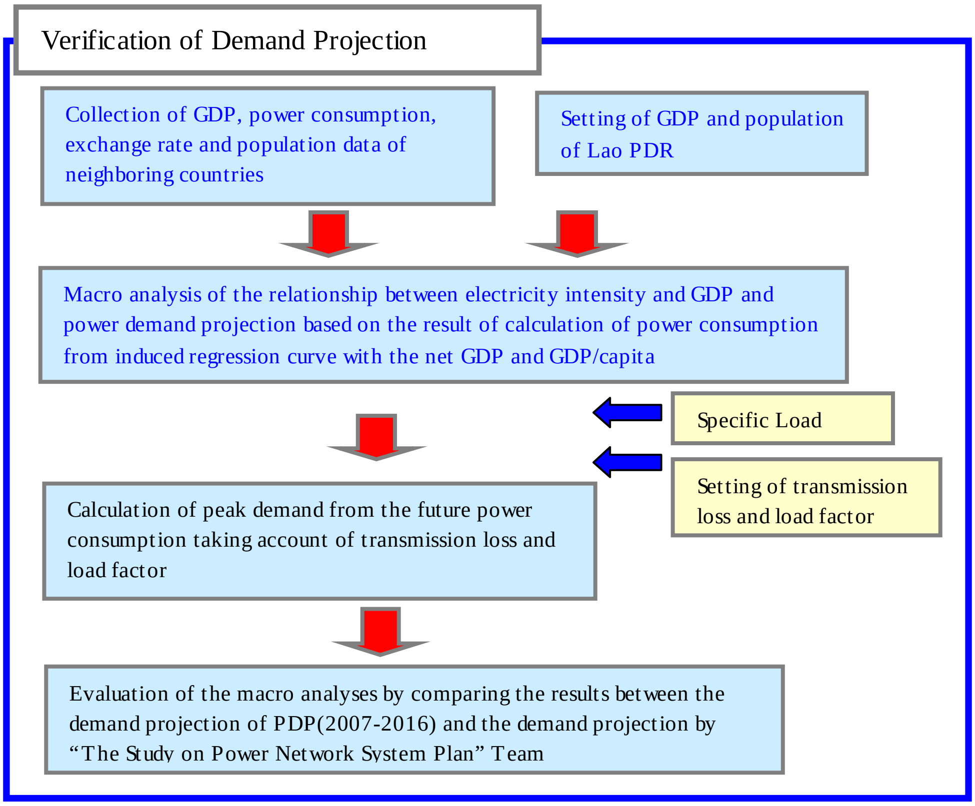


Source: Key Indicator ADB, Government Information regarding Lao PDR & Japan

Figure 2.3.2 Electricity Intensity and GDP

$$\log(\text{Elec.Consumption/GDP})=0.777+0.865\log(\text{GDP/capita})-0.060\log(\text{GDP/capita})^2$$

Power demand up to 2030 is examined by setting the base case to 7% and the high case to 9% in the economic growth ratio. In the southern area, an aluminum refining plant named SLACO is scheduled to be operated around 2014 and it will have about 1,000 MW of load. If this load is considered in the power demand projection, another scenario should be studied in the projection. Nevertheless, this plant will be constructed in the southern area, and the load of SLACO is eliminated in this demand projection. The methodology of demand projection is shown below.



The population up to 2020 that was used for the demand projection was taken from the report "Results from the Population and Housing Census 2005". The population projection after 2020 was based from the "World Population Prospects" (the 2008 revision)", (United Nations Population Division), which forecasts the population to reach 8,854,000 by year 2030 (Figure 2.2.3).

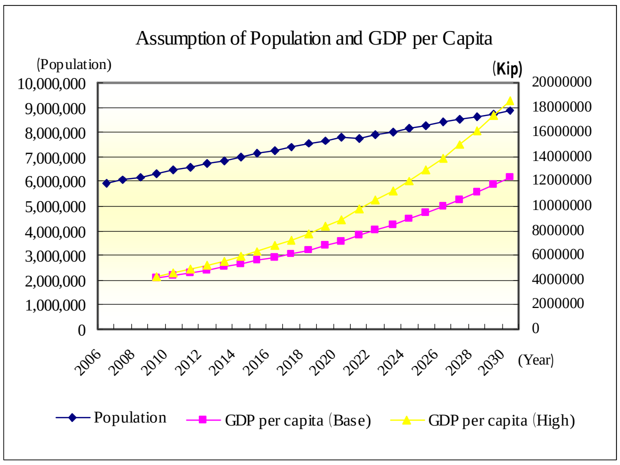


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Figure 2.3.3 Assumption of Population

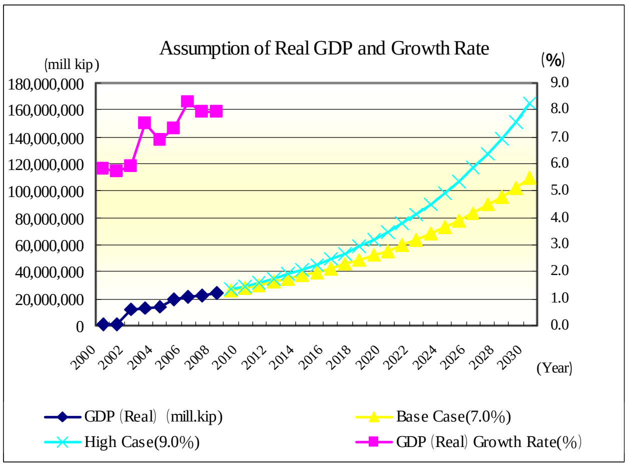

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Figure 2.3.4 Assumption of GDP Growth Rate

The transmission loss and load factor values are set as shown in Figure 2.3.5 and Figure 2.3.6, respectively. The value of transmission loss is set at 15% from 2020 to 2030. As for the load factor, it is assumed to increase until it reaches 70% by year 2030, which is the same value applied by the Network System Team.

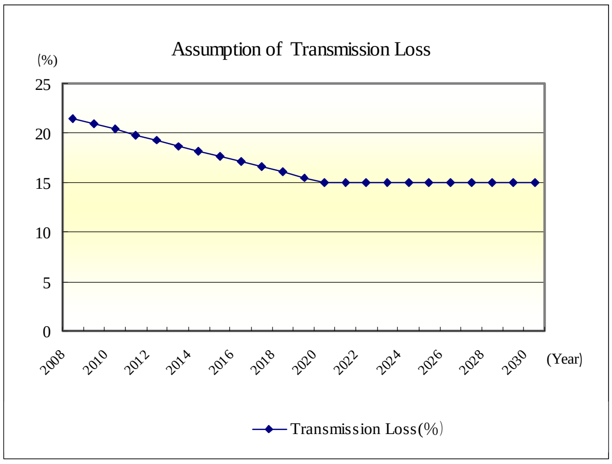

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Figure 2.3.5 Assumption of Transmission Loss

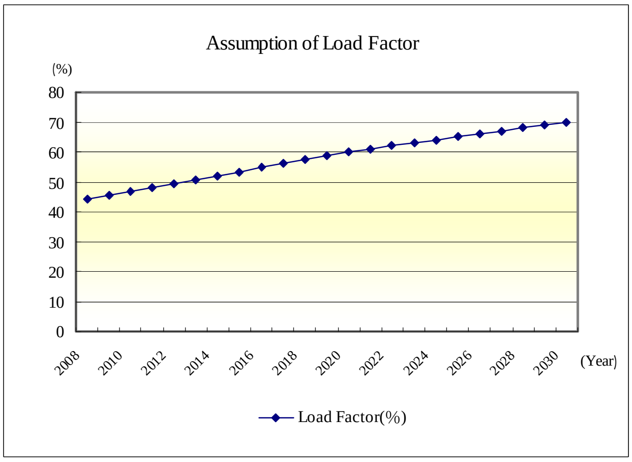

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Figure 2.3.6 Assumption of Load Factor

Figure 2.3.7 shows the result of the demand projection. EdL's demand projection result is shown by the orange line. The projected results in this survey are shown by the green and light blue lines for 9% and 7% in GDP growth, respectively. In year 2020, the peak demand for the base case could reach 1812 MW, and 2398 MW for the high projection case.

It is forecasted that the peak demand in 2030 in the base case could reach 3,637 MW, and 6,892 MW in the high case. These results indicate large discrepancies from the results projected by "The Network System Team", especially on the result after 2020, which is shown by the blue and pink lines. In particular, the discrepancy in the high case is quite large. Since the forecasted year after 2021 is different from JICA Survey Team projection, the difference in the population data virtually becomes the main reason of the discrepancy in the demand. Although the source of data is the same, the different population data in different forecasted years resulted to a discrepancy of about one million in the population forecast as of 2030.

It can be recognized that the discrepancy after 2023 in the projected peak demand is not so big in the base case. These data will be applied to the JICA survey, and provided that the growth rate is kept at 7% of the GDP, the result of the projection will be adequate. However, it is difficult for the GDP rate to be maintained at 7% until 2030 considering the ongoing global economic crisis. It is deemed most likely therefore, that around 2030, the growth rate would be saturated because the GDP/per capita is also considered to be saturated by that time. Therefore, the actual peak demand trend is closer to that of "The System Network Team". Accordingly, this future peak demand values should be applied for the peak demand projection for Northern and C1 areas.

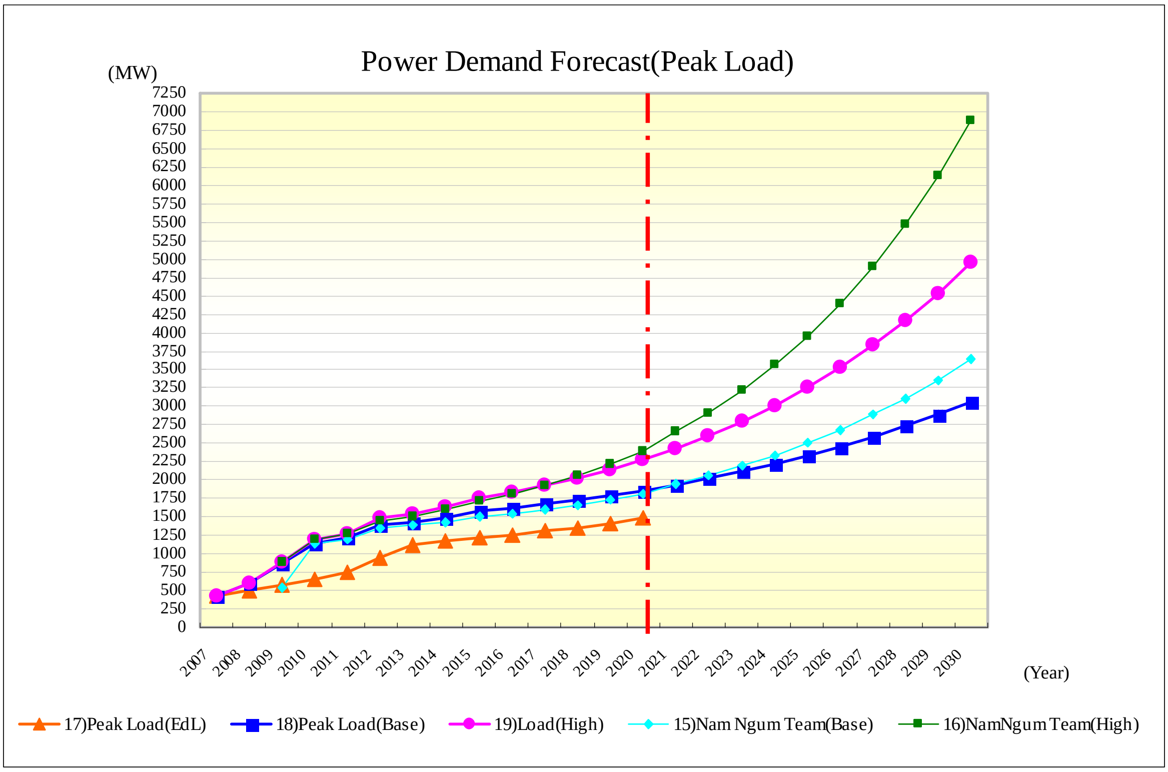

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Figure 2.3.7 Power Demand Forecast

Company or Project Name	MW	Year		Year													
				2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Phou Bear Mining	*49.1*	*2008*	*C1*		*49.1*	*49.1*	*49.1*	*49.1*	*49.1*	*49.1*	*49.1*	*49.1*	*49.1*	*49.1*	*49.1*	*49.1*	*49.1*
Sinno Lao	*20*	*2008*	*C1*		*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*
Lao Younesin Mining Development	*5*	*2008*	*N*		*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*
Iron/coal Mining	*12*	*2008*	*C1*		*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*
Steel Making Plant	*64.5*	*2008*	*C1*		*64.5*	*64.5*	*64.5*	*64.5*	*64.5*	*64.5*	*64.5*	*64.5*	*64.5*	*64.5*	*64.5*	*64.5*	*64.5*
Lao-China Development Mining	*10*	*2009*	*N*			*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
Vinakomin Lao Co.	*10*	*2009*	*C1*			*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
Vang Vient Mining Co.	*12*	*2009*	*C1*			*12*	*12*	*12*	*12*	*12*	*12*	*12*	*12*	*12*	*12*	*12*	*12*
Vientiane Commerce	*5*	*2009*	*C1*			*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*
Iron/coal Mining	*13.5*	*2009*	*C1*			*13.5*	*13.5*	*13.5*	*13.5*	*13.5*	*13.5*	*13.5*	*13.5*	*13.5*	*13.5*	*13.5*	*13.5*
Steel Making Plant	*85.5*	*2009*	*C1*			*85.5*	*85.5*	*85.5*	*85.5*	*85.5*	*85.5*	*85.5*	*85.5*	*85.5*	*85.5*	*85.5*	*85.5*
UC Xaunglong Co. Laos	*10*	*2010*	*N*				*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
Cement factory	*9.5*	*2010*	*C1*				*9.5*	*9.5*	*9.5*	*9.5*	*9.5*	*9.5*	*9.5*	*9.5*	*9.5*	*9.5*	*9.5*
United	*10*	*2010*	*C1*				*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
Iron/coal Mining	*34*	*2010*	*C1*				*34*	*34*	*34*	*34*	*34*	*34*	*34*	*34*	*34*	*34*	*34*
Steel Making Plant	*224*	*2010*	*C1*				*224*	*224*	*224*	*224*	*224*	*224*	*224*	*224*	*224*	*224*	*224*
Deuktian	*40*	*2011*	*C1*					*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
Chinhourdow Chinher	*25*	*2012*	*C1*						*25*	*25*	*25*	*25*	*25*	*25*	*25*	*25*	*25*
Phou Bear Mining	*52*	*2012*	*C1*						*52*	*52*	*52*	*52*	*52*	*52*	*52*	*52*	*52*
Dow Lao	*40*	*2012*	*C1*						*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
C Xaune Koden Element Chemical	*10*	*2012*	*N*						*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
Unan Mining Copper Industry Oudomxay M	*20*	*2012*	*N*						*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*
Toun Haung Lao-China Mining	*10*	*2012*	*N*						*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
Lao Jongxaig Mine and Magnet	*10*	*2012*	*C1*						*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
UC Xaunglong Co. Laos	*20*	*2014*	*N*								*20*	*20*	*20*	*20*	*20*	*20*	*20*
	801.1			-	***150.6***	***286.6***	***574.1***	***614.1***	***781.1***	***781.1***	***801.1***	***801.1***	***801.1***	***801.1***	***801.1***	***801.1***	***801.1***
Lao cement industry	*17*	*2008*	*C2*		*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*
Many companies	*20*	*2009*	*C2*			*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Lanxang Mineral	*74*	*2009*	*C2*			*74.0*	*74.0*	*74.0*	*74.0*	*74.0*	*74.0*	*74.0*	*74.0*	*74.0*	*74.0*	*74.0*	*74.0*
Chaugyan EC Unan	*25*	*2009*	*S*			*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*
Lao Alminium Industries	*40*	*2009*	*S*			*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
Lao cement industry	*60*	*2010*	*C2*				*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*
Shinoma	*20*	*2012*	*S*						*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Shinoma	*8*	*2012*	*S*						*8.0*	*8.0*	*8.0*	*8.0*	*8.0*	*8.0*	*8.0*	*8.0*	*8.0*
Army Mining company	*50*	*2015*	*S*									*50.0*	*50.0*	*50.0*	*50.0*	*50.0*	*50.0*
	314				***17.0***	***176.0***	***236.0***	***236.0***	***264.0***	***264.0***	***264.0***	***314.0***	***314.0***	***314.0***	***314.0***	***314.0***	***314.0***
	1,115.1				***167.6***	***462.6***	***810.1***	***850.1***	***1,045.1***	***1,045.1***	***1,065.1***	***1,115.1***	***1,115.1***	***1,115.1***	***1,115.1***	***1,115.1***	***1,115.1***

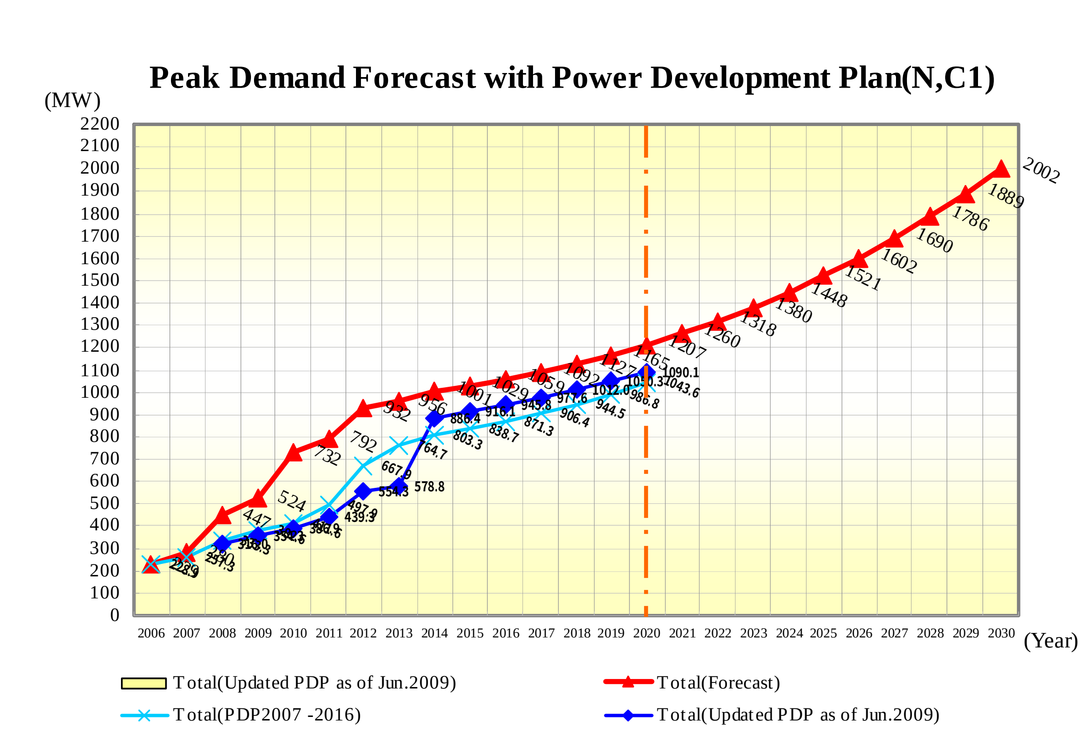
Source: EdL

Figure 2.3.8 Specific Demand

2.3.4 POWER DEMAND PROJECTION FOR NORTHERN AND C1 AREAS

Based on the peak demand value and the growth rate that were calculated by the aforementioned macro method, each regional demand for Northern, C1, C2 and Southern area has been assumed after adding specific demand in the regions after the projection of future load of substations located in each province.

Figure 2.3.9 shows the peak demand forecast for C1 and Northern areas until 2030, which are expected to be supplied by NN1 hydro power station.



Prepared by JICA Survey Team

Figure 2.3.9 Peak Demand Forecast(N,C1)

The peak demands for northern and C1 areas are estimated at 1,207 MW in 2020, and 2,002 MW in 2030. In the demand projection in this JICA survey, the peak demand value is close to the value of the demand projection by EdL, which is shown in light blue, and the demand of 1,044 MW in 2020. Recently, the development plans with specific demands have been reviewed, and EdL has revised the projection result shown in blue line upwards, and set closer to 1090 MW in the 2020 demand. With this result, future daily loads curves will be assumed.

2.4 ANALYSES OF POWER SUPPLY AND DEMAND

2.4.1 GENERAL

In the power interchange with EGAT of Thailand, the balance of volume between import and export has recently been reversed, such that the import volume exceeded the export volume in 2006. If this situation continues in the future, it will become a burden on the finances of EdL.

Under circumstances of advantageous power transaction for EGAT in the PPA, the development of power sources is regarded as a prime task, but the power development plans mostly accounting for IPP projects are susceptible to economic conditions. Therefore, the development plans are prone to be delayed. In the expansion of NN1, it is necessary to properly identify the future demand and to properly address the demand requirements by working out an optimal operating pattern and to introduce the pattern to maximize benefit based on appropriate installed capacity.

As to the method for the load curve projection, in the wake of the present trend of daily load curves and the balance of power supply and demand, future daily load curve is worked out using the aforementioned projected value. Moreover, for the projected daily load curves, the operating pattern of the expanded NN1, together with the future prominent power development plans, will be studied based on the proper reservoir operation.

2.4.2 BALANCE OF PRESENT POWER SUPPLY AND DEMAND

The electric power for C1 area is being supplied by NN1 (155 MW), Nam Mang 3 and Nam Leuk (60 MW), in which the respective outputs of them are mutually controlled.

On the other hand, small-scale hydropower stations such as Namdon, Nam Ko and Namggay are supplying the power to decentralized small-scale consumers in the northern area. In the 2007 records, the generated energy within Lao PDR is 1,398 GWh, and imported energy, including the power used by mining industries, is 792 GWh, while exported energy is 269 GWh.

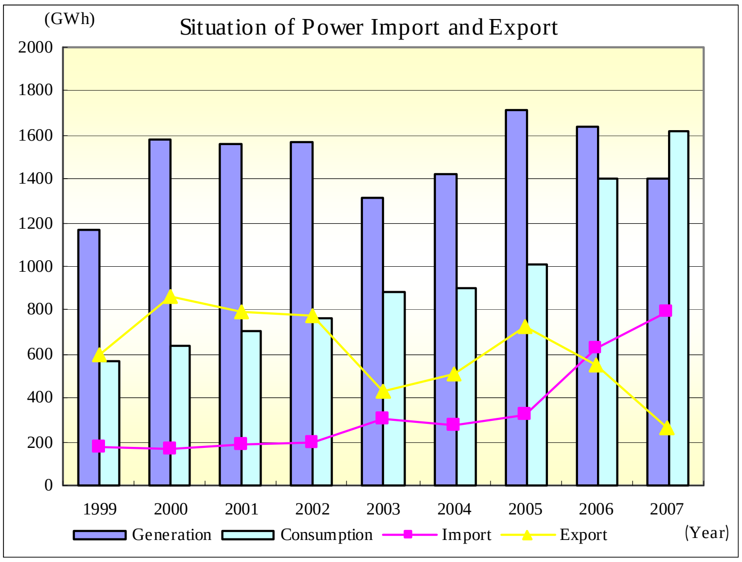


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Figure 2.4.1 Situation of Power Import and Export

The 2008 data shows that power output is insufficient in the dry season and highly dependent on the power imported from EGAT. In the rainy season, power is exported to EGAT since EdL has surplus power. Currently, power import exceeds power export throughout the year. In order to cover energy shortage in the dry season, imported energy especially in the peak hours is much more than exported energy in the rainy season.

2.4.3 PRESENT DAILY LOAD TREND

Figure 2.4.2 shows a daily load curve as of 2008. The peak load occurs during nighttime when everybody uses lights. The night peak load is between 19:00 and 20:00 in the dry and rainy seasons. The average load occurs during daytime and generally, the average load during weekdays is lower than during holidays. Figures 2.4.3 and 2.4.4 show that peak load during the dry season tends to transpire at 19:00 hrs in January and at 20:00 in June. This shows that the trend in June is more moderate than that of January. The data from 2004 to 2008 shows that the peak loads are increasing every month.

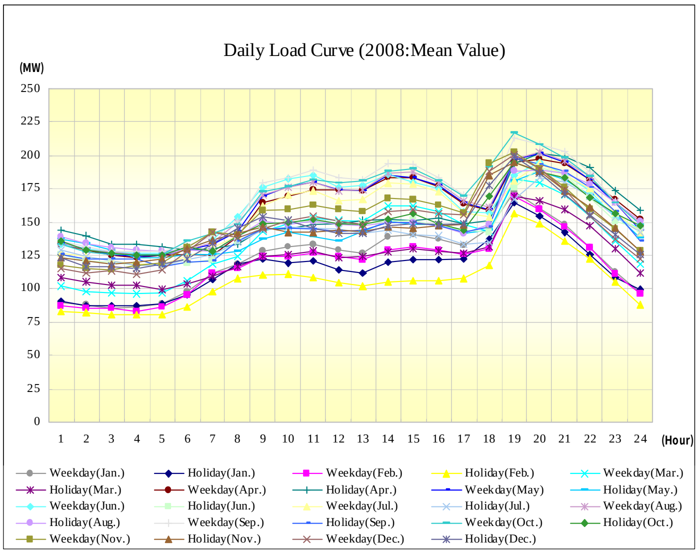

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Figure 2.4.2 Daily Load Curve(2008)

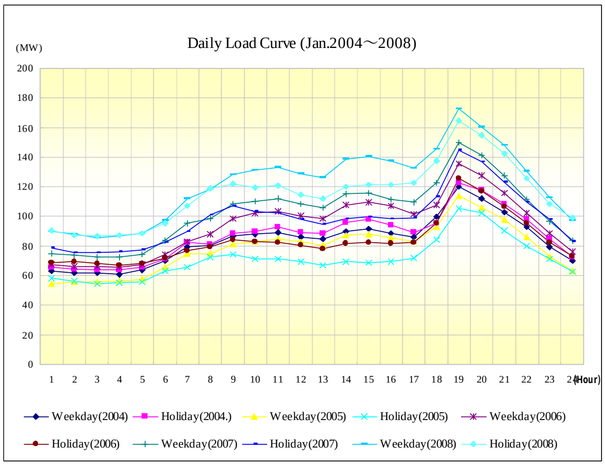

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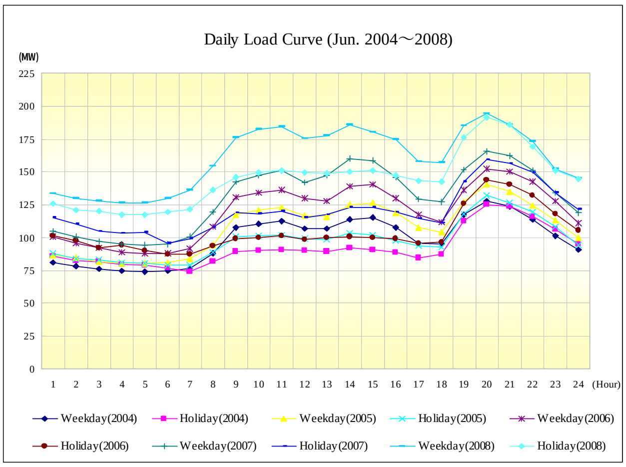
Figure 2.4.3 Daily Load Curve(Jan.2004-2008)

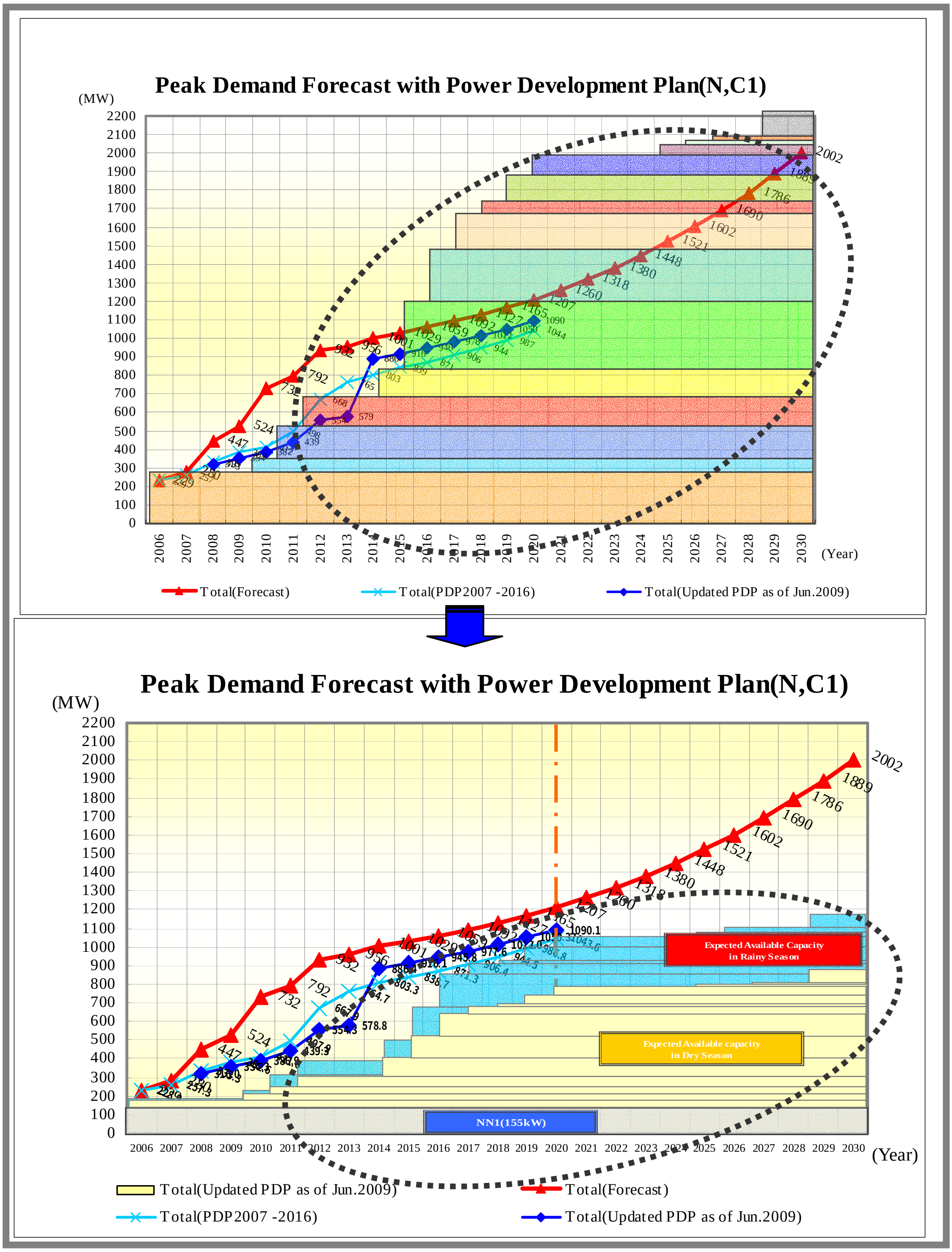


Prepared by JICA Survey Team

Figure 2.4.4 Daily Load Curve(Jun.2004-2008)

2.4.4 BALANCE OF POWER SUPPLY AND DEMAND IN FUTURE

Figure 2.4.5 shows the relationship between power supply and demand until 2030. The installed capacity of power supply in the development plan is demonstrated as shown in Figure 2.4.5, which is based on the latest PDP for the C1 and northern areas. It is planned that the supply capacity would be sufficient to cater up to the power demand in the year 2016. In the development plan, the hydropower plants are the main sources of power supply. The capacity of the hydropower plants are highly influenced by the rainfall intensity, irrespective of run-of-river type or reservoir type. Accordingly, during rainy season, it is actually impossible to keep generating the installed capacity. It is assumed that the average available output should be set such as shown in the lower graph in Figure 2.4.5.



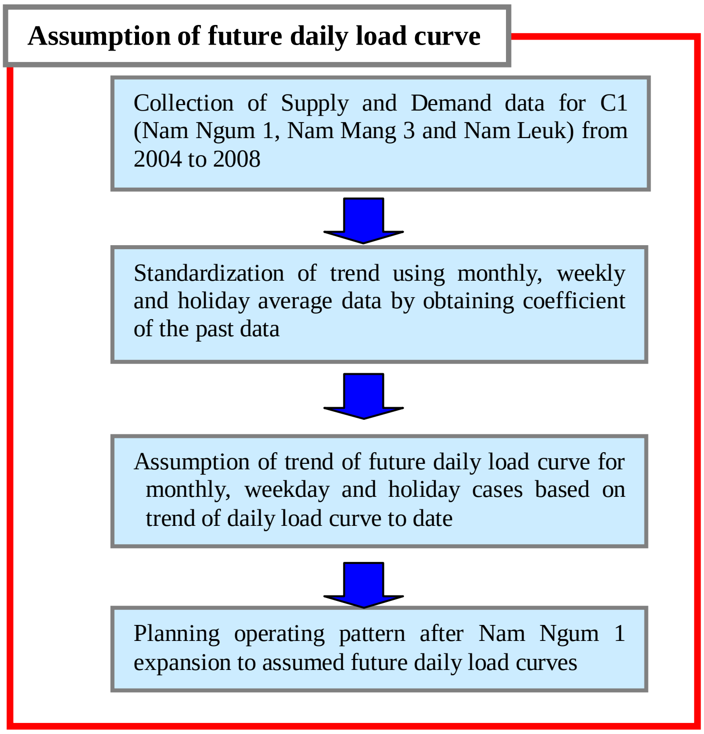
Prepared by JICA Survey Team

Figure 2.4.5 Peak Demand Forecast with Power Development Plan

The blue area in the figure indicates an assumed average available output during the rainy season, which has been set to about 50% of the installed capacity based on the probability curve graph projecting the available amount of water. The average available output of the dry season is indicated by the yellow area, which has been set to about 30% of the installed capacity projected in the probability curve of available water. This result indicates that the total generated energy, including for the both of rainy and dry season, could not meet the demand even in 2015, which means that the volume of imports will still exceed the exports except for some years.

2.4.5 ASSUMPTION OF FUTURE DAILY LOAD CURVE TREND

In order to study the optimal operating pattern for the expanded Nam Ngum 1 hydropower station, future daily load curve should be assumed first. In the review of the pattern, no change has been noted in the daily load curves from 2004 to 2008, and therefore, the future load curves are assumed to keep the same pattern as the past load curves for the time being. In order to formulate the pattern of future daily load curves, the actual past data were averaged and divided by past peak power value, and coefficients were obtained from the past data. The daily load curves have been demonstrated by applying the future peak demand in the C1 and northern areas, which has been projected until 2025 in the Chapter 2.3.4. The curves are assumed and shown in monthly, weekday, and holiday cases from 2009 to 2025 over the past 17 years and the process is shown in the flow chart below.



Figures from 2.4.6 to 2.4.11 show daily load curves of weekdays and holidays, as of 2015, 2020 and 2025. It is in the year 2015 that the extension of NN1 will be completed and will begin its operation. The figure of daily load curve is presumed to show the same trend, therefore, the difference between the demand of off-peak and peak time becomes larger. For these daily load curves, an optimal operation plan for NN1 will be proposed for high production, commensurate to appropriate reservoir operation.

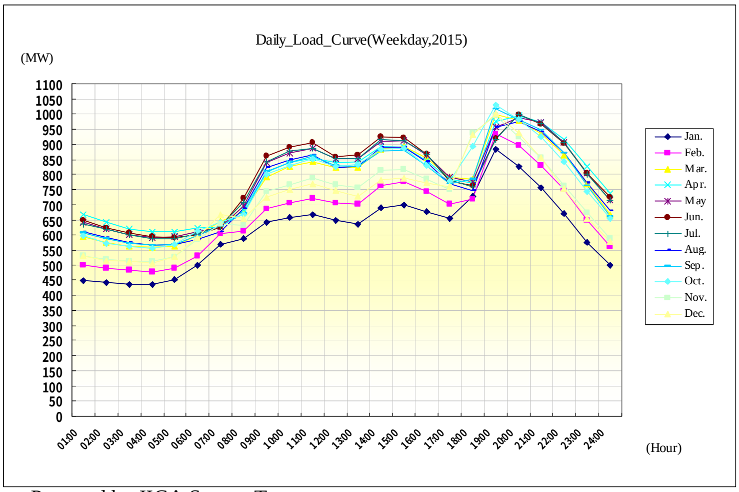


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Figure 2.4.6 Daily Load Curve (2015, Weekday)

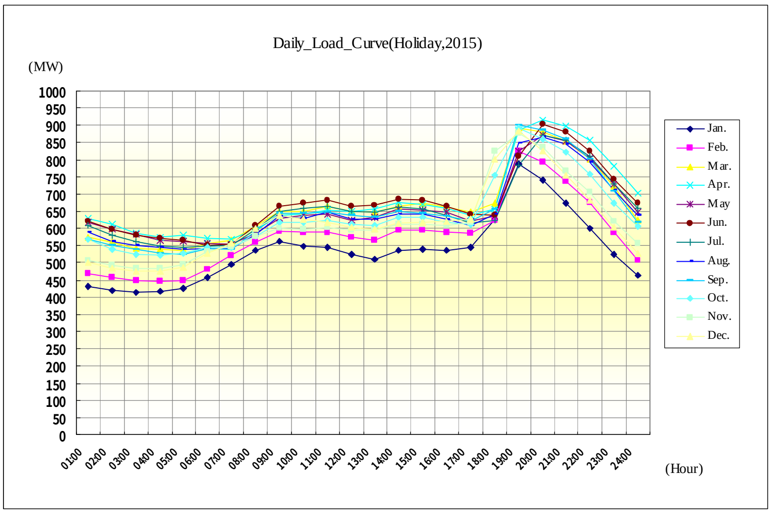

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Figure 2.4.7 Daily Load Curve (2015, Holiday)

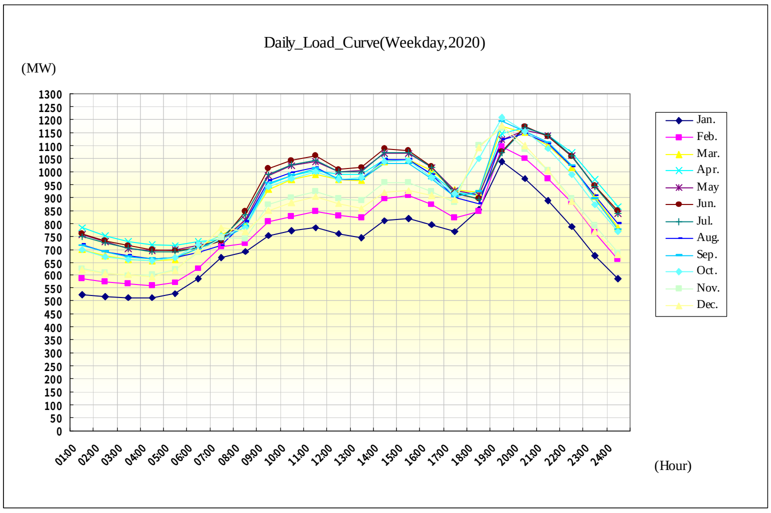

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Figure 2.4.8 Daily Load Curve (2020, Weekday)

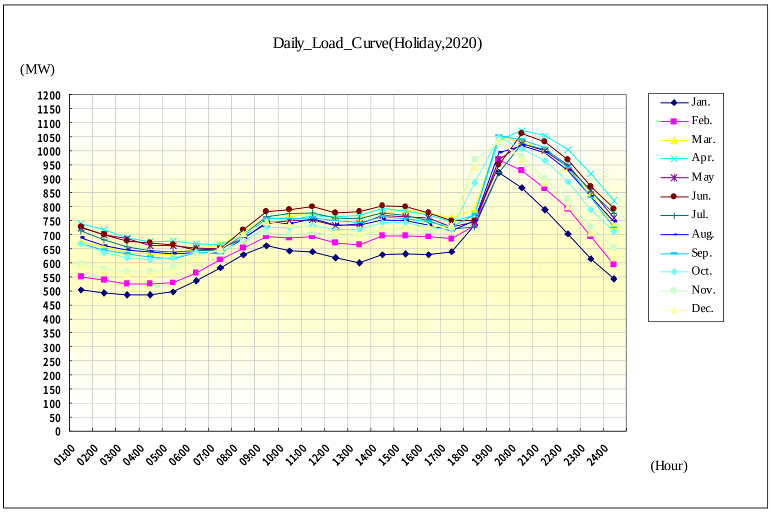

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Figure 2.4.9 Daily Load Curve (2020, Holiday)

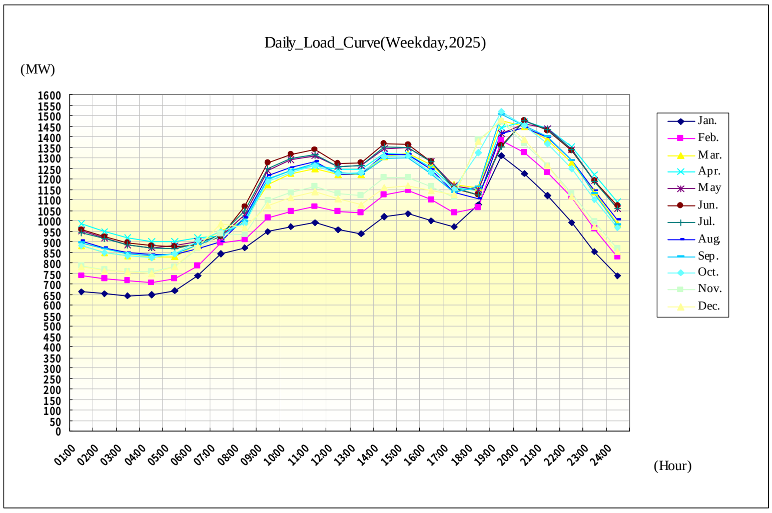

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Figure 2.4.10 Daily Load Curve (2025, Weekday)

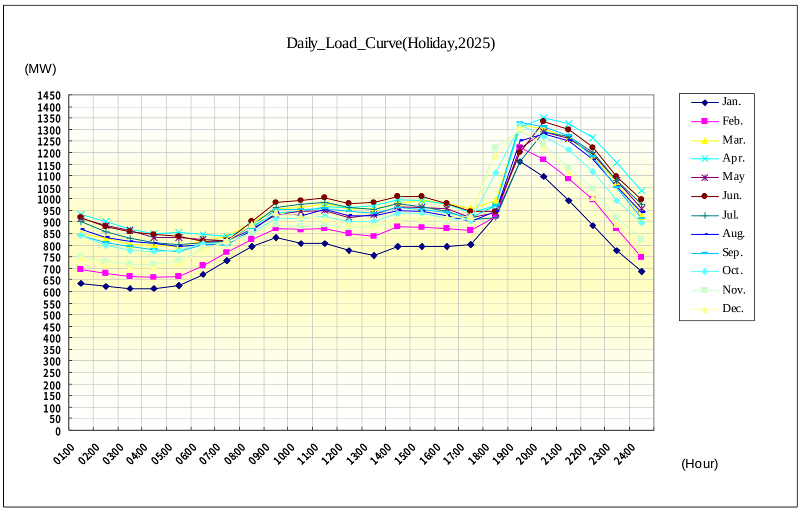

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Figure 2.4.11 Daily Load Curve (2025, Holiday)

CHAPTER 3 PRESENT CONDITION OF THE NN1 HYDROPOWER STATION AND NAM NGUM RIVER BASIN

3.1 PRESENT CONDITION OF NN1 HYDROPOWER STATION

3.1.1 HISTORICAL POWER GENERATION OF NN1 HYDROPOWER STATION

The Nam Ngum 1 (NN1) Hydropower Station started the generation of power in 1971. It was developed in the Nam Ngum River system with the largest reservoir in Laos with 7 billion m^3 capacity. The NN1 Hydropower Station has been expanded as the main power source for the metropolitan area (C1 area) and the present installed capacity is 155 MW. The plant factor of the power station was 66 % at the beginning, and it became 74 % due to the increase of inflow to the reservoir from the Nam Son diversion developed in 1995 at 65 m^3/s and the Nam Leuk Hydropower Project developed in 2000 at 15 m^3/s. The principal features of NN1 are shown in Table 3.1.1.

Table 3.1.1 Principal Features of the Nam Ngum River Basin andNN1 Hydropower Station

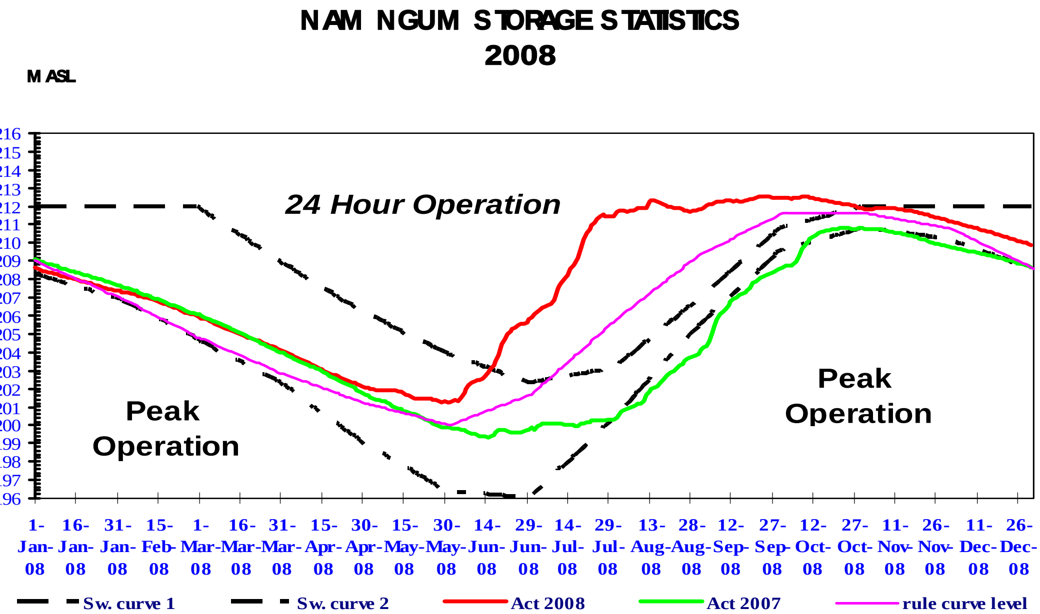
Feature	Data	Description
River Basin Area	8,460 km^2 [1]	Nam Ngum basin only
Annual Average Inflow	382 m^3/s	Including inflows from Nam Song Diversion and Nam Leuk Hydropower Station (Average for 2001 - 2008)
Installed Capacity	155MW	Unit - 1, 2 : 17.5 MW x 2, Unit - 3, 4, 5 : 40 MW x 3
Reservoir Capacity	7.03 bil m^3	at W.L. 212.0 masl
Reservoir Area	370 km^2	at W.L. 212.0 masl
Dam Height	75 m	Concrete Gravity Type
Dam Length	468 m	-
Dam Volume	360,000 m^3	-

Prepared by JICA Survey Team


NN1 Hydropower Station

The NN1 Hydropower Station is being operated to meet the power demand in the C1 area by coordination with Nam Leuk Hydropower Station and Nam Mang 3 Hydropower Station commensurate to each capacity of power generation. The power generation of NN1 is being planned aiming at optimum reservoir management. The total power output and time period of power generation of each unit is decided on the basis of reservoir operation rule curve relative with its season and reservoir water level. The rule curve is shown in Figure 3.1.1. The actual reservoir water level in each year is however affected by the volume of inflow into the NN1 reservoir and deviates easily from the rule curve as shown in the curves for 2007 and 2008 in the figure.

[1] Referred to NN1 Completion Report (1972). In NNRBDSP report (2009), the area is 8,275 km^2.

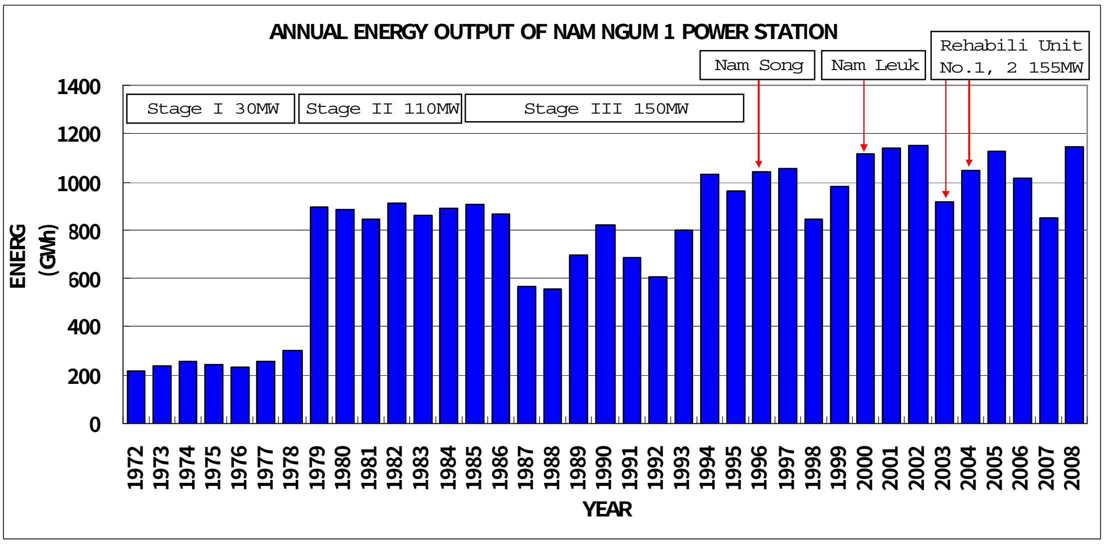


Source: NN1 Hydropower Station

Figure 3.1.1 Present Rule Curve of Nam Ngum 1 Hydropower Station

(1) Power Generation History

The power generation history of NN1 Power Station from 1971 up to now is shown in Figure 3.1.2. The NN1 has started its power generation with 30 MW installed capacity. Consequently, it was expanded up to 110 MW with additional 2 units of 40 MW in 1979. Then, in 1985, NN1 was expanded up to 150 MW, with an additional one unit of 40MW. Afterwards, the annual power generation was increased due to the increase of inflow into the NN1 reservoir from Nam Song Diversion in 1996, and diversion from Nam Leuk Hydropower Station in 2000. Furthermore, Units No.1 and No.2 were rehabilitated from 2003 to 2004, hence the total installed capacity became 155MW at present. The recent annual power generation ranges between 1,000 and 1,150 GWh.

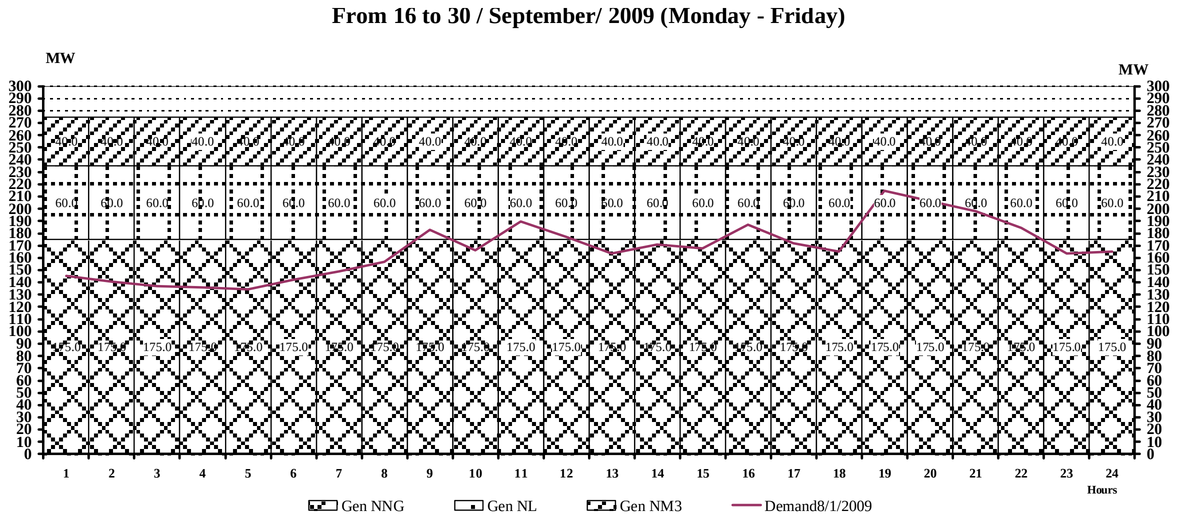


Source: NN1 Hydropower Station

Figure 3.1.2 Historical Energy Output of Nam Ngum 1 Power Station

(2) Daily Load Curve and Power Generation Pattern

The NN1 Hydropower Station is being operated to serve the power demand in C1 area by combination of power generation with Nam Leuk and Nam Mang 3 Hydropower Station as mentioned above. All power supply are from hydropower stations, that generate power in full capacity in rainy season and with limited power generation during the dry season due to less inflow into the reservoir. The power generation patterns in the rainy and dry seasons are shown in Figure 3.1.3 and 3.1.4, respectively. As shown in Figure 3.1.3, the total power output of the three power stations in rainy season is 275 MW with full capacities and it exceeds the daily load curve for 24 hours. In this case, the surplus generated power is exported to Thailand.



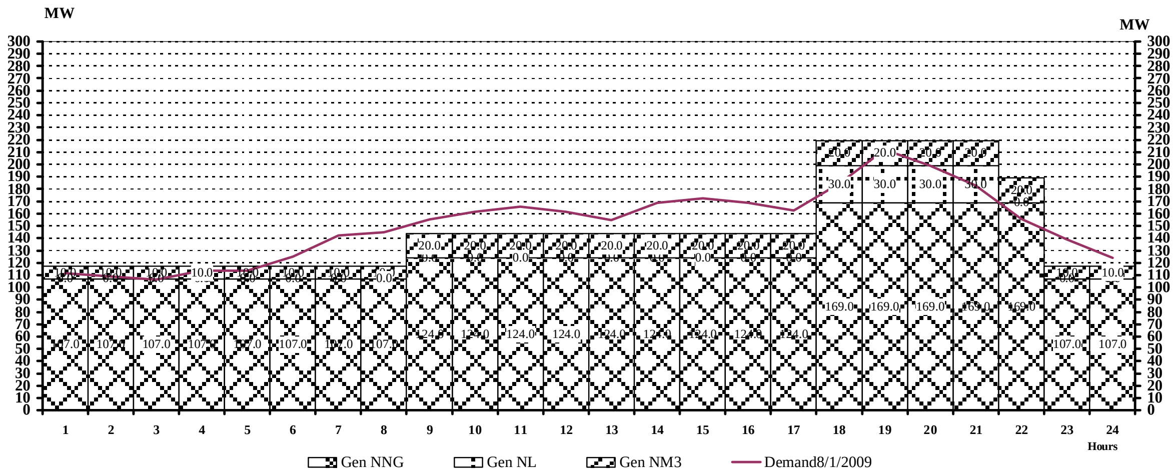
Source: NN1 Hydropower Station

Figure 3.1.3 Power Generation Plan with Combination of Nam Ngum 1, Nam Leuk and Nam Mang 3 (Typical case in Rainy Season)

As shown in the power generation pattern for the dry season in Figure 3.1.4, the power generation of Nam Leuk is limited for four hours to cover only the night peak power demand. The NN1 Hydropower Station is operated to meet each power demand in off-peak, day peak and night peak times as much as possible. However, the total power output of the three power stations falls below the daily load curve for some hours. In this case, the power shortage is supplemented with power import from Thailand. However, the amount of import power from Thailand is limited to 100 MW due to the capacity of power transmission of the existing system in Thailand. Therefore, the NN1 is required to operate to meet the power demand as shown in the daily load curve to minimize as much as possible getting the power supply imported from Thailand.

The daily load will increase with similar load curve pattern year by year. The power demand in off-peak time is expected to be covered with the new hydropower development plan such as domestic IPP in the PDP, and the power demand of night peak time should be covered with NN1 Power Station with expansion because it has high capability of flexible control of power output with its huge reservoir.

From 7 to 15 / January/ 2009 (Monday - Friday)



Source: NN1 Hydropower Station

Figure 3.1.4 Power Generation Plan with Combination of Nam Ngum 1, Nam Leuk and Nam Mang 3 (Typical Case in Dry Season)

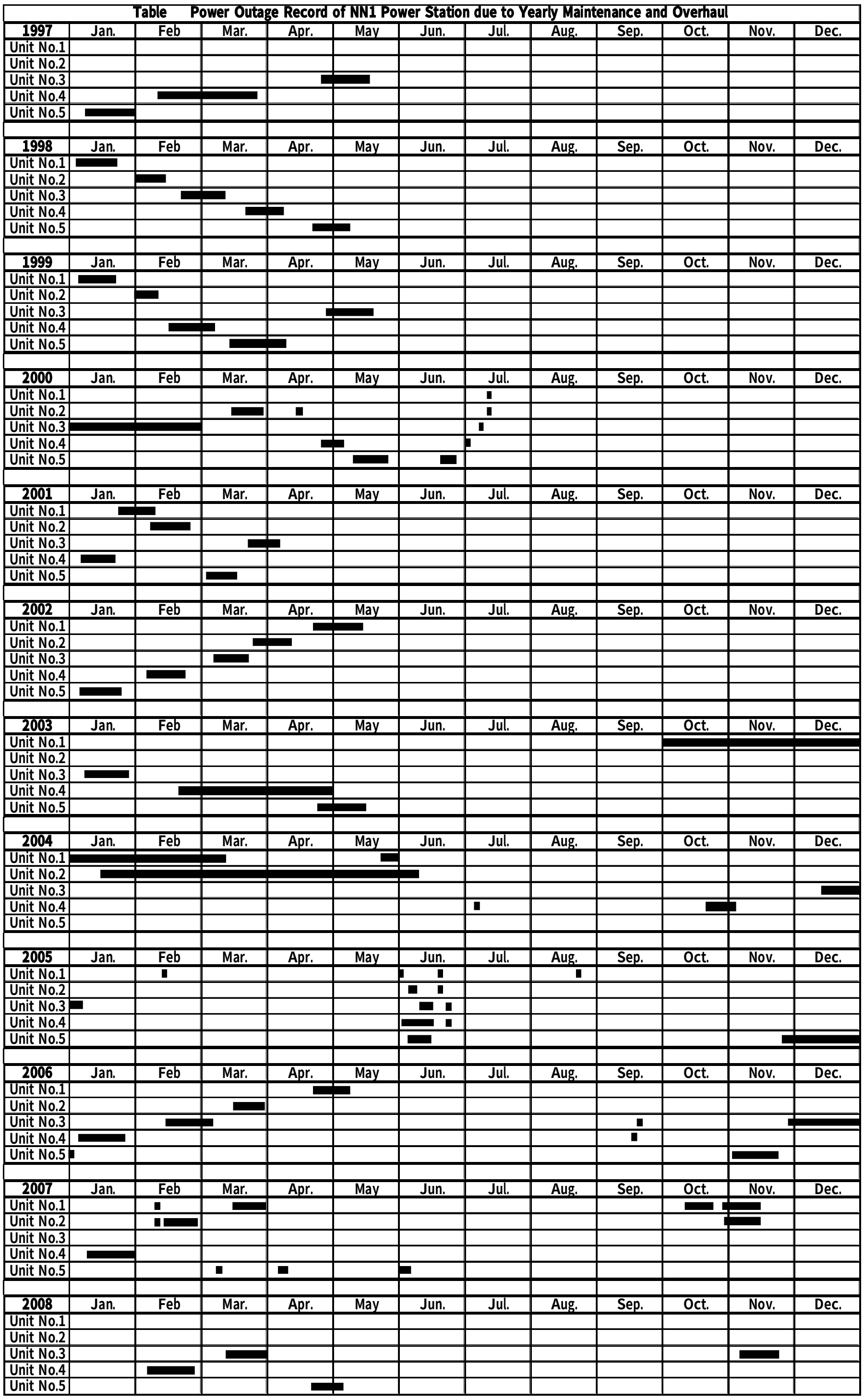
3.1.2 MAINTENANCE OF NN1 HYDROPOWER STATION

The NN1 has started power generation of Units No.1 and No.2 with installed capacity of 30 MW and has been expanded up to 155 MW after the stepwise development. The Units No.1 and No.2 were rehabilitated from 2003 and 2004 and presently operating in good condition. The regular maintenance of Units No.1 and No.2 is carried out once a year for 20 days. On the other hand, Units No.3 and No.4, which have not yet undergone any overhauling works ever since, are scheduled to undergo overhaul in dry season of 2010 and 2011, respectively. Unit No.5, which started power generation in 1985, was overhauled in mid-February to mid-June 2009. Yearly maintenance for Units No.3, No.4 and No.5 are being carried out within 30 days in dry season.

According to the opinion of staff of NN1 Hydropower Station, the timing of maintenance is limited within the dry season and flexible adjustment of the maintenance schedule is difficult.

(1) Maintenance Record of Existing Power Generation Facilities

The power outage record of NN1 power station from 1997 to 2008 was obtained from NN1 Hydropower Station and plotted in Figure 3.1.5. The power outages occurred mainly due to yearly maintenance and rehabilitation of Unit No.1 and No.2, and these were recorded in a five-month period in 2003 and 2004, respectively. Basically, the annual maintenance is carried out in dry season to avoid inefficient spillage of water from reservoir. However, the inflow into NN1 reservoir will be well-regulated due to commencement of power generation of NN2 Hydropower Station in 2011. It is expected that the inflow into NN1 reservoir in dry season will increase and reservoir water level will be kept at relatively high elevation and the periodic maintenance, which has been based on the seasonal fluctuation of reservoir water level, is expected to be changed.



Source: NN1 Power Station

Figure 3.1.5 Power Outage Record of NN1 Power Station due to Yearly Maintenance and Overhaul

The operation hour ratios of each unit in recent years were obtained from NN1 Hydropower Station and summarized in Table 3.1.2. The operation hour ratio in 2003 and 2004 are not so high because of the implementation of the rehabilitation of Units No.1 and No.2. Likewise, the recorded operation hour ratio in 2007 is only 68% due to less inflow into NN1 reservoir in special dry year. In the case of year 2005, 2006 and 2008, the operation hour ratios range between 83% and 85%, which seems to be high for the reservoir-type hydropower station.

Table 3.1.2 Operation Ratio Recorded at NN1 Power Station

Unit %

	2003	2004	2005	2006	2007	2008
Jan.	80.8	55.1	77.3	83.9	65.7	62.5
Feb.	69.5	54.2	87.8	88.5	63.1	63.9
Mar.	72.3	69.1	100.0	81.8	70.4	74.9
Apr.	86.6	74.6	96.3	80.8	83.1	85.3
May	90.0	72.6	66.1	89.0	84.0	94.5
Jun.	89.6	90.6	56.9	95.7	73.0	97.0
Jul.	77.9	89.1	55.1	95.6	88.9	100.0
Aug.	90.0	99.4	97.3	100.0	66.0	99.9
Sep.	63.6	100.0	99.9	71.5	54.0	99.8
Oct.	64.0	84.9	99.8	71.4	47.3	98.3
Nov.	58.3	74.4	85.0	72.3	56.2	71.6
Dec.	58.5	72.4	80.0	67.0	66.2	69.6
Ave.	75.1	78.0	83.5	83.1	68.2	84.8
Note	Rehabilitation of Unit No.1 and No.2		Normal Year	Normal Year	Dry Year	Normal Year

Source: NN1 Power Station

Though all power generation units receive a yearly maintenance, the opportunity of overhaul or rehabilitation is quite limited. It is important to develop the adequate maintenance schedule for the power generation Unit No.1 to No.5 and prolong life of important infrastructure in Laos. If the NN1 Hydropower Station has additional power generation unit, the operation ratio of existing power generation units will be lowered and the flexible arrangement of maintenance for existing 5 units would be easier than present conditions. Further, due to reduction of operation ratio of existing power generation, the frequency of repair of consumable parts of power generation units will be decreased and yearly maintenance cost also will be reduced.

(2) Maintenance Plan of Power Generation Facilities

According to the information of staff in NN1 Hydropower Station, the period required for proper and adequate yearly maintenance is shown in Table 3.1.3. The maintenance period is scheduled in the dry season to avoid inefficient spillage of water from the reservoir. On the basis of this yearly maintenance period, the maximum operation hour ratio is calculated to be 92.6%, and it was found that the operation hour ratios recorded in recent years are not so far from this ratio.

Table 3.1.3 Power Outage for Yearly maintenance

	Period required for yeary maintenance (days)	Preparation Period	Period of Power Outage
Unit No. 1	18	3	21
Unit No. 2	18	3	21
Unit No. 3	28	3	31
Unit No. 4	28	3	31
Unit No. 5	28	3	31
Total			135

Sorce: NN1 Power Station

After commencement of NN2 power generation in 2011, the inflow into NN1 reservoir will be regulated and the difference of flow conditions in the rainy and dry seasons will be decreased. Therefore, the arrangement of timing of the periodic maintenance will be reconsidered.

3.2 PRESENT CONDITION OF HYDROPOWER DEVELOPMENT PLAN IN NNRB

In the NNRB, many hydropower development plans are in the process, aiming at effective utilization of the rainfall and river flow. There are many big-scale IPP projects for power export to Thailand, which are under construction or planning stages. On the other hand, a domestic IPP project for domestic power supply is also ongoing. These various hydropower development plans are classified into two groups, which consist of the projects located in the upstream area of NN1, and the projects located in the downstream area. These projects have the possibility of power generation coordinated with the NN1 Hydropower Station. The location map and diagrams of the hydropower plans, which are in existence, under construction, and under study stage, are shown in Figure 3.2.1 and Figure 3.2.2.

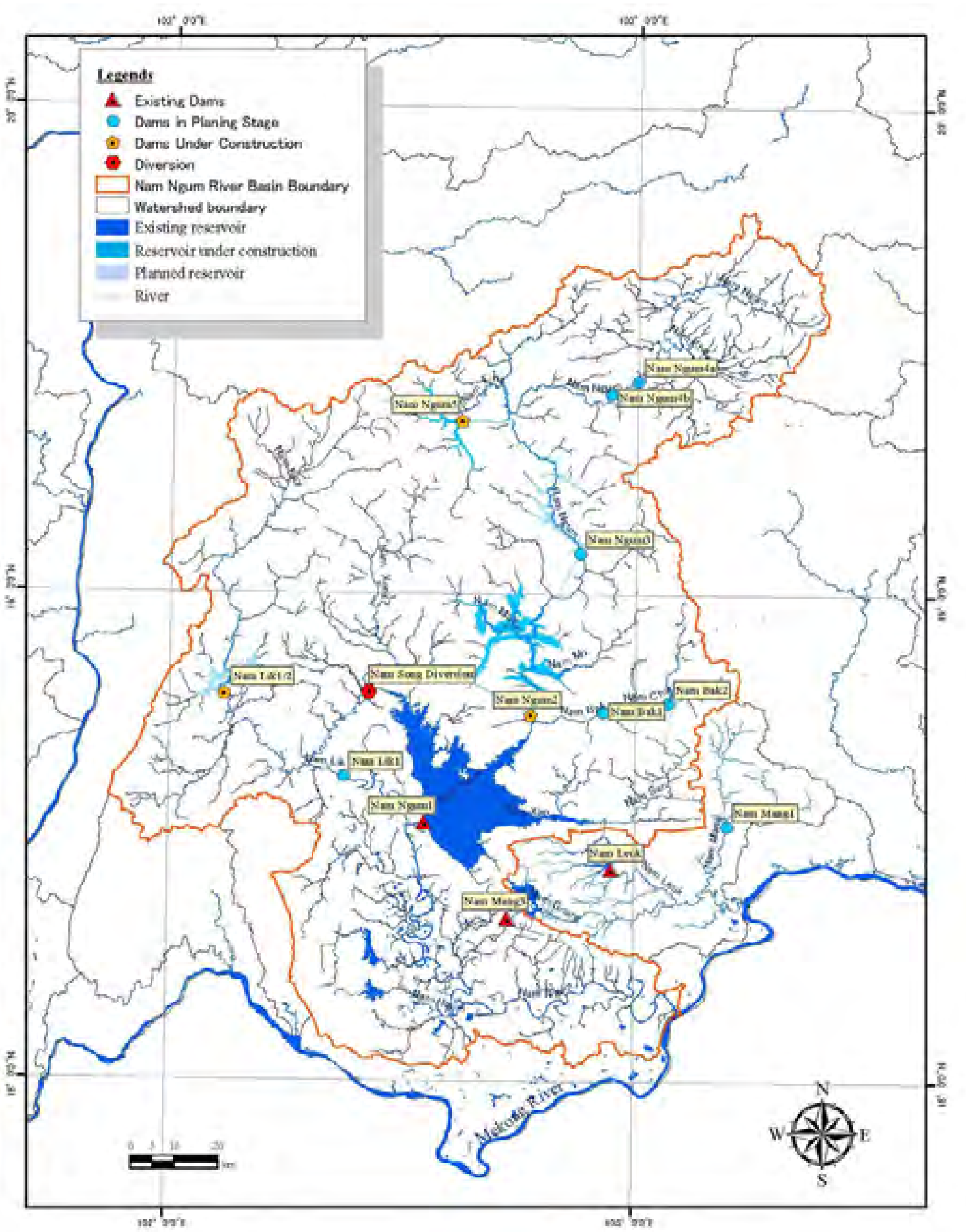


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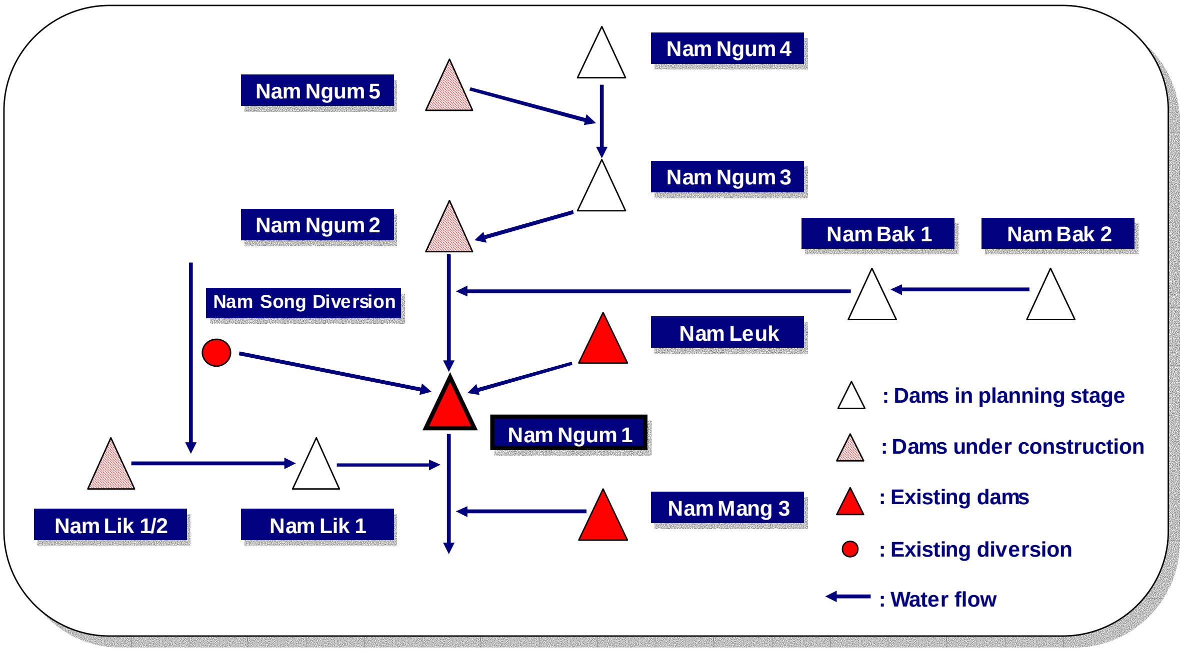
Figure 3.2.1 Location Map of Existing and Planned Hydropower Development Plan



Prepared by JICA Survey Team

Figure 3.2.2 Diagrams of Existing and Planned Hydropower Development Plan

3.2.1 HYDROPOWER DEVELOPMENT PLANS UPSTREAM OF THE NNRB

The project features of hydropower projects located in the upstream of NN1 Dam are summarized in Table 3.2.1.

Table 3.2.1 Project Features of IPP Projects Located in the Upstream of Nam Ngum 1 Dam

Items＼Project	Nam Ngum 2	Nam Ngum 3	Nam Ngum 4	Nam Ngum 5	Nam Bak 1	Nam Bak 2
Purpose	IPP (Export)	IPP (Export)	IPP (Export)	IPP (Domestic)	IPP (Export)	IPP (Domestic)
Status	Under construction	Under PPA negotiation	Pre-F/S	Under construction	Pre-F/S	Pre-F/S
Main Developer	Southeast Asia Energy Limited	GMS Power	Saigon Invest Group	NN5PC	Southeast Asia Energy Limited	Southeast Asia Energy Limited (Thailand)
Planned Commencement of Power Generation	2011 January	-	-	2011	-	2016
Principal Feature						
Catchment area (km^2)	5,640	3,888		483	597	320
Storage at FSL (MCM)	6,774	1,407		314	250	190
Average annual inflow (MCM)	6,270	3,090		719	750	400
Type of dam	CFRD	RCC		RCC	RCC	RCC
Dam Height (m)	181	220	125	99	83	85
Design flood of spillway (m^3/s)	10,855	7,900		3,231	1800	963
Powerhouse	Above ground	Underground		Semi-ground	Semi-ground	Semi-ground
Rated output (MW)	615	440	185	120	115	68
Average annual energy (GWh)	2,310	1,919	748	400	600	357

Prepared by JICA Survey Team

Regarding the hydropower projects summarized in the table above, the impact from each development plan to the NN1 Hydropower Station was studied and discussed hereunder:

(1) Nam Ngum 2 Hydropower Project

The Nam Ngum 2 (NN2) Hydropower Development Project is under construction at the upstream of the Nam Ngum 1 reservoir, aiming to commence the power generation beginning 2011. The project has a concrete-faced rockfill dam of 181 m in height. The installed capacity is 615 MW and all the generated power will be exported to Thailand on the basis of the PPA with EGAT. The catchment area of NN2 is 67% of NN1 and the effective reservoir volume is 2,994 MCM. Therefore, the inflow into NN1 reservoir after commencement of power generation of NN2 will be closely regulated throughout the year. In case of impounding in NN2 reservoir to be scheduled from April 2010 to February 2011, it should be noted that the inflow into NN1 reservoir will be decreased temporarily.

Since the completion date of NN1 expansion is expected in 2015, which will be four years later from the commencement of NN2 power generation, the NN1 expansion project was studied on the basis of inflow data in Nam Ngum 1 reservoir which will be regulated by the NN2 reservoir operation.

As the first step for reservoir operation study, the reservoir operation rule for power generation of NN1 after the commencement of power generation of NN2 Hydropower Station should be studied because the inflow condition into NN1 reservoir will be regulated drastically due to NN2. As a result, the annual power generation will increase since the reservoir water level will be kept at relatively high elevation and inefficient spillage of water from the reservoir will be lessened. Under such condition, the additional annual power generation of NN1 with the expansion was evaluated. The study results are presented in Chapter 5.

(2) Nam Ngum 3 Hydropower Project

The Nam Ngum 3 (NN3) hydropower development project is planned at the further upstream of NN2 project site and the catchment area is 69% of NN2. Although the detailed design of the project has been completed, the timing of commencement of power generation is not yet fixed because the PPA was not finalized between the developer and EGAT. The effective storage volume of NN3 reservoir is 979 MCM, which is 33% of the NN2 reservoir. It is expected that the river flow downstream of the NN3 reservoir will be regulated compared to NN3 before construction. While the degree of river flow regulation caused by NN3 is smaller than that by NN2, the future inflow into NN2 will be more stable due to the NN3 power generation.

(3) Nam Ngum 4 Hydropower Project

The Nam Ngum 4 (NN4) hydropower development is planned at still further upstream of the NN3 project site and the Pre-FS has been carried out. The project site and construction schedule have not been fixed yet. It is expected that the NN4 project will also regulate the river flow of Nam Ngum River and it will affect the future inflow into the NN3 reservoir.

(4) Nam Ngum 5 Hydropower Project

The Nam Ngum 5 (NN5) hydropower project is under construction at the Nam Ting River which is the right tributary located upstream of the NN3 project site. The RCC dam, 99 m in height, will be constructed and power generation is scheduled to start in 2011. The catchment area is 413 km^2 and the effective storage volume of the reservoir is 314 MCM. It is less than 10% of the scale of NN2 hydropower project. Although the installed capacity is 120 MW, the power output generated in the dry season is limited to 45 MW. The change of river flow pattern due to NN5 hydropower project does not seem to affect the inflow into the NN1 reservoir because of the size of reservoir of NN5 and the distance between NN5 project site and NN1 reservoir.

The NN5 hydropower project is the IPP for domestic power supply. The generated power will be supplied to the C1 and northern areas through coordination with NN1, Nam Leuk and Nam Mang 3, on the basis of the PPA with EdL.

(5) Nam Bak 1 Hydropower Project

The Nam Bak 1 (NB1) hydropower project is planned at Nam Bak River, which is the left tributary of Nam Ngum River, by the same developer of NN2. The RCC dam of 83 m in height will be constructed and the installed capacity is 115 MW. The purpose of this power generation is to export power to Thailand. It is planned to have a cascade hydropower development with the Nam Bak 2 hydropower project to be developed at the upstream of NB1.

In the NB1 hydropower project, the river flow of Nam Bak River will be diverted into Nam Ngum River just at the downstream side of NN2 power station. Since the inflow into Nam Ngum River from Nam Bak River will be regulated by the NB1 hydropower project, the total seasonal inflow into NN1 reservoir will not change drastically because of the huge inflow released from NN2.

(6) Nam Bak 2 Hydropower Project

The Nam Bak 2 (NB2) hydropower project is planned at the upstream of NB1 project site by the IPP of NN2. The RCC dam of 85 m in height will be constructed and the installed capacity is 68 MW. The generated power will be supplied to C1 and north area for domestic consumption. It is planned to have a cascade hydropower development with the Nam Bak 1 hydropower project to be developed at downstream of NB2.

The inflow into NB2 reservoir will be regulated and re-used in NB1, and finally flow into NN1 reservoir. The inflow into NN1 reservoir will not change drastically throughout the year because of the development of NB2.

3.2.2 HYDROPOWER DEVELOPMENT PLAN FOR DOMESTIC POWER SUPPLY NEAR NNRB

The project features of hydropower projects located near the Nam Ngum River Basin and related to NN1 with regards to coordination of power generation are summarized in Table 3.2.2.

Table 3.2.2 Project Feature of Hydropower Project related with Nam Ngum 1 Power Generation

Items＼Project	Nam Leuk	Nam Mang 3	Nam Lik 1/2	Nam Lik 1
Purpose	IPP (Domestic & Export)	IPP (Domestic & Export)	IPP (Domestic)	IPP (Domestic)
Status	Existing	Existing	Under construction	F/S
Main Developer	EdL	EdL	China International Water & Electric Corp.	Hydro Engineering Co.
Planed Commencement of Power Generation	2000	2004	2010	2011
Principal Feature				
Catchment area (km^2)	274	65	1,993	5,050
Storage at FSL (MCM)	154	45	1,095	61.3
Average annual inflow (MCM)	438	-	2,690	5,786
Type of dam	Rockfill	RCC	CFRD	Rockfill
Dam Height (m)	46.5	22	101.4	21
Design flood of spillway (m^3/s)	2,100	57	2,080	9,150
Powerhouse	Above ground	Above ground	Above ground	Above ground
Rated output (MW)	60	40	100	61
Average annual energy (GWh)	230	134	395	249

Prepared by JICA Survey Team

Regarding the hydropower projects which consist of two existing power plants, one project under construction, and one project in planning stage and the relation with NN1 power generation is summarized as follows:

(1) Nam Leuk Hydropower Project

Regarding the hydropower projects which consist of two existing power plants, one project under construction, and one project in planning stage and the relation with NN1 power generation is summarized as follows:

(2) Nam Leuk Hydropower Project

The Nam Leuk hydropower project is located at the Nam Leuk River which is the left tributary of Nam Mang River. The river flow of Nam Leuk River is being diverted from the upstream end of Nam Leuk reservoir to Nam San River which is located in the NNRB with a concrete dam of 46.5 m in height, which was constructed for the power generation of 60 MW, with water head of 181 m. The power generation started in 2000. Due to diversion from Nam Mang river basin to NNRB, the inflow into NN1 reservoir increased by 15 m^3/s on the average, and the annual energy generated at the NN1 Hydropower Station has also increased.

The Nam Leuk Hydropower Station is generating power to supply to the C1 and northern areas to complement with NN1 and Nam Mang 3 Hydropower Stations. The power generated at the Nam Leuk Hydropower Station is supplied to the surrounding area first and the excess electricity is supplied to the Vientiane City through the NN1 Hydropower Station.

Since the reservoir size is relatively small, the Nam Leuk hydropower station generates the power only for four hours at night peak time in dry season. In the rainy season, it generates full power with 60 MW for 24 hours.

For the Nam Leuk Hydropower Plan, the dam, hydropower station, and the 85-km transmission line were constructed through co-financing from Japanese Government and ADB, and it has contributed to the improvement of the power supply system in the C1 area.

(3) Nam Mang 3 Hydropower Project

The Nam Mang 3 (NM3) hydropower project is located at the Nam Gnong River, which is the most upstream tributary of Nam Mang River. The water of Nam Gnong River is diverted from the upstream end of Nam Mang 3 reservoir to Nam Ngum River, which is located in the downstream NNRB, with a RCC dam 22 m in height. The installed capacity is 40 MW and the power generation started in 2004. While the main purpose of this diversion scheme was hydropower generation, the released water used for the power generation is being supplied for the 2,900-ha paddy field for multipurpose water use. The Nam Mang 3 hydropower station is supplying electricity to cover the domestic power demand in cooperation with NN1 and Nam Leuk hydropower stations. The size of the reservoir is small and the power output in the dry season is limited to less than half of the installed capacity.

The Nam Mang 3 hydropower project was constructed with the assistance from Chinese funds. The civil works, electrical and mechanical works have been carried out by a Chinese contractor.

(4) Nam Lik 1/2 Hydropower Project

The Nam Lik 1/2 hydropower project is located at the Nam Lik River, which is the right tributary of Nam Ngum River. The confluence of Nam Lik River with Nam Ngum River is about 3.5 km downstream from NN1 hydropower station. The river flow will be stored with the concrete-faced rockfill dam (CFRD), 101 m in height. The hydropower station is located at the downstream of the dam and generates power of 100 MW. The Nam Lik Hydropower Station is under construction aiming to commence the power generation in the first half of 2010.

The generated power will be supplied to the domestic demand center on the basis of PPA with EdL. Since the effective reservoir volume of Nam Lik 1/2 is 1,095 MCM which is quite bigger than Nam Leuk and Nam Mang 3 Hydropower Stations, it has the possibility to be main power source for domestic power supply in the future, similar to the NN1 Hydropower Station.

The Nam Lik 1/2 project will have a big reservoir and will regulate the river flow throughout the year. Therefore, the river flow in the dry season will increase after the commencement of the power generation of Nam Lik 1/2. The released water from the Nam Lik 1/2 will merge with the Nam Song River and will finally join together with the outflow from the NN1 Hydropower Station. In this case, the study on the daily and seasonal fluctuation of water level of Nam Ngum River due to outflow from NN1 Hydropower Station, and the daily and seasonal fluctuation of river water level due to Nam Lik 1/2 were also considered. The study results of the water level fluctuation at the downstream of confluence of the Nam Ngum River and the Nam Lik River due to NN1 expansion is presented in Chapter 6.

(5) Nam Lik 1 Hydropower Project

The Nam Lik 1 hydropower project is planned as run-off river type at the downstream of the confluence of the Nam Lik River and Nam Song River. The height of concrete dam will be 21m and the generating capacity will be 61 MW. The F/S is already completed and the commencement of the power generation is planned in 2011.

The Nam Lik 1 dam will receive water from the Nam Lik River regulated at Nam Lik 1/2 reservoir and the flow from the Nam Song River. The river flow of Nam Song is being limited to small volume due to the Nam Song Diversion which diverts the river flow to NN1 reservoir since 1996.

The information on hydropower development projects in and near the NNRB is discussed above. In order to set up the condition for the study on the optimum expansion plan of NN1 Hydropower Station and development of hydropower operation policy in NNRB, the inflow to NN1 reservoir and the relationship between NN1 power generation and other power plants was considered carefully.

3.2.3 OUTLINE OF “NAM NGUM RIVER BASIN DEVELOPMENT SECTOR PROJECT”

The Nam Ngum River Basin Development Sector Project was implemented aiming to conform with the integrated water resources management plan (IWRM) of NNRB, which was co-financed by ADB and AFD.

The project consists of three components as follows:

1) Strengthening the capacity of the Water Resources Coordination Committee (WRCC)
2) Development of a river basin model for the Nam Ngum-1 reservoir to optimize power generation, mitigate floods, and improve water use efficiency in the Basin , and
3) Improvement of watershed management by strengthening the capacity of rural communities and concerned government departments.

Since the study contents of Component 2 mentioned above are related with survey contents of this preparatory survey, the JICA Survey Team obtained and studied the final report completed in March 2009.

The report for Component 2 is composed of four items as shown below:

i) Data Base and Monitoring Network

The existing meteorological and hydrological data were compiled and analyzed, and the database was made. Through the confirmation and data correction of river flow data on the basis of rainfall data, the river flow data was developed for modeling.

ii) River Basin Modeling

The hydrological analysis of NNRB, development of river basin model, hydropower development planning, and preparation of scenario for management plan were carried out. In this chapter, the rainfall-runoff analysis method by tank model is explained in detail.

iii) Reservoir Management

The versatile program “PERCIFAL” was developed by using the dynamic program for analysis of optimum reservoir management for the coordination among existing hydropower plants. A sample analysis was made using “PERCIFAL” for integrated reservoir management of NN1, Nam Leuk and Nam Mang 3, and its results were explained. Furthermore, the study on the result of reservoir operation rule curve after the commencement of NN2 power generation was recommended.

The power generation loss of NN1 due to impounding of the NN2 reservoir and power generation benefit of NN1 after starting the normal reservoir operation of NN2 was also explained. There is no mention about the expansion plan of NN1 Hydropower Station.

iv) Capacity Building

Capacity building was carried out through the three steps mentioned above. A users’ training program for the rainfall-runoff model “MORDOR” and versatile program “PERCIFAL” for optimum reservoir management was held for staff of DOE and EdL, including those from the NN1 Hydropower Station.

As the results of confirmation of the final report of「Nam Ngum River Basin Development Sector Project, the possibility of the analysis for optimum reservoir management by PERCIFAL is explained. However, the concrete proposal for the optimum reservoir management in the future is not mentioned. Therefore, the JICA Survey Team carried out the “NN1 Reservoir Management Plan” and “Optimum Reservoir Management Plan of the NNRB” by using the original program developed in this preparatory survey.

CHAPTER 4 PURPOSE AND OPERATION POLICY OF EXPANSION OF NAM NGUM 1 HYDROPOWER STATION

4.1 CIRCUMSTANCES OF THE NN1 HYDROPOWER STATION

4.1.1 GROWTH OF NIGHT PEAK POWER IN DAILY LOAD

As shown in Figures 2.4.3 and 2.4.5, the recent increase in the night peak demand is growing every month. During weekdays, peak power is drastically increasing not only at night time but also in the daytime, with the latter reaching the night time peak demand. The future demand projection presented in Section 2.3 presumes that this tendency will last for the time being.

There is a risk that some power supply restriction or power outage is forced for Lao PDR due to reasons of power exporting country such as accident in the country. Accordingly, in terms of enhancing power security, it is expected that EdL would supply as much possible power required in Lao PDR from their power stations. It is expected that NN1 will assume the role of supplying the power to cover the peak demand on a priority basis.

4.1.2 EFFECT ON RIVER FLOW CONDITION DUE TO HYDROPOWER DEVELOPMENT IN UPSTREAM NNRB

The NN1 Hydropower Station generates power since 1971. The annual energy production was increased by additional inflows into NN1 reservoir which consist of Nam Song Diversion in 1996 and implementation of Nam Leuk Hydropower Project in 2000. Although there is some variation between wet and drought years, the annual power generation has increased gradually. In addition, several hydropower development plans with dam construction are in progress and as first one of these plans, the Nam Ngum 2 Hydropower Project will commence power generation for export to Thailand in 2011. As mentioned in the previous Chapter, the inflow into NN1 reservoir will be regulated throughout the year due to storage function of NN2 reservoir. As a result, power generation of NN1 Hydropower Station at a relatively higher reservoir water level will be possible and the inefficient water release through the spillway will be decreased. The annual power generation is expected to increase by 6 % on the average.

Considering such inflow condition after 2011, the NN1 Hydropower Station is being planned to be expanded aiming at a more efficient water usage. In this expansion, the new rule curve for the reservoir operation with additional power generation facilities will be studied to seek the effective use of river water.

For the time being, the NN1 Hydropower Station is affected by the commencement of the power generation of NN2. After that, the Nam Ngum 5, Nam Ngum 3 and Nam Ngum 4 are scheduled to be developed in the near future and the total storage function of the upstream area of NNRB will be enhanced. This means that the power generation capacity of NNRB will increase efficiently and it will contribute to the expansion of the power generation capacity in Laos.

In this preparatory survey, the Survey Team confirmed the study concept of the prior implemented "Nam Ngum River Basin Development Sector Project" (NNRBDSP) funded by ADB and AFD, and selected the optimum expansion plan through the effective utilization of data collected from the NNRBDSP.

4.1.3 AGING OF EXISTING POWER GENERATION FACILITIES AND MAINTENANCE SCHEDULE

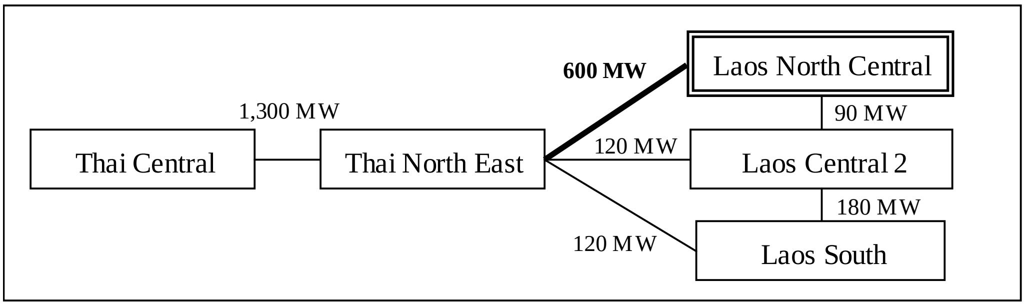
The purpose of the expansion of NN1 is to provide adequate power supply during night peak demand of the future daily load curve by shifting the power generation pattern from off-peak time to peak time. On the other hand, the increase of annual power generation due to the relatively high reservoir water level and improved efficiency of water release through spillway is realized by commencement of the power generation of NN2 in 2011, and it may be considered as benefit from NN2 project. For the expansion of NN1 Hydropower Station in 2015, the same kind of benefit can be counted.

However, the increase of annual power generation due to regulated inflow into the NN1 reservoir from NN2 means that the operation ratio of power generation facilities increases throughout the year. As a result, the time period allocated for the yearly maintenance, which is carried out during the dry season at present will be shortened. According to the information from the staff of the NN1 Hydropower Station, it is necessary to ensure sufficient period for adequate maintenance of NN1 power generation facilities, which are very important infrastructure in Laos.

The Survey Team will therefore evaluate the indirect benefits such as decrease of frequency of repairs and reduction in maintenance cost of the power generation facilities in the future.

4.1.4 TRANSMISSION INTERCHANGING CAPACITY WITH NEIGHBORING COUNTRY

Based on the present power development plan, transmission interchanging capacity as of 2016 is shown in Figure 4.1.1. At present, the capacity for power interchange is limited to 100 MW, but in 2016, the total capacity of power interchange is expected to become about 600 MW in the northern and C1 areas. At the same time, interchanging capacity between the C1 and C2 areas will be about 90 MW. It is important for NN1 to supply the generated power at a possible high price. Furthermore, it is necessary to grasp the future transmission network configuration because the development progress will highly affect the economical efficiency of power supply and demand analysis.



Source: The Study on Power Network System Plan in Lao People's Democratic Republic

Figure 4.1.1 Power Interchange in 2016

4.2 PRINCIPLE FOR THE OPERATION OF NN1

4.2.1 GENERAL

The top priority expected for NN1 operation will be given to satisfy the domestic power demand of the northern and C1 areas. Given that the transmission network of the C1 area will be connected to the C2 area in the future, it is expected that the power supply for C2 area will likewise be covered.

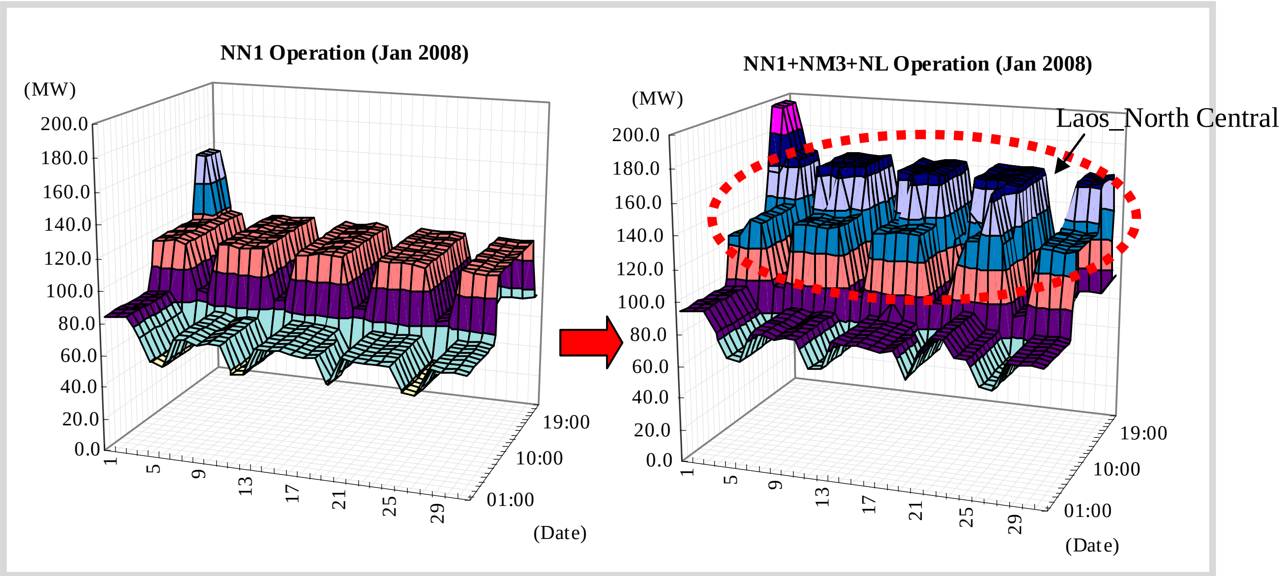
Moreover, one of the prerequisites for the operational policy of the expanded NN1 in the future is to maintain its function as the important power station for the power supply to the capital area with sufficient reliability. On the other hand, the maximization of economic benefits should be sought in drawing up the operation plan.

At present, the operation plan of NN1 is made for two patterns: one for weekdays and the other for holidays, referring to the latest recorded load pattern. The projection of operational patterns for weekday and holiday cases are often referred to the recorded load of the previous weeks.

In drawing up the operational plan, power generation for night peak should be the first priority and daytime peak and off-peak should be the second priority and the third priority, respectively. The plan should be based on the Rule Curve determined by the available volume of water. This methodology to be applied is reasonable in terms of the present tariff rates of import and export, but it is necessary to review the operation plan according to the revision of the conditions based on the PPA, which will be revised in the future.

4.2.2 PRESENT OPERATION PATTERN

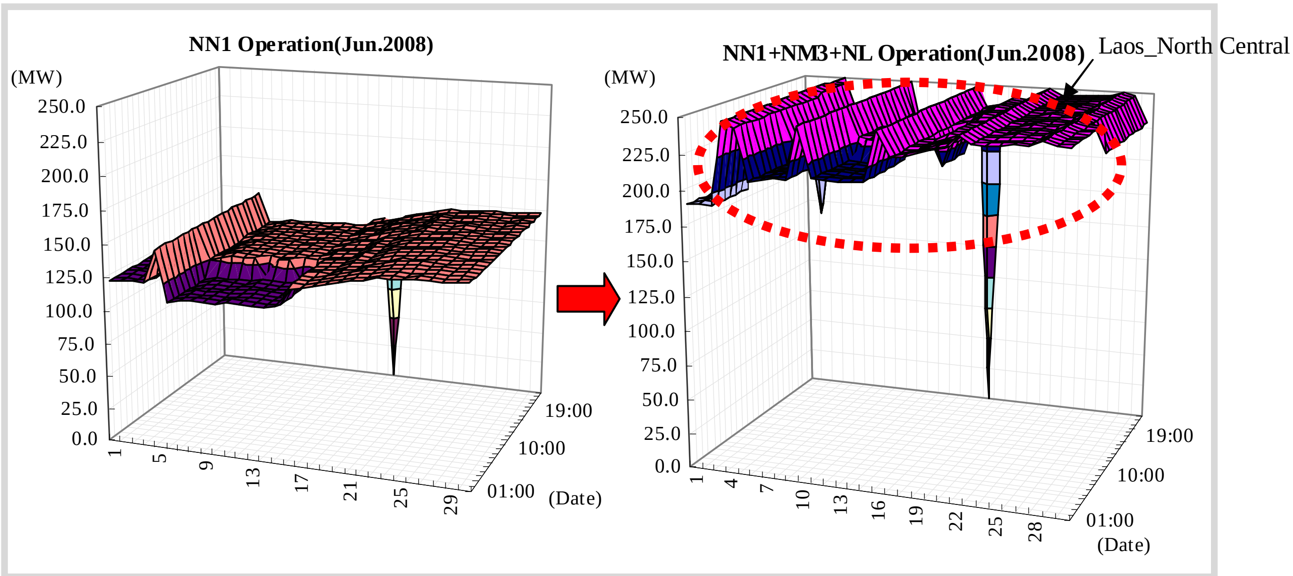
The lower right figure shows operation records of NN1 Power Station, NM3 and NL, and the lower left figure shows an operation record of the independent NN1. The right figure indicates an additional output from NM3 and NL. NN1 follows the TOU (Time of Use) operation, which is separated into two ranges of off-peak and peak, based on the PPA with EGAT. The shortage of power is expected to be supplemented by NM3 and NL, but the power stations only have small capacity of reservoirs. Even with the addition of the NM3 and NL power generation in the dry season, the power supply of the three main power stations cannot meet all the power demand requirements.



Prepared by the JICA Survey Team

Figure 4.2.1 Operation Records in Jan.2008

The figure below shows the operation records of NN1, NM3 and NL as of June 2008. In the rainy season, it was found out that NN1 is operated to its maximum capacity, determined by the volume of available water irrespective of the off-peak and peak time ranges. Similarly, NM3 and NL have been operated at maximum capacity level following the available volume of water for generation. During the rainy season, the surplus power generated can be exported.



Prepared by the JICA Survey Team

Figure 4.2.2 Operation Records in June.2008

4.2.3 STUDY OF OPERATION PATTERN IN 2015

For the graph of the daily load curve demonstrated before, an available volume of water necessary for the output of 40MW of the candidate capacity has been allocated according to the order of the supply priority for the night and daytime peaks, so as to maximize the economic benefits while maintaining the minimum water level in the downstream. As a result, the figures below can be demonstrated to the projected daily load curve for the assumed operation pattern. The pink line shows the assumed operation pattern for 40 MW that has been regarded as the most feasible case in the selection of expansion capacity. In 2015, regardless of the rainy and dry seasons, the supply capacity cannot satisfy the total annual demand requirements. In this situation, given that economic benefit is taken, it is prerequisite to operate generators based on the import tariff with EGAT.

- Operation pattern in order to catch up with the peak demand in the peak time wherever possible.
- Operation pattern so as to increase the generated power output in off-peak time as well as in peak time. The pattern suppresses the peak imported power of the month that records the highest power consumption assumed in the dry season in order to reduce the excess charge in the status of imports over exports.

As of 2015, it can be assumed that all power stations situated in the C1 and northern areas other than NN1 could be operated as power stations for base load. Therefore, the following operation pattern can be suggested as the most appropriate operation.

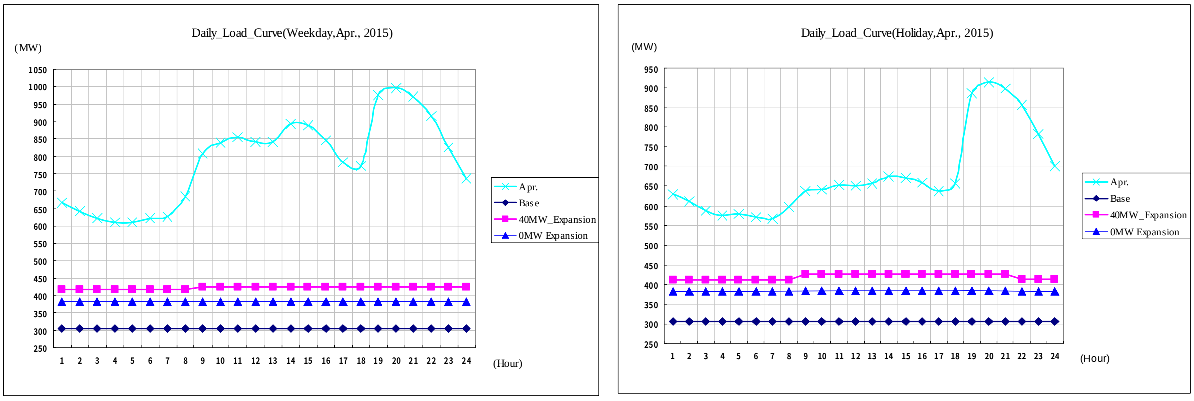


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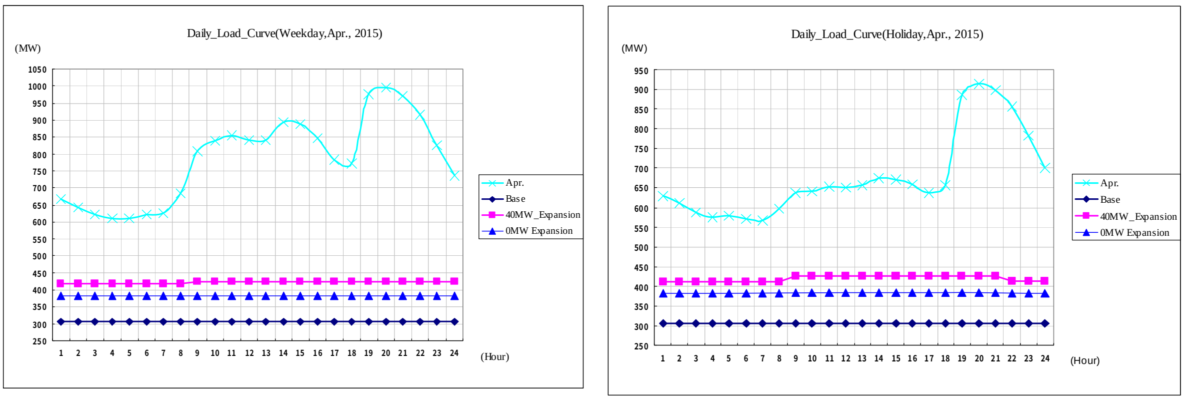
Figure 4.2.3 Expected Operation Pattern in Apr.2015



Prepared by the JICA Survey Team

Figure 4.2.4 Expected Operation Pattern in Sep.2015

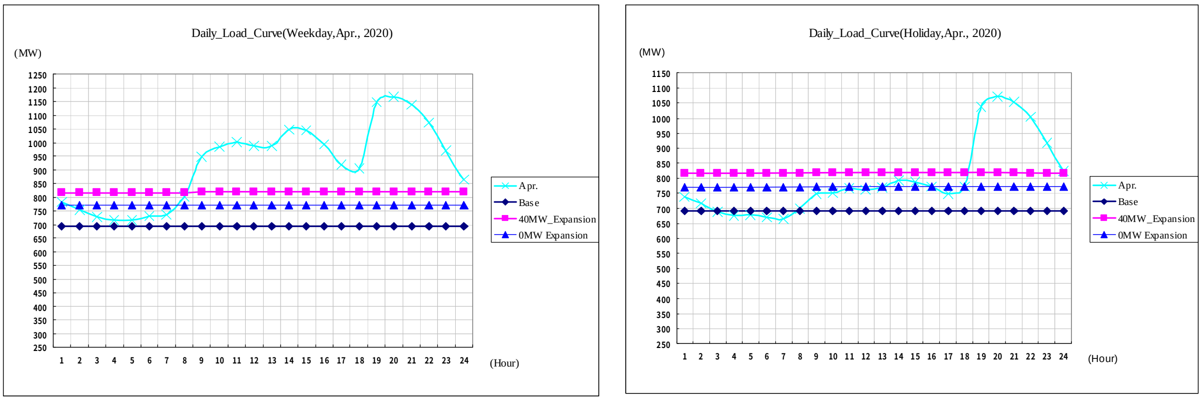
4.2.4 STUDY OF OPERATION PATTERN IN 2020

Figure 4.2.5 and Figure 4.2.6 demonstrate operation patterns for the assumed daily load curve in 2020.

The same method as that of 2015 has been applied for 2020 for the projection of the curve, and the power stations other than NN1 are assumed as power stations for the base load in this stage of the survey.

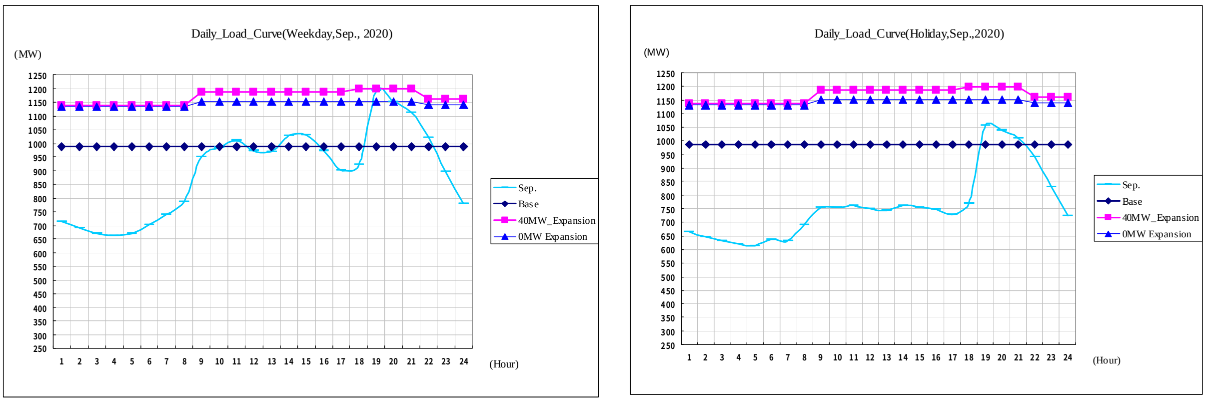
In the dry season, the generated available output is not expected to meet the peak power. On the other hand, in the off-peak time of the season, there could be some surplus power supply for export..

It is suggested that minimizing volume of the import rather than supplying the power for export in off-peak time can make a greater economic benefit. Basically, surplus electric power in the off-peak time should be supplied to the C2 area within a capacity of at least 90MW as much as possible. In addition, in order to know the comprehensive operational patterns in the whole area, it is important to know the patterns, taking into account the flexibility of the output in the operation of relatively large-sized power stations such as Nam Man 3 and Nam Leuk, along with Nam Ngum 1 for both dry and rainy seasons.



Prepared by the JICA Survey Team

Figure 4.2.5 Expected Operation Pattern in Apr.2020



Prepared by the JICA Survey Team

Figure 4.2.6 Expected Operation Pattern in Sep.2020

4.2.5 STUDY OF OPERATION PATTERN IN 2025

As of 2025, the power demand from the year 2020 is assumed to be drastically increasing. Especially in the dry season, power supply capacity will have difficulties in satisfying the power demand requirements. On the other hand, in the rainy season, except for night peak time, the supply capacity can satisfy the demand for its service area. In the present network plan in Lao PDR, part of the power supply surplus generated in off-peak time can be allocated for the supply to the C2 area within a network capacity of 90MW. However, most of the generated power in off-peak time will be allocated for export. In terms of the capacity of the network and power interchange tariff with EGAT, the generated power in off-peak time should be shifted to night peak time, given that the agreement with EGAT is continuously applied in accordance with the present PPA. However, in 2025, the network capacity in the C2 area is expected to be strengthened by developing transmission line network across Lao PDR. Essentially, most of the surplus power generated in off-peak time is expected to be supplied for adjacent areas, including C2.

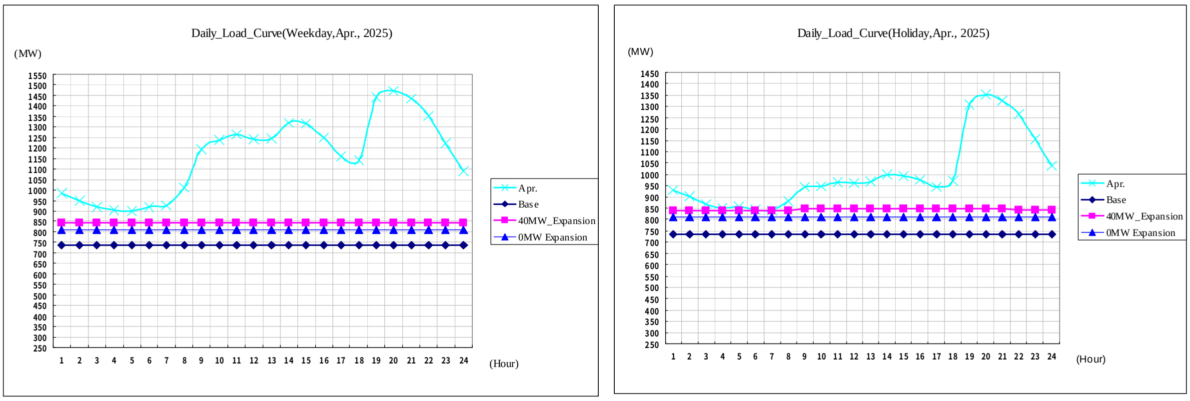


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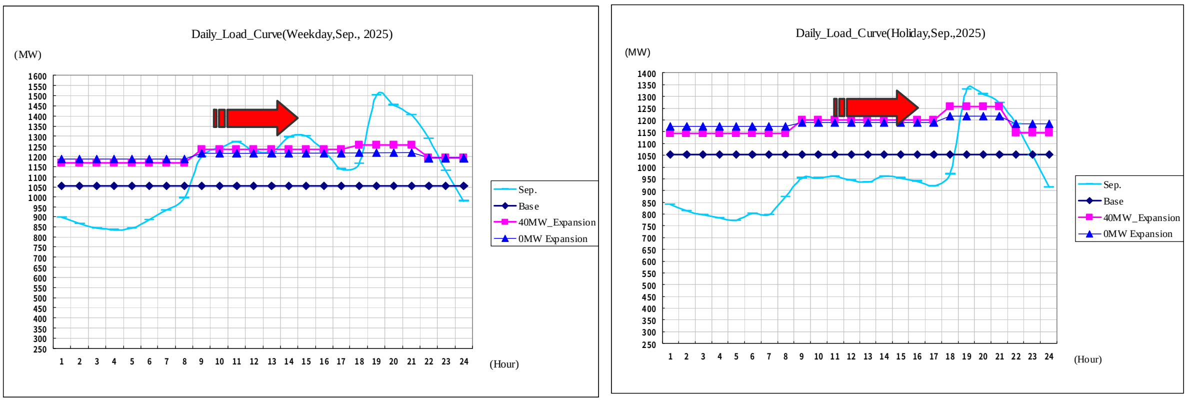
Figure 4.2.7 Expected Operation Pattern in Apr.2025



Prepared by JICA Survey Team

Figure 4.2.8 Expected Operation Pattern in Sep.2025

4.3 POLICY OF POWER TRANSMISSION

4.3.1 SYSTEM CONFIGURATION AROUND NAM NGUM 1 HYDROPOWER STATION

(1) Current Situation of System around Nam Ngum 1 Hydropower Station

As shown in Figure 4.3.1, five circuits of 115 kV transmission lines are connected at Nam Ngum 1 Hydropower Station as of 2009. Four circuits of the above lines are connected as power supply line to the Vientiane Municipality, including the C1 area. Another single circuit is the interconnection line between Nam Ngum 1 Hydropower Station and Nam Leuk. In case either one of the generators of the two power stations becomes in faulty condition, this interconnection line will be operated in order to make up for the power supply, which shall be generated by the fault power station. Two circuits of the four circuits that supply to Vientiane Municipality are connected to Naxaythong S/S which is located about 61km from Nam Ngum 1 P/S, and supply power to Phontong S/S in Vientiane via Naxaythong S/S. The other two circuits are connected to Thalat S/S which is located about 5 km from Nam Ngum 1 P/S and also supply power to Phontong S/S via Phon Soung S/S. Phontong S/S and Thanaleng S/S are interconnected with the system of EGAT. Surplus power supply of Phontong S/S and Thanaleng S/S are exported to Thailand through the interconnection line of EGAT.

A single circuit of 115 kV transmission line located at Thalat S/S is achieved to Luang Prabang S/S over 212 km via Vangvieng substation. The line located at the Xieng Ngen switching yard is connected to the Xayaboury substation. The other single circuit line located at the Thalat substation is connected to the Non Hai substation via the Ban Dong substation.

Source: System Planning Office, EdL

Figure 4.3.1 System Configuration of C1 Area, Vientiane Municipality, 2009

(2) System Configuration around Nam Ngum 1 Hydropower Station after Expansion

The system configuration in 2016 around Nam Ngum 1 P/S after the completion of the expansion of Nam Ngum 1 Hydropower Station is shown in Figure 4.3.2.

Source: System Planning Office, EdL

Figure 4.3.2 System Configuration of C1 Area, Vientiane Municipality, 2016

The system configuration of the 115 kV transmission line around Nam Ngum 1 P/S will not be changed in 2016, and there is no plan for the additional transmission line from Nam Ngum P/S to the Vientiane Municipality. Generated power supply of Nam Lik 1/2 will be supplied to Vientiane Municipality by a 230 kV transmission line, which will be constructed from Hin Heup S/S to Naxaythong S/S by 2011. Surplus power of Nam Leuk P/S and Nam Mang 3 P/S will be supplied from C1 Area to C2 Area by 115 kV transmission line which will be connected from Pakxan S/S to Pakbo S/S via Thakek S/S.

Although Thalat S/S is presently supplying the power to Vanvieng S/S and Ban Don S/S, all power supplied from Nam Ngum 1 to Thalat S/S will be supplied to Vientiane in 2016, since the hydropower station will be actively constructed in the northern area.

4.3.2 FUNDAMENTAL TECHNICAL CRITERIA AND STUDY CONDITIONS

Basically, the power system of EdL is to be planned so as to maintain appropriate system voltage and fault current level, without causing power outage for Laos' domestic power demand. EdL's technical criteria for power system planning are described below.

(1) Power Flow

1) Under normal operation, loads of transmission lines and transformers shall be within their rated capacities.

2) In case of a single circuit fault for the section with more than double circuits, the power flow

of the remaining facilities shall be within the rated capacities.

3) Power transmission from the generators with single circuit transmission line is allowed when the generator rejection is not significant in case of a single circuit fault.

4) In case of a single fault of a 115/22 kV transformer, the loads of the remaining transformers shall be within 110% of the rated capacities.

5) In case of a single fault of a 230/115 kV transformer, the loads of the remaining transformers shall be within the rated capacities after reducing the power export to Thailand by restricting the specified power outputs of generators.

(2) System Voltage

1) Under normal operation condition, the bus voltage in the transmission system shall be within the range from 95% to 105% of the nominal voltage. In case of a single contingency, bus voltage shall be within the range from 92% to 108% of the nominal voltage.

2) The power factors of the generators shall be within the range from 90% (leading) to 85% (lagging).

(3) Fault Current

Based on system planning standard of EdL, the fault current of the transmission system shall not exceed the maximum fault current shown in Table 4.3.1.

Table 4.3.1 Allowable Maximum fault Current

Voltage Level	Maximum Fault Current
230 kV	40～50 kA
115 kV	25～31.5 kA
22 kV	25～31.5 kA

Prepared by JICA Survey Team

(4) Stability

1) Power system stability shall be maintained without restricting the generation output of the principal power plants or interrupting the power supply during operation. In the case of a permanent three-phase short circuit fault, after clearing the fault by main protection relays, do not consider any reclosing operations.

2) Fault clearing times by main protection relays are shown in Table 4.3.2.

Table 4.3.2 Fault Clearing Times by Main Protection Relays

Voltage Level	Maximum Fault Current
230 kV	100 ms
115 kV	140 ms

Prepared by JICA Survey Team

(5) Transmission Line and Main Bus of Substations

The allowable current carrying capacity of the transmission line and the main bus of substations and the transmission capacity of transmission lines in case of normal conditions and N-1 contingency are shown in Table 4.3.3. In addition, the temperature within the ( ) indicates the allowable maximum temperature rise of conductors.

Table 4.3.3 Allowable Current and Transmission Capacity of Standard Conductors

Location	Conductor	Normal Condition (80)		N-1 Contingency (90)	
		A	MVA	A	MVA
Transmission Line	ACSR240	480	96	590	120
Main Bus of Substations	ACSR240			590	120
	ACSR300x2			1394	278
	HDCC325			875	174
	HDCC400			950	189

Prepared by JICA Survey Team

(6) Substations

PSS/E data of the power system for 2009 to 2016 were provided by EdL. For newly planned substations which were not considered in the PDP 2007-2016, the following conditions are assumed.

1) As a 230 kV bus configuration, one-and-one half (1+1/2) method is basically applied. Application of double bus arrangement is also considered by role of each substation.

2) 115/22 kV Transformers

a) 30 MVA by one transformer, 3 banks in maximum in a substation

b) Maximum load target is 60 MVA, and surplus power is secured.

3) 230/115 kV Transformers

a) The capacities of primary and secondary sides are determined with the predicted power flow.

b) The voltage of 22 kV and the delta winding are applied to the tertiary sides. The capacity of the tertiary side is basically 30% that of primary and secondary sides.

c) On-load tap changers are applied.

4) Standard Impedance

The impedances of power supply transformers are as shown in Table 4.3.4.

Table 4.3.4 Standard Impedance

Voltage	Impedance between Primary and Secondary Sides
230/115kV	12.0%
115/22kV	8.5%

Prepared by JICA Survey Team