No.

Ministry of Energy and Mines
Electricite du Laos
EDL-Generation Public Company
Lao People's Democratic Republic

LAO PEOPLE’S DEMOCRATIC REPUBLIC

STUDY ON

POWER SUPPLY AND DEMAND IN CENTRAL REGION IN

LAO PEOPLE’S DEMOCRATIC REPUBLIC

FINAL REPORT

SUMMARY

AUGUST 2012

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

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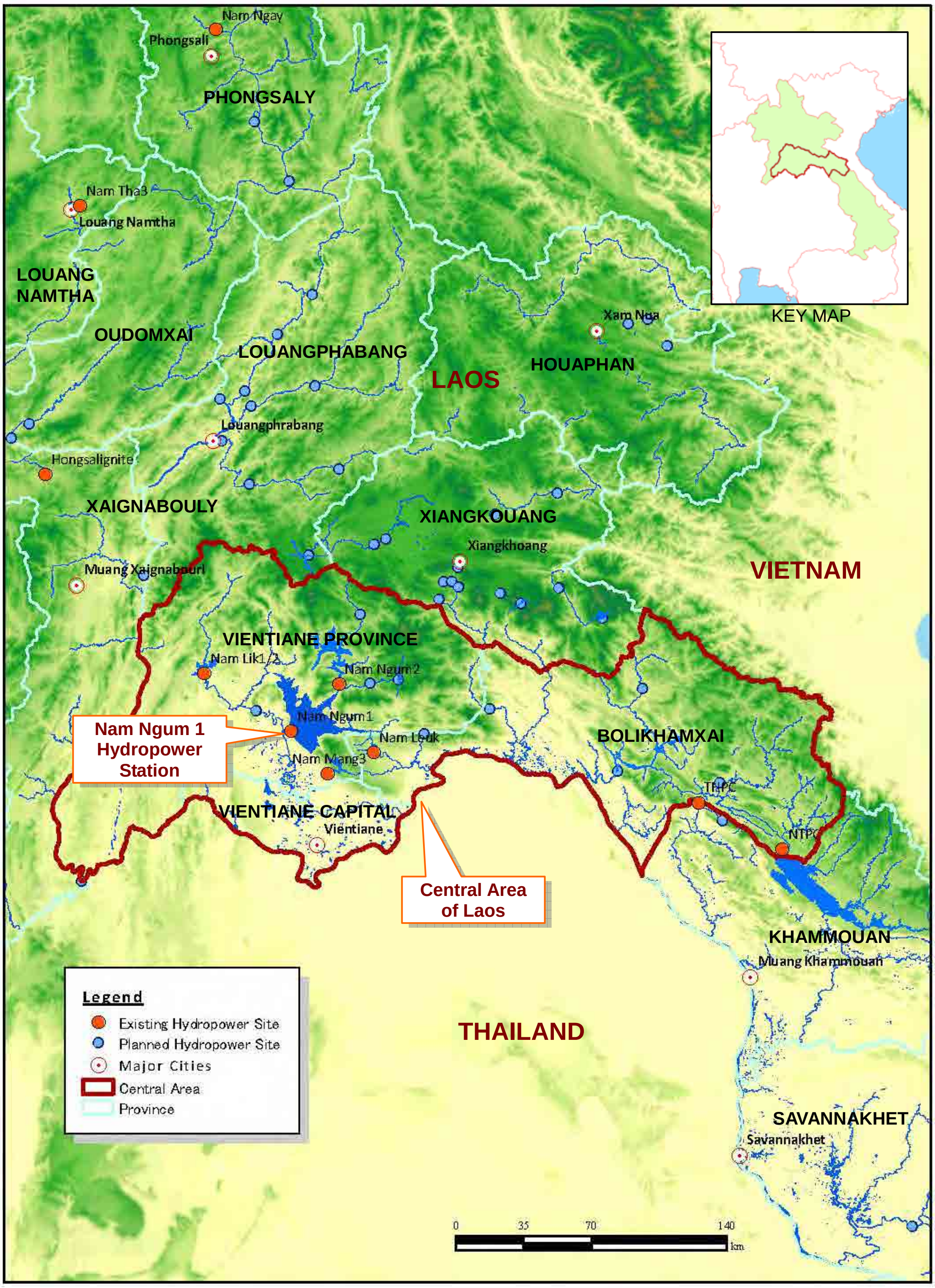

Prepared by the Study Team

Location Map of the Study Area

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Abbreviations

Terms	
Abbreviations	**English**
Lao PDR agencies	
DMH	Department of Meteorology and Hydrology
CDEP	Committee for Development of Electric Power
CPC	Committee for Planning and Cooperation
DEB	Department of Energy Business, MEM
DEPP	Department of Energy Policy and Planning, MEM
DEM	Department of Energy Management, MEM
DOE	Former Department of Electricity, MEM
EDL	Electricite du Laos
EDL-Gen	EDL-Generation Public Company
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
MONRE	Ministry of Natural Resources and Environment
STEA	Science, Technology & Environment Agency
WREA	Water Resources and Environment Agency
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	
AAU	Assigned Amount Unit
B.	"Ban" Village in Laotian language
BOT	Built-Operate-Transfer
CA	Concession Agreement
CDM	Clean Development Mecah
CER	Certified Emission reduction
COD	Commercial Operation Date
ECA	Export Credit Agencies
EIA	Environmental Impact Assessment
EMMP	Environmental Management & Monitoring Plan
EPC	Engineering, Procurement and Construction
EPMs	Environmental Protection Measures
ERU	Emission Reduction Unit
ET	Emission Trading
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
IOD	Initial Operation Day
IPDP	Indigenous Peoples Development Plan
IPP	Independent Power Producer
IPP(d)	Independent Power Producer for domestic power supply

Terms	
Abbreviations	**English**
IPP(e)	Independent Power Producer for exporting electricity
IWRM	Integrated Water Resources Management
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
NNRB	Nam Ngum River Basin
O&M	Operation and Maintenance
ODA	Official Development Assistance
PDA	Project Development Agreement
PDP	Power Development Plan
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	
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

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Increasing Power Demand in Lao PDR

In Lao People's Democratic Republic (PDR), the domestic power load and energy demand from 2001 to 2010 rapidly increased from 13.4% to 15.0%, respectively. This increase in electricity demand is mainly due to the increase in electrification rate of households, which is directed through the Lao government's electricity policy. Other factors such as construction of a speed railway and development of copper or bauxite mining are also the driving forces that increase total electricity demand. This increasing trend in electricity demand is expected to continue.

Electric Power Policy and Hydropower Development Plan

In August 2010, the Power Development Plan (PDP), with an objective year from 2010 to 2020 was formulated to achieve the target to secure social development through power supply and acquisition of foreign exchange by the power export. After the formulation of the PDP, it is recognized that PDP should be updated with the updated power demand forecast, and the PDP was updated in August 2011 by the study done among relevant authorities. The updated version of PDP is called PDP 2010-2010 (Revision-1). In the updated PDP, the revision of the demand forecast was made for the electricity demand of the speed railway construction and operation, and mining development in the southern area of the country.

Nam Ngum 1 Hydropower Expansion Plan

The NN1 hydropower station Expansion was studied in the preparatory survey on the Nam Ngum 1 hydropower station expansion by JICA in 2009. The survey studied to add 40MW turbine and generator beside the existing power house, and a final report was submitted in January 2010. The purpose of the expansion is to increase the power output during night peak hours from 6:00 p.m. to 10:00 p.m. by allocating reservoir water from off-peak hours to peak hours to meet the increased power demand. The survey showed that the expansion of the power plant enables to decrease the import of power import during peak hours. It also increases the annual energy by reducing spill-out during rainy season. The survey considers the inflow regime changes due to the

Photo taken by the Study Team
Nam Ngum 1 Hydropower Station (2012)

storage effect of the Nam Ngum 2 (NN2) hydropower that aims to export power to Thailand.

Two years have passed since the report was submitted and it was understood that the external conditions have been changed since the preparatory survey. The changes in external conditions include a large modification in power demand forecast, modification in power development plan, modification in transmission line network development plan, changes in electricity tariff, power exchange condition with EGAT, and foreseen yen loan interest rate. In this line, it is necessary to confirm the necessity of NN1 expansion plan along the changes in the external conditions.

1.2 OBJECTIVES OF THE STUDY

The objectives of the Study are: to review the power supply and demand balance in the central area of Lao PDR, to clarify the issues which impede supply for the peak load demand in the central area, and to identify optimum countermeasures which includes the expansion of the NN1 hydropower station to meet the peak load demand. The expansion scale of NN1 hydropower station is presumed to 40MW.

1.3 STUDY AREA

The study area is the central area of Lao PDR (Vientiane Capital, Vientiane and Bolikhamxai Province). The northern area and neighboring country (such as Thailand) is included, if necessary.

1.4 COUNTERPART OF THE STUDY

The main counterpart of the preparatory survey is the EDL and the EDL-Generation Public Company (EDL-Gen), with technical support of MEM. The NN1 hydropower station is under the control of EDL-Gen. If necessary, the Study Team will collect information from hydropower IPPs such as NN2 hydropower and Nam Lik 1/2 hydropower.

1.5 TEAM MEMBERS

In order to assess the various work items such as detailed study of power supply and demand, or re-evaluation of NN1 expansion project, the Study Team was organized with the corresponding members as shown in Table 1.1.1 below.

Table 1.1.1 Study Team Staff Composition

No.	Name	Position/Field of Expertise
1	Sohei UEMATSU	Team Leader/Hydrology and Basin Network Operation
2	Masahiro IWABUCHI	Power Supply and Demand Analysis/Power System Analysis
3	Yusaku MAKITA	Economic and Financial Analysis
4	Mayumi GOTO	Environmental and Social Consideration

Prepared by the Study Team

CHAPTER 2 PRESENT SITUATION OF THE POWER SECTOR IN LAO PDR

2.1 OUTLINE OF POWER SECTOR IN LAO PDR

General Structure of Power Sector in Lao PDR

The Ministry of Energy and Mines (MEM) is a regulatory ministry for the electric power and mining sectors in Lao PDR. The Electricite du Laos (EDL) is a national power entity under MEM which is responsible for the transmission and distribution of electricity assets in Lao PDR. EDL manages electricity imports into its grids and exports from its power stations. The EDL Generation Public Company (EDL-Gen) is a public company responsible for the power generation of previous EDL-owned power stations.

The Department of Electricity (DOE) was established by the Ministry of Industry and Handicraft (MIH) in 1994. The DOE was responsible for the management and planning for the electric power sector, managing the strategy, policies and legal framework of its electricity and power development plans. In 2006, the department was transferred to MEM which was established as a ministry for the mining and energy industry in 2006. In 2012, the organization of MEM was reformed and DOE was divided into two departments and one institute.

Organization of the Ministry of Energy and Mines

In 2012, Department of Electricity (DOE) in MEM was reorganized into two departments and one institute namely the Department of Energy Policy and Planning (DEPP), the Department of Energy Management (DEM) and the Institute of Renewable Energy Promotion. Among these departments, DEPP is placed as the center of energy-related policy making. Other than former DOE departments, MEM is composed of the Department of Energy Business (DEB), the Cabinet Office, the Inspection Department and the Personnel Departments. DEB was previously named “Department of Energy Promotion and Development” and this department is a regulatory authority to manage IPP project development and examining proposed projects.

Present Status and Organization of EDL

EDL was established in 1959 as an electricity department of the Ministry of Public Utilities. EDL was then incorporated as a public service corporation in 1997. According to the directives of the Government of Lao for its business restructuring on electricity industries in Lao PDR, the generation section was separated into the EDL-Gen in 2011. Therefore, EDL is in charge of electrical transmissions in the national level as well as the design, construction, operation/ management of power distribution equipment, and managing importing and exporting power with neighboring countries. EDL implements power development projects, including large-scale hydroelectric projects for domestic power supply. The developed power plants are to be transferred to EDL-Gen for operation and maintenance.

Present Status and Organization of EDL-Gen

EDL-Generation Public Company (EDL-Gen) was established on the 15th of December 2010 as the first publicly-held enterprise in Lao PDL listed on the Lao Securities Exchange (LSX). At present, the EDL-Gen is in charge of the operation and maintenance of existing hydroelectric power stations which includes Nam Ngum 1, Nam Leuk, Xeset 1, Xeset 2, Selabam and Nam Dong.

2.2 CURRENT OPERATION PATTERN OF EXISTING POWER STATIONS

General

Currently, there are 16 small to large scale hydropower stations in operation. Among these hydropower stations, nine hydropower stations are owned by EDL. The existing hydropower stations in Lao PDR are shown in Table 2.2.1.

Table 2.2.1 Existing Power Plants in Lao PDR

No.	Power Plant	Province	Installation Cap. (MW)	Comercial Operation Date	Owner-ships (Note*)	Market	Remarks
1	Nam Dong	Luangprabang	1	1970	EdL	Laos	
2	Selabam	Champasak	5	1970	EdL	Laos	
3	Nam Ngum 1	Vientiane	155	1971	EdL	Laos/ Thailand	
4	Xeset 1	Saravane	45	1990	EdL	Laos/ Thailand	
5	Nam Ko	Oudomxay	1.5	1996	EdL	Laos	
6	Theun-Hinboun	Bolikhamxay	210	1998	IPP(e)	Laos/ Thailand	
7	Houay Ho	Champasak/ Attapeu	152.1	1999	IPP(e)	Laos/ Thailand	150MW (Export) and 2.1MW (Domestic)
8	Nam Leuk	Vientiane	60	2000	EdL	Laos/ Thailand	
9	Nam Ngay	Phongsaly	1.2	2003	EdL	Laos	
10	Nam Mang 3	Vientiane	40	2004	EdL	Laos/ Thailand	
11	Xeset 2	Saravane	76	2009	EdL	Laos	
12	Nam Theun 2	Khammuane	1088	2009	IPP(e)	Laos/ Thailand	Off take 75 MW (Domestic)
13	Nam Ngum 2		615	2011	IPP(e)	Thailand	
14	Nam Lik 1/2		100	2010	IPP(d)	Laos	
15	Nam Tha 3	Luangnamtha	1.25	2011	IPP(d)	Laos	
16	Nam Nhon	Borkeo	3	2011	IPP(d)	Laos	
	Micro-hydro		0.15	2011	EDL	Laos	
	Micro-hydro		1.178	2010	Prov.	Laos	
	Solar		0.474	2011	Prov.	Laos	
	Diesel		1.513	2011	Prov.	Laos	
Total			**2557.4**				
EdL			**384.85**				
IPP(d)			**104.25**				
IPP(e)			**2065.1**				
Prov.			**3.17**				

EdL: Electricité du Laos (EdL)
IPP: Independent Power Producer
IPP(e): Exporting IPP
IPP(d): Domestic IPP

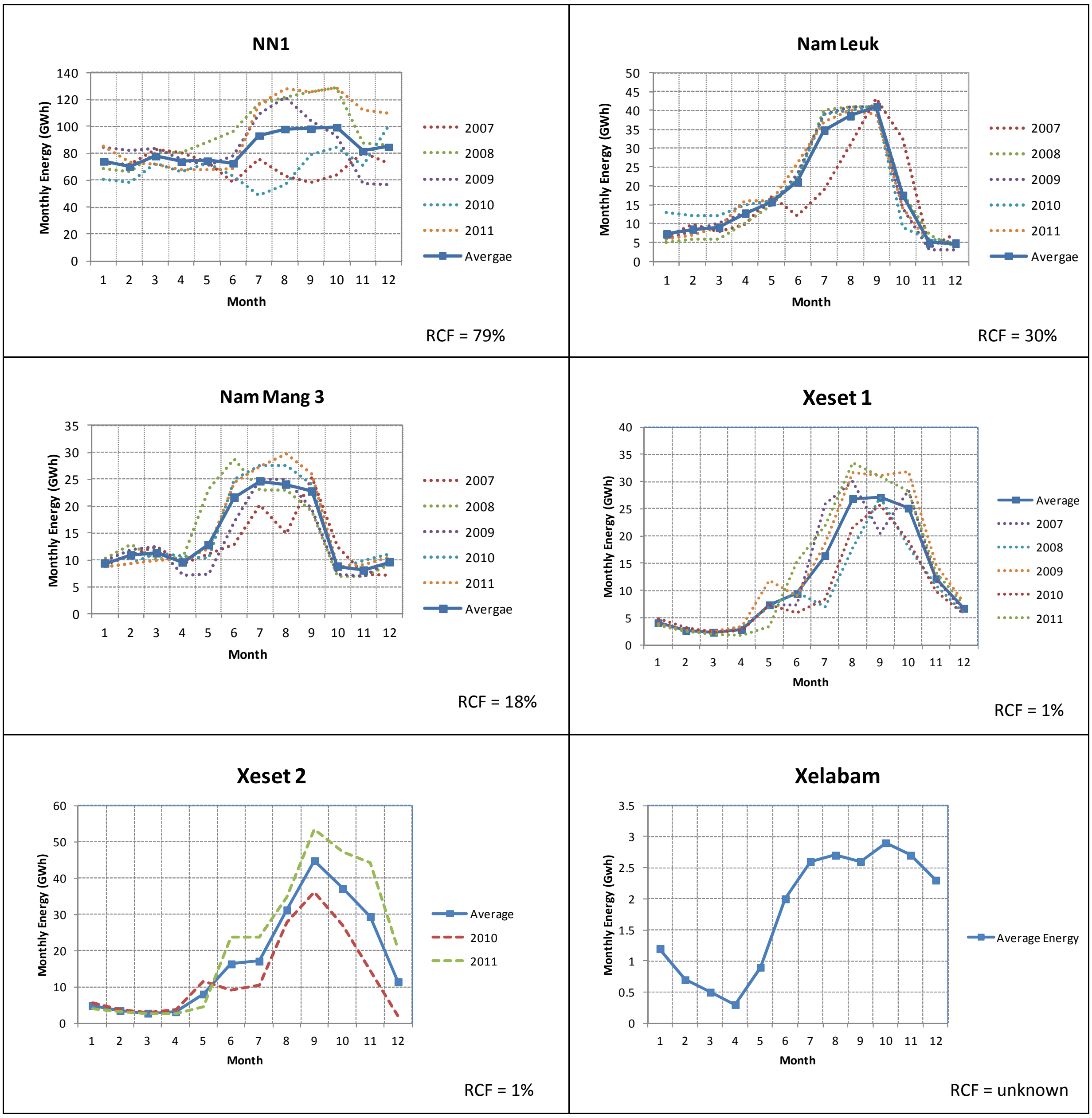
Note: Install capacity of “micro-hydro” is aggregate of install capacity of micro-hydro power plants.
Source: PDP 2010-2020 Revision-1

Monthly Energy Output of Existing Power Stations

In this study, the operation record of the medium to large scale hydropower operations for domestic power supply are collected from EDL-Gen's power stations and IPP(d).

(1) EDL-Gen's Hydropower Stations

The monthly operation pattern of the medium to large scale hydropower stations for the past five years are collected and shown in Figure 2.2.1.



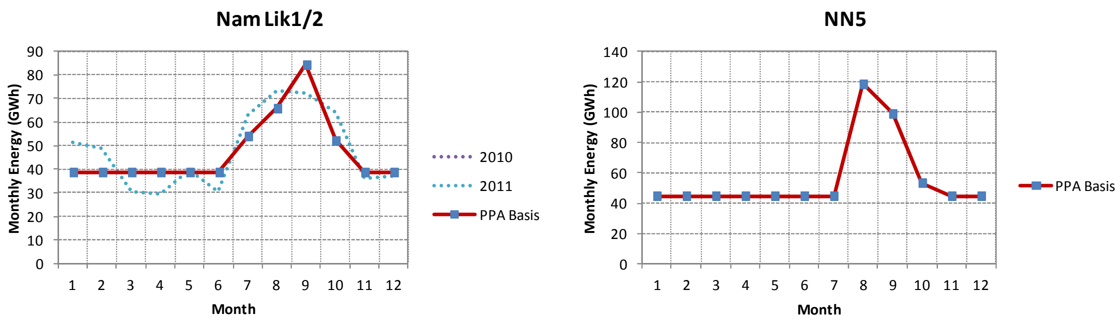
Prepared by the Study Team

Figure 2.2.1 Monthly Energy Fluctuation of Existing Hydropower Plants Owned by EDL-Gen

As Xeset 1 and Xeset 2 have small reservoir capacity, the monthly energy decrease significantly during the dry season. NN1, on the other hand, has a large storage capacity, therefore, it can generate a certain amount of electricity during dry season. Nam Leuk and Nam Mang 3 have drop in monthly energy production in the dry season. The dry season monthly energy of Nam Leuk is about 18% to the monthly energy in wet season. For the Nam Mang 3 case, the dry season monthly energy is 40% to that of the wet season. Nam Mang 3 is also responsible for irrigation supply, therefore it has to stably release water for power generation during the dry season.

(2) IPP for Domestic Power Supply

The hydropower plant of IPP(d) is currently only Nam Lik 1/2 is in operation, and Nam Ngum 5 (IPP(d)) is planned to commence the operation in the end of year 2012. The operations record of Nam Lik 1/2 and monthly average capacities of Nam Lik 1/2 and Nam Ngum 5 stated in the PPA are shown in Figure 2.2.2.



Prepared by the Study Team

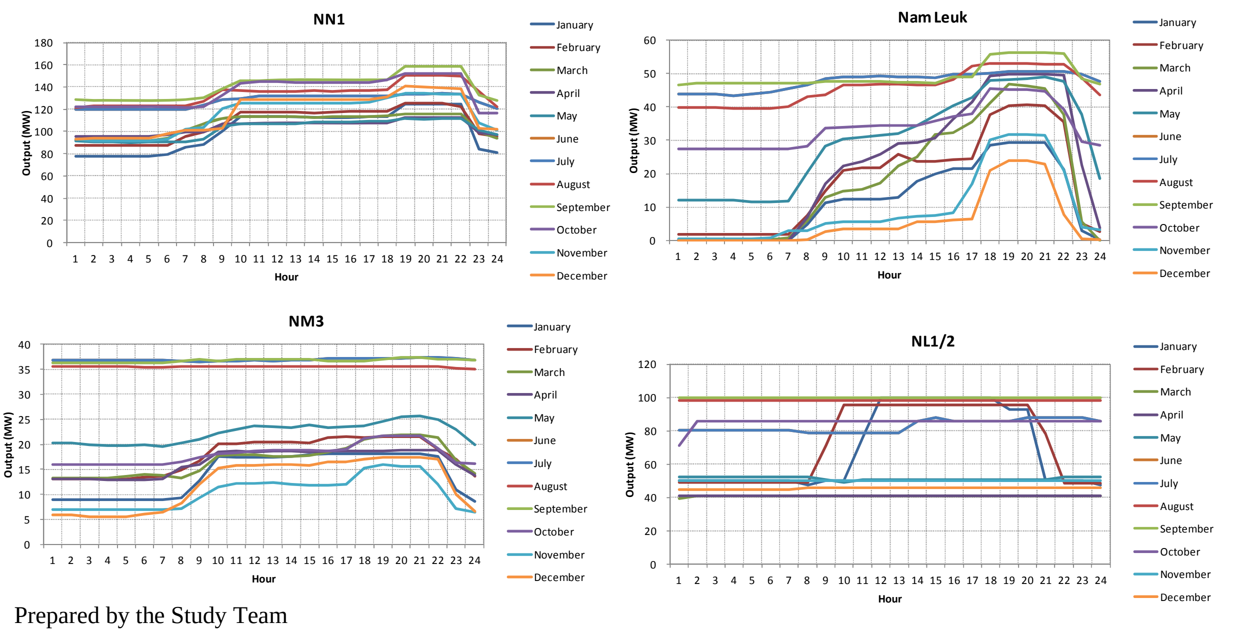
Figure 2.2.2 Monthly Energy Output of Nam Lik1/2 and Nam Ngum 5

As shown in the figure above, the monthly average capacity is constant except during rainy season. The operation record of Nam Lik 1/2 shows some departure from the planned monthly energy.

Unlike EDL-Gen's hydropower stations, the IPP(d) hydropower stations have a more stable energy output except during the wet season.

Daily Energy Output of Existing Power Stations

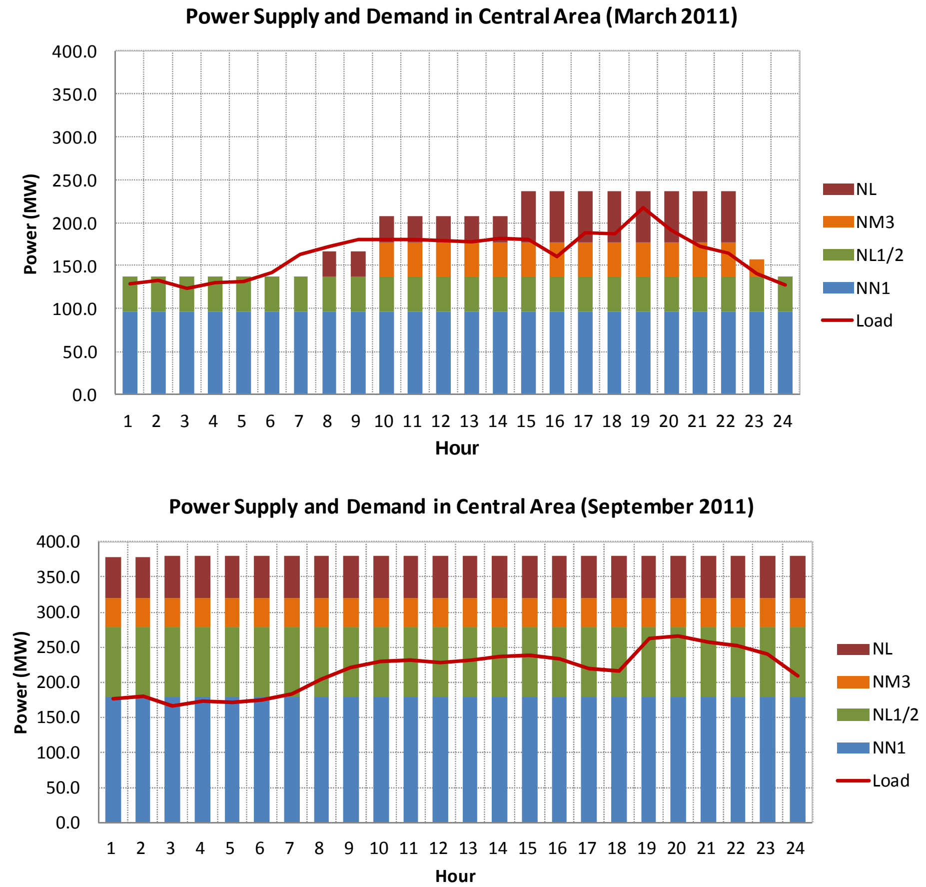
The daily power generation records available for the Study are NN1, Nam Leuk, Nam Mang 3 and Nam Lik 1/2. The average daily operation record on weekdays for these power stations during the recent past five years are shown in the figure below.



Prepared by the Study Team

Figure 2.2.3 Daily 24-Hour Operation of Nam Ngum 1, Nam Leuk, Nam Mang 3 and Nam Lik 1/2 Hydropower Stations.

The aggregate output of the power stations for supplying power to the central area is shown in Figure 2.2.4.



Prepared by the Study Team

Figure 2.2.4 Power Supply for Central Area in March and September 2011

Figure 2.2.4 shows the power supply and demand balance in March and September 2011, which is a typical operation of the dry and wet seasons. As shown in the figure, NN1 and NL1/2 supply power for base load, while NM3 and NL supply power for peak load. During the wet season, all of the power stations operate at full capacity for 24 hours.

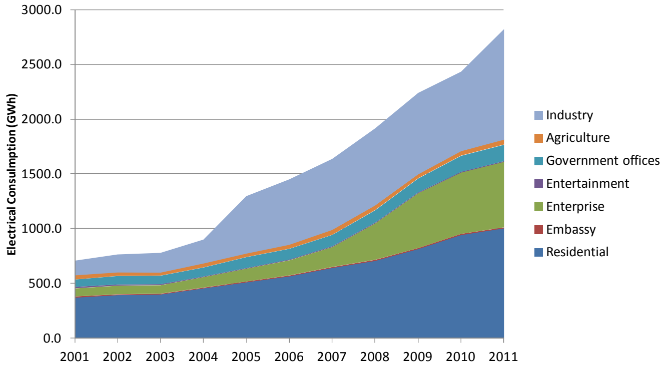
In general, NN1 power station supplies power for base load as well as peak load during the dry season. It is noted that, in the dry season of 2011, NN1 does not operate for peak power supply since the power supplies closely meet the daily demand as shown in Figure 2.2.4. Therefore, it was not necessary for NN1 to increase power during peak hours.

2.3 PRESENT SITUATION OF ELECTRICAL POWER SUPPLY AND DEMAND BALANCE

Power Demand in Laos

In Lao PDR, the average annual growth rate of domestic energy consumption and peak power demand has recorded an increase of more than 10% from 2001 to 2010, mainly because of the rapid increase of power demand in the country. The total average growth rate of energy consumption from 2001 to 2011 is relatively higher at 14.6%. As of 2011, the total energy consumption has reached 2,832.2 GWh, which consists of 1548.5 GWh in the central area, 278.7 GWh in the northern area and 1,004.9 GWh in the southern area.

The energy demand for residential users has been growing at an annual rate of over 10% from 1990 and reached 1,003 GWh (35.5%) in 2011. About 1,009.51 GWh (35.8%) is for industrial demand.



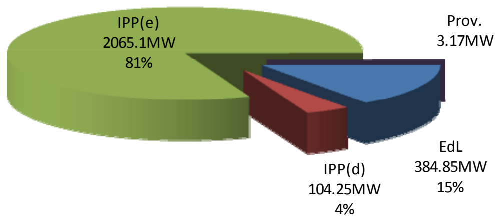
Consummners Type	2011
Residential	1,003.17
Embassy	9.43
Enterprise	597.73
Entertainment	7.78
Government offices	148.99
Agriculture	46.31
Industry	1,009.51
Total (GWh)	2,823

Source: PDP 2010-2020

Figure 2.3.1 Statistics of Electrical Consumption by Consumer Category

Power Generation in Laos

The existing power plants in Lao PDR are listed in Table 2.2.1. The ratio of generation by EDL, IPP(e) and IPP(d) is shown in Figure 2.3.2.



Source: PDP 2010-2020 Revision 1

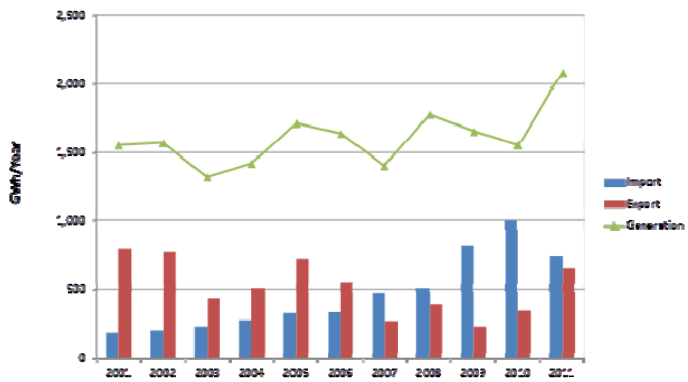
Figure 2.3.2 Ratio of Generation by EDL, IPP (e) and IPP (d)

The installation capacity achieved 2,557 MW total in 2011. However, 2065 MW of power was used for generation of power for export purposes by IPPs. The rest of the generating facilities, i.e. EDL and domestic IPP, estimated at 489 MW are used for domestic use, which does not reach the peak demand of 649 MW. The power import from neighboring countries compensates for the power shortage.

Power Trade with Neighbor Countries

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

In Lao PDR, power export used to be one of the significant means to earn foreign money. The gross amount of export, except for IPP, was larger than that of import until 2006. Hence, the import amount has exceeded the export amount in yearly gross amount since 2007. The export grew and import decreased because of precipitation augmentation in 2011, as shown in Figure 2.3.3.



Source : PDP 2010-2020 Revision-1

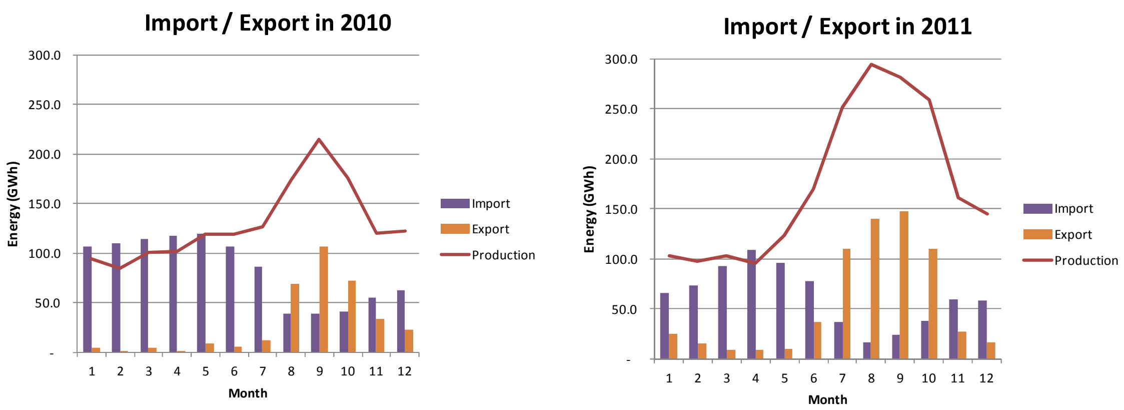
Figure 2.3.3 Past Record of Power Trade with Neighbor Countries

Future power demand is expected to drastically increase. It is presumed that this trend will continue as of this time. However, an interchange tariff in import from Thailand is set at a 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 to the excess portion of the import tariff. Overpower 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 for domestic use is urgently needed.

Seasonal Variation of Power Import and Export

Figure 2.3.4 shows the seasonal variation of power import and export in recent years.



Prepared by Study Team

Figure 2.3.4 Seasonal Variation of Power Trade

As indicated in the above record in 2010 and 2011, the power export generally exceeds the import during rainy season. On the contrary, the power import exceeds the export during dry season in recent years. The volume of power export tends to follow the annual energy production, which depends on the rainfall variation. For example, the export relatively increased in 2011 because it was a wet year.

Table 2.3.1 shows the list of existing international interconnection transmission lines, except expanded 22 kV distribution lines, for power import from Thailand.

Table 2.3.1 Existing International Interconnection Transmission Lines

No.	Substations		Length	No. of Circuit		Voltage	Conductor	Capacity
	EDL (Area)	EGAT	(Km)	Existing	Futrue	(kV)	(Sq.mm)	(MW)
1	Phontong (Central)	Nongkhai	26	2	2	115	240	100 x 2
2	Thanaleng (Central)	Nongkhai	9	1	1	115	240	100
3	Paksan (Central)	Bungkan	11	1	2	115	240	100
4	Thakhek (South)	Nalhonphanom	10	2	2	115	240	100 x 2
5	PakBo (South)	Mukdahan 2	5	1	2	115	240	100
6	Bang Yo (South)	Sirinthon P/S	61	1	1	115	240	100

Prepared by the Study Team based on PDP 2010-2020 Revision 1

Currently, there are six 115 kV transmission lines internationally connecting the EGAT system in Thailand and the EDL domestic system in Lao PDR. Three out of six transmission lines are connecting the Vientiane Capital and Nonkai in Thailand. The capacity of a single ACSR 477 MCM conductor with 240 mm^2 diameter is 100 MW for 115 kV, so that the total capacity between Thailand

and Vientiane capital is estimated at 400 MW.

2.4 FINANCIAL STATUS OF EDL AND EDL-GEN

(1) EDL

EDL has recorded a constant net profit from 2007 to 2010. However, its operational profit rates have been as low as 1% to 4% except 2008 where the energy sales increased by 279 GWh. EDL has constantly received in-kind subsidy in the form of additional capital contribution from the government, which accounts for 37,590 million Kip in 2009 and 12,480 million Kip in 2010.

As a state-owned company, EDL funding relies on capital contribution from the government and borrowings from external assistance loans from JBIC, World Bank, ADB, etc., denominated in foreign currencies. Its recent debt service coverage ratios (0.88 in 2009 and 0.80 in 2010) show that the operating cash flow cannot cover the debt service mainly due to its low profitability.

(2) EDL-Gen

The EDL-Generation Public Company (EDL-Gen) was established on December 15, 2010 by separating the six existing hydropower plant assets of EDL and their operation. While EDL holds 75% of the company shares, the rest is owned by private investors through the initial public offering held in December 2010. EDL-Gen has been listed on the Lao Securities Exchange since then.

EDL-Gen concluded the power purchase agreement with EDL in December 2011. The wholesale electricity tariff set for power generation by EDL-Gen is 413.89 Kip/kWh with annual escalation of 1%. In contrast with the low profitability of EDL as a domestic electricity provider, EDL-Gen has fair profitability as shown in its 10.8% ROA in 2011. The return on equity is calculated as 14.4%.

(3) Domestic Tariff

In 2011, the actual average tariff for EDL customers is 559 Kip/kWh or USD 7 cents. EDL applies a flat rate tariff system, which does not apply time-of-day rates or seasonal rates. The past tariff level was not considered sufficient for cost recovery and sound profitability. According to estimates in the Tariff Study Update (2009) implemented through World Bank support, the entire tariff revenue including exports covers only 61% of the costs. Cross-subsidizing continuously exists from medium and high voltage customers (101% cost recovery) to low voltage customers (50% cost recovery).

The government decided to gradually increase the domestic tariff until 2017. The planned tariff increase is about 20% in 2012 and 2% annually from 2013 through 2017. From the 2011 tariff level, the total increase will be around 32% by 2017.

(4) International Trade Tariff

Although electricity export is one of the major sources of foreign currency acquisition, EDL imports electricity to meet the demand-supply balance mainly due to seasonal change in energy generation.

The following table shows the cross-border trade tariff with EGAT (Thailand) via high voltage transmission lines (115kV).

Table 2.4.1 International Trade Tariff

	From	To	Peak (Mon-Fri 09:00-22:00)	Off-peak (Mon-Fri 22:00-09:00, Holidays 24hrs)	Locations	Remarks
EDL Export	**EDL**	**EGAT (Thailand)**	**THB 1.60 / kWh (4.99 US cents)**	**THB 1.20 / kWh (3.75 US cents)**	Nam Ngum 1(C1) , Xeset 1 (South)	
EDL Import	**EGAT (Thailand)**	**EDL**	**THB 1.74 / kWh (5.43 US cents)**	**THB 1.34 / kWh (4.18 US cents)**	Vientiane (C1), Bolixamxai (C1), Khamouan (C2), Savannaket (C2), Bangyo (Sounth)	*** For C1 and South PPAs: Surcharges applied in case of EDL annual trade deficit with EGAT**
	EGAT (Thailand)	**EDL**	THB 2.7595 / kWh (8.61 US cents)	THB 1.3185 / kWh (4.12 US cents)	Xepon Gold & Copper Mine (C2), Cement Factory (C2)	Fixed Service Charge, Demand Charge, Fuel Adjustment are applied

*** PPAs for C1 and South: The following surchage is applicable in case of EDL annual trade deficit with EGAT**

Unit Price: Demand Charge = 74.14THB/kW
Energy Charge: Peak = 3.8376 THB/kWh, Off-peak = 2.33966THB/kWh
Ft (Fuel Adjustment: Variable) = 0.30 THB/kWh (as of June 2012, Ministry of Energy, Thailand)
Servive Charge = 312.24THB/month (Fixed)

A. Normal Import Tariff (THB) = Annual Peak Import (kWh) * 1.74 THB/kWh + Annual Off-peak Import (kWh) * 1.34 THB/KWh
B. Identify the month of maximum energy consumption (kWh) by EDL:
(i) Demand Charge (THB) = Peak load of the month (kW) * 74.14THB/kW
(ii) Energy Charge (THB) = Peak Import of the month (kWh) * 3.8376 THB/kW + Off-peak Import of the month (kWh) * 2.3966 THB/kWh
(iv) Ft Charge (THB) = Total Import of the month * Ft (THB/kWh)
(v) Service Charge (THB) = 312.24 THB (Fixed)
(vi) Sum of (iii) to (vi) divided by Total Import of the Month (kWh) = Average Tariff (THB/kWh)
C. Average Normal Import Tariff (A. divided by total annual import) minus (vi) Average Tariff (THB/kWh) = Surcharge Unit Price (THB/kWh)
D. C. Surcharge Unit Price (THB/kWh) * Annual Excess Import (deficit) (kWh) = Surcharge Payment of the year (THB)

Source: EDL

The export-import tariff for C1, C2 and the south grids has characteristics of (i) small price difference between peak time and off-peak time (about 1.25 US cents/kWh) and (ii) basic import tariff is THB 0.14/kWh (0.44 US cents/kWh) higher than export to EGAT. Surcharge payment is required additionally in case EDL imports exceed its exports in a year. Surcharge calculation is based on the domestic tariff in Thailand. The excess import by EDL is virtually charged with similar prices as the electricity consumers in Thailand (7.3 to 12.0 US cents/kWh). As far as it is balanced, the cross-border electricity trade between EDL and EGAT is regarded as a mutual interchange under international cooperation.

CHAPTER 3 POWER SUPPLY AND DEMAND BALANCE FORECAST

3.1 REVIEW OF ENERGY AND PEAK DEMAND FORECAST IN PDP

Review of Demand Forecast in PDP 2010-2020 (Revisinon-1)

EDL officially announced and incorporated the future power demand projection and power supply plan for the whole Lao PDR service areas in the Power Development Plan (PDP) 2010-2020 (Revision-1) issued in August 2011 which is the latest official development plan. The records of the power consumption and development plan for the whole Lao PDR and specifically, also for the northern, central, and southern areas are summarized in the PDP.

The PDP includes full details of the demand forecast, which is mainly categorized into residential sector and large industries. The demand for residential sector is projected based on the number of population, households and villages. These forecasts will not be changed in this Study. Meanwhile, the Study Team particularly reviewed the large industrial demand in the latest PDP because of the delay in the implementation of various projects.

The demand load for large industries is individually reviewed in the following manner:

(1) Load for the construction and operation of railway project

The Laos-China High-speed Railway Project is now underway. The project is a railway network that extends from Lao-China border to Vientiane. The demand load for the construction of railway was originally considered for four years from the start of the construction work in 2011. The load for the railway station and running trains was estimated until 2015 in the latest PDP.

According to the Department of Energy Policy and Planning, MEM replied that the construction work has not yet commenced and that MEM has no information on its commencing time. Consequently, the Study Team estimated that the given time period for railway demand is three years behind the original schedule, i.e. construction will start in 2014 and operation of trains in 2018.

(2) Load of special economic zone (SEZ)

The Study Team collected information on the demand load of SEZ in the future at the Secretariat Office of Lao National Committee for SEZ. However, the Study Team did not obtain further information on SEZ projects, therefore, the demand load of SEZ shown in PDP were considered in review of demand forecast.

(3) Load for the construction of hydropower stations

EDL considered the demand load for the construction of hydropower stations into the load forecast. These loads were commonly calculated as 15% of installed capacity for each hydropower station, with an estimated demand period of two years before the commercial operation date (COD).

The Study Team addressed that the calculation of 15% installed capacity may not be adequate for large-scale hydropower stations which needs a higher demand load. The Study Team suggested EDL to adjust the load for construction period to reduce them being less than 4MW.

(4) Load for the operation of mining

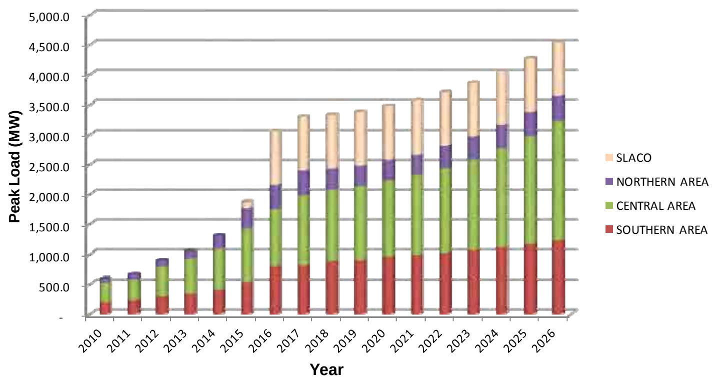
The Study Team collected information from the Department of Mines and confirmed that further specific demand for the development of new mining was not available.

The power required for the bauxite mining project of the Sino-Lao Corporation (SLACO) in the southern area is estimated at 900 MW for the first stage. Due to a large demand for mining activities, the load forecast was studied distinctly with or without SLACO. The SLACO demand will be discussed with development scenarios (Case 1 to Case 4) in Sub-Clause 3.3.1 in Main Report.

<u>Annual Energy and Peak Load Demand Forecast Reviewed by the Study Team</u>

Based on the review of large-scale industrial electricity demands, the annual energy and peak load demand forecast for northern, central and southern area were updated by the Study Team.

As shown in Figure 3.1.1, the peak load for Lao PDR is projected to rapidly increase in 2017 with an additional demand of 900 MW for SLACO. The peak load will achieve 2577 MW in 2020 and 3374 MW in 2025 (excluding SLACO). The peak load for the central area is also projected to increase from 196.2 MW in 2010, to 1,274.9 MW in 2020 and 1,800.3MW in 2025.



Prepared by the Study Team

Figure 3.1.1 Peak Load Forecast for Lao PDR

Table 3.1.1 Annual Energy and Peak Load Forecast in Lao PDR

Energy Demand (Including System Losses)

Unit: GWh

	Actual 2010	Forecast 2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NORTHERN AREA	**284.0**	**378.2**	**544.5**	**593.7**	**1,255.2**	**1,992.4**	**2,463.3**	**2,521.8**	**2,110.7**	**2,071.8**	**2,108.3**	**2,129.5**
RESIDENTIAL SECTOR	284.0	314.4	342.6	370.8	400.6	431.4	464.1	499.4	539.2	582.1	628.3	678.2
LARGE INDUSTRIES	-	63.8	201.9	222.9	854.6	1,561.0	1,999.2	2,022.4	1,571.4	1,489.7	1,480.0	1,451.3
CENTRAL AREA	**1,634.8**	**1,814.9**	**2,764.5**	**3,288.2**	**3,832.8**	**5,004.0**	**5,322.7**	**6,372.9**	**6,537.2**	**6,792.6**	**7,060.4**	**7,434.1**
RESIDENTIAL SECTOR	1,403.6	1,504.2	1,615.6	1,739.2	1,877.0	2,030.9	2,202.9	2,395.3	2,660.0	2,968.0	3,326.9	3,746.0
LARGE INDUSTRIES	231.1	310.7	1,148.9	1,549.1	1,955.8	2,973.2	3,119.7	3,977.6	3,877.2	3,824.6	3,733.5	3,688.0
SOUTHERN AREA	**1,048.0**	**1,209.0**	**1,590.1**	**1,946.4**	**2,369.3**	**3,337.6**	**5,013.9**	**5,077.9**	**5,526.6**	**5,634.8**	**6,003.1**	**6,172.3**
RESIDENTIAL SECTOR	608.9	664.9	739.5	813.0	892.5	979.2	1,074.0	1,180.9	1,317.1	1,469.4	1,640.0	1,831.6
LARGE INDUSTRIES	439.1	544.1	850.6	1,133.4	1,476.8	2,358.4	3,939.9	3,897.0	4,209.5	4,165.4	4,363.0	4,340.6
TOTAL FOR RESIDENTIAL SECTOR	**2,296.6**	**2,483.5**	**2,697.7**	**2,923.1**	**3,170.0**	**3,441.4**	**3,741.0**	**4,075.6**	**4,516.4**	**5,019.5**	**5,595.3**	**6,255.9**
TOTAL FOR LARGE INDUSTRIES	**670.2**	**918.6**	**2,201.4**	**2,905.4**	**4,287.2**	**6,892.6**	**9,058.8**	**9,897.1**	**9,658.1**	**9,479.7**	**9,576.5**	**9,479.9**
GRAND TOTAL	**2,966.8**	**3,402.1**	**4,899.1**	**5,828.4**	**7,457.2**	**10,334.0**	**12,799.9**	**13,972.7**	**14,174.5**	**14,499.2**	**15,171.8**	**15,735.8**

Peak Load

Unit: MW

	Actual 2010	Forecast 2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NORTHERN AREA	**65.9**	**81.4**	**107.5**	**115.5**	**225.6**	**338.9**	**409.4**	**418.8**	**347.3**	**339.7**	**344.5**	**346.7**
RESIDENTIAL SECTOR	65.9	71.2	75.7	80.1	84.6	89.0	93.7	98.7	104.3	110.3	116.7	123.5
LARGE INDUSTRIES	-	10.2	31.8	35.4	141.0	249.8	315.7	320.1	242.9	229.4	227.8	223.2
CENTRAL AREA	**321.7**	**347.5**	**497.1**	**597.9**	**687.4**	**900.5**	**953.5**	**1,166.3**	**1,193.7**	**1,234.3**	**1,274.9**	**1,331.5**
RESIDENTIAL SECTOR	289.7	305.3	322.6	341.7	363.0	386.6	412.9	442.2	483.7	531.7	587.3	651.8
LARGE INDUSTRIES	32.0	42.1	174.5	256.2	324.4	513.9	540.5	724.1	710.0	702.6	687.5	679.7
SOUTHERN AREA	**196.2**	**220.9**	**286.0**	**329.6**	**397.3**	**529.0**	**796.0**	**807.5**	**881.9**	**900.1**	**958.3**	**985.3**
RESIDENTIAL SECTOR	136.2	145.3	158.3	170.4	183.2	196.9	211.7	228.3	249.8	273.4	299.6	328.6
LARGE INDUSTRIES	60.0	75.6	127.7	159.2	214.1	332.1	584.2	579.2	632.2	626.6	658.6	656.7
TOTAL FOR RESIDENTIAL SECTOR	**491.8**	**521.8**	**556.7**	**592.2**	**630.7**	**672.6**	**718.3**	**769.1**	**837.8**	**915.5**	**1,003.7**	**1,104.0**
TOTAL FOR LARGE INDUSTRIES	**92.0**	**127.9**	**334.0**	**450.8**	**679.5**	**1,095.8**	**1,440.5**	**1,623.4**	**1,585.1**	**1,558.6**	**1,574.0**	**1,559.5**
GRAND TOTAL	**583.8**	**649.8**	**890.7**	**1,043.0**	**1,310.2**	**1,768.3**	**2,158.9**	**2,392.6**	**2,422.9**	**2,474.1**	**2,577.6**	**2,663.5**

Prepared by the Study Team

3.2 REVIEW OF GENERATION DEVELOPMENT PLAN IN PDP

Procedures for the Review of Generation Development Plan in PDP

The Study Team reviewed and renewed the annual supply capacity in PDP in the following manners:

(1) For confirming the projects of EDL power stations, the Study Team carried out hearing investigation to EDL engineers. The accuracy of CODs for all planned power stations was confirmed from the project status. If the project is delayed, the COD will be postponed to an appropriate year, considering four to five years of construction period depending on the scale of the project.

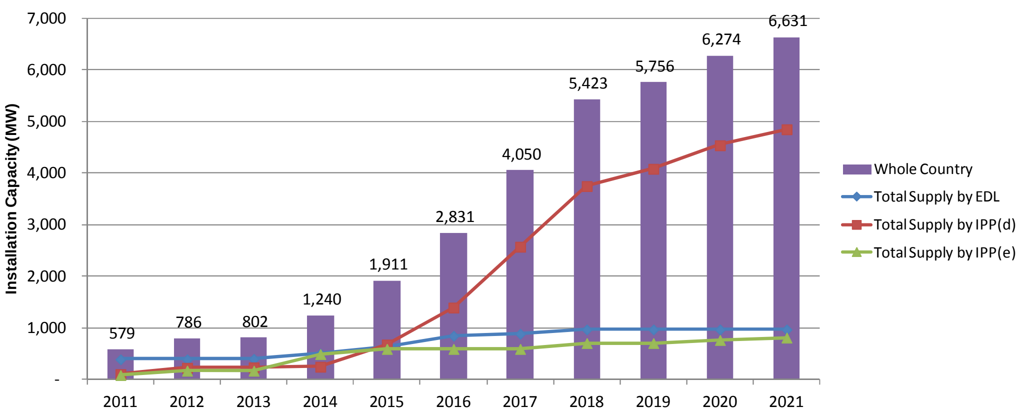
(2) For confirming the projects for IPP power stations including IPP(d) and off-take from IPP(e), the Study Team carried out hearing investigations to persons in charge of IPP projects in the Department of Energy Business Additionally, the Study Team confirmed the project status in the progress report for IPP projects. Then, COD was also checked similarly to the above (1).

(3) If a project has serious technical issue and cannot move ahead, such project would be deemed canceled and deleted from the project list[1].

(4) The annual supply capacities up to 2026 for the northern, central, and southern areas were updated in the "demand–supply balance sheets".

Generation Development Plan Reviewed by the Study Team

In summary, the installed generation capacity for the whole country is assumed to achieve 1911MW in 2015 and 6274 MW in 2020 as shown in Figure 3.2.1.



Prepared by the Study Team

Figure 3.2.1 Projection of Installed Generation Capacity

The sum of the installed generation capacity of IPP power stations (including IPP(e) and IPP(d)) will occupy 84.6% of the whole country in 2020. Of the total installed capacity, only 15.4% will be owned by EDL. This means most of the power generation for domestic use will be provided by IPPs in the future. The IPP hydropower stations are obliged to guarantee the daily generation required in the PPA. This means that IPP power stations may not flexibly be able to contribute to the power system control.

1 In this Study, only one project (Nam Ngum Down Hydropower Station) was deleted from the list of generation development plan in the demand-supply balance done by the Study Team, because it was found out that the head was too small during its F/S.

In case of hydropower station, if the actual generation does not reach the installed generation capacity, the actual generation will be reduced to one third to one fourth in dry season, depending on the seasonal variation of water level on the river. Under the circumstance, the actual generation will be less than the installed generation capacity.

Development Scenarios in PDP

EDL analyzed four cases of the supply-demand balance in the PDP as mentioned below.

(1) Case 1 excluded power demand of SLACO (900MW) and hydropower projects of Sekong 4 and 5 and Nam Kong.

(2) Case 2 included power demand of SLACO (900MW). The Sekong 4 and 5, and Nam Kong 1 will supply SLACO with power through EDL system. The hydropower stations in Mekong River that are on the stage of development (Xayabury, Don Sahong, and Thakho) are also taken into consideration, but M. Kalum (600MW) was not included.

(3) Case 3 also included the SLACO demand (900MW). All major projects, i.e., M. Kalum (600MW), Sekong 4 and 5, Nam Kong 1, and all Mekong projects are included. However, as mentioned in the foregoing paragraph, since both power plants of M. Kalum and Sekong 4 may not be developed at the same time, Case 3 was considered not feasible.

(4) Case 4 also included the SLACO demand, Sekong 4 and 5 and Nam Kong 1, but M. Kalum and Mekong hydropower projects were not considered.

The above four (4) options were mainly differentiated by large-scale projects in the southern area. It will not significantly affect the demand-supply balance in the central area. As for Case 2, Case 3, and Case 4, the demand–supply balance will face a serious problem in power shortage to meet the demand, including SLACO in 2016. The Study Team tentatively selected Case 1 for further study and analysis on a monthly and daily demand-supply balance in the central area. Although Case 1 included an uncertainty on the implementation of M. Kalum Coal-fired Power Plant (600 MW), this power source can replace Sekong 4 and 5 and Nam Kong 1 (total 565 MW) since both have approximately the same scale of power generation, if M. Kalum project is not realized.

3.3 POWER DEMAND–SUPPLY BALANCE ANALYSIS ON ANNUAL BASIS

EDL estimated the demand-supply balance for the northern, central and southern areas for Case-1 in the PDP. The Study Team revised this demand-supply balance in consideration of the updated peak load and installed generation capacity in the above sub-clause (reserved margin was not considered).

Demand–Supply Balance for the Central Area of Lao PDR

The peak load and power generation forecast for the central area were combined into Table 3.3.1 and Table 3.3.2 to see the demand-supply balance.

Table 3.3.1 Comparison of the Demand and Supply Energy for the Central Area

Central Unit: GWh

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Demand	1,634.8	1,814.9	2,764.5	3,288.2	3,832.8	5,004.0	5,322.7	6,372.9	6,537.2	6,792.6	7,060.4	7,434.1
Supply	1,806.0	1,831.0	2,155.5	2,155.5	2,224.8	2,224.8	2,224.8	3,281.6	4,988.0	4,988.0	4,988.0	4,988.0
Balance	171.2	16.0	-609.1	-1,132.8	-1,608.1	-2,779.3	-3,097.9	-3,091.4	-1,549.2	-1,804.5	-2,072.4	-2,446.0

Prepared by the Study Team

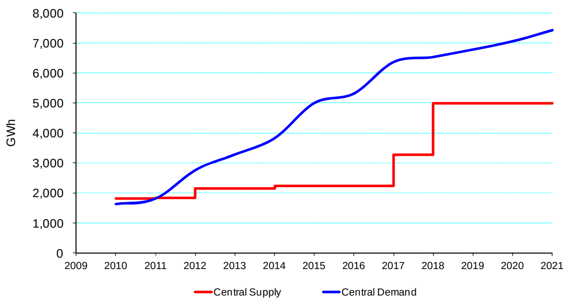
Table 3.3.2 Comparison of the Peak Load and Supply Capacity for the Central Area

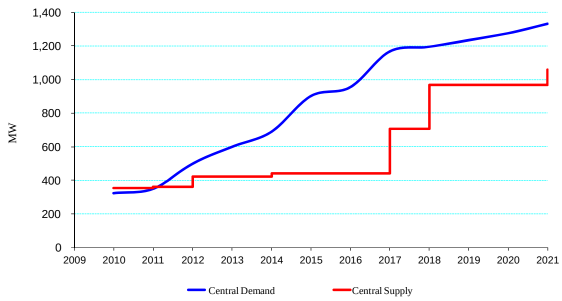
Central Unit: MW

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Demand	321.7	347.5	497.1	597.9	687.4	900.5	953.5	1,166.3	1,193.7	1,234.3	1,274.9	1,331.5
Supply	355.0	361.0	422.6	422.6	441.6	441.6	441.6	705.6	969.6	969.6	969.6	1,059.6
Balance	33.3	13.5	-74.5	-175.3	-245.8	-458.9	-511.9	-460.7	-224.1	-264.7	-305.3	-271.9

Prepared by the Study Team

The annual power generation up to 2011 in the central area seemed sufficient in the balance sheet. The installed generation capacity also seemed to have enough supply. However, the power supply for the central area will fall short of demand in 2012 and the power shortage will be experienced in the future.





Prepared by the Study Team

Figure 3.3.1 Demand–Supply Balance for the Central Area

The actual output may be reduced from one third to one fourth during dry season, depending on the seasonal variation of water level. Besides, the load will significantly vary from peak to off-peak in a day. Therefore, the annual demand-supply balance may be used to see the rough estimates of demand-supply balance as initial step, and further analysis on the monthly and daily basis will be required.

Demand-Supply Balance for the Northern Area of Lao PDR

In the future, the transmission line networks for the northern, central, and southern areas will be integrated with 115 kV and 230 kV transmission lines. The demand-supply balance for the northern and southern areas will affect the power system in the central area through the transmission network. Hence, the northern and southern demand-supply balances were also reviewed by the Study Team in this Study.

The updated demand-supply balance for the northern area is summarized in Table 3.3.3 and Table

3.3.4[2].

Table 3.3.3 Comparison of the Demand and Supply Energy for the Northern Area

North Unit: GWh

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Demand	284.0	378.2	544.5	593.7	1,255.2	1,992.4	2,463.3	2,521.8	2,110.7	2,071.8	2,108.3	2,129.5
Supply	20.6	37.7	537.7	574.7	607.3	2,726.1	5,957.1	6,747.6	9,910.5	10,774.2	11,915.2	12,880.4
Balance	-263.4	-340.5	-6.8	-19.0	-647.8	733.7	3,493.8	4,225.7	7,799.8	8,702.4	9,806.9	10,751.0

Prepared by the Study Team

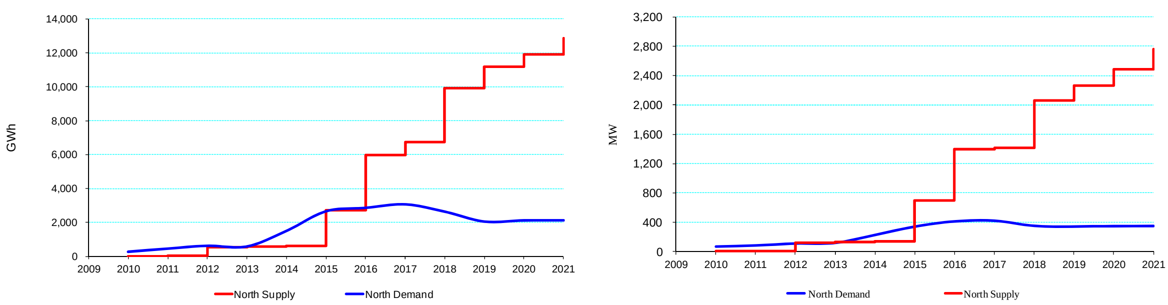
Table 3.3.4 Comparison of the Peak Load and Supply Capacity for the Northern Area

North Unit: MW

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Demand	65.9	81.4	107.5	115.5	225.6	338.9	409.4	418.8	347.3	339.7	344.5	346.7
Supply	3.7	7.4	127.4	132.4	141.0	694.5	1,401.5	1,416.5	2,062.5	2,260.8	2,488.8	2,755.8
Balance	-62.2	-74.0	19.8	16.8	-84.6	355.6	992.0	997.6	1,715.2	1,921.1	2,144.3	2,409.1

Prepared by the Study Team

As presented in the above balance sheet, the annual power generation in the northern area from 2010, 2011 and 2014 resulted negative values. Accordingly the supply in the said period were not enough to meet to the demand. Meanwhile, the power generation will rapidly increase after 2015 due to the completion of large scale projects, including Nam Ou 2, 5, and 6 (540 MW in total) in 2016 and Nam Ou 1, 3, 4, and 7 (616 MW in total) in 2018. Accordingly, the power balance will be extremely improved in 2016 and surplus power is expected to be fed to the central from the northern area or to be exported to neighboring countries through transmission networks. The surplus energy in the northern area is supposed to achieve 10,175 GWh in 2021.



Data Source: PDPP 2010-2020 Revision -1, Prepared by the Study Team

Figure 3.3.2 Demand–Supply Balance for the Northern Area

<u>Demand–Supply Balance for the Southern Area of Lao PDR</u>

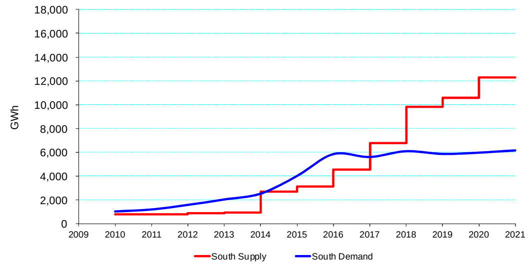
The demand-supply balances for the southern area are presented in the following development scenarios: Case 1 to Case 4, as illustrated in Figure 3.3.3.

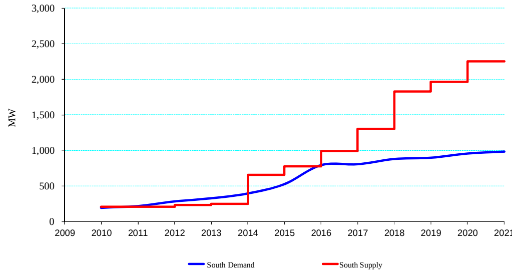
As for Case 2, Case 3, and Case 4, the demand–supply balance will face a serious problem in power shortage to meet the demand, including SLACO in 2016. The Study Team tentatively selected Case 1 for further study and analysis on a monthly and daily demand-supply balance in the central area as mentioned foregoing clause.

[2] Xayabury, 60MW off-take from IPP(e) (Mekong Development, COD in 2020) is included.

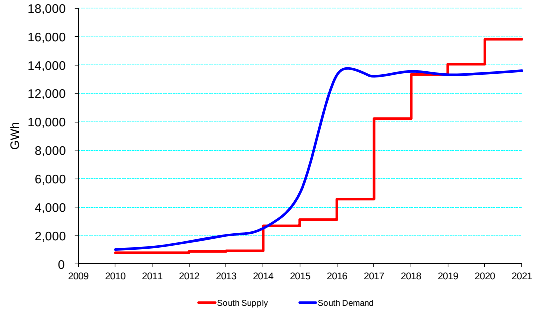
Energy Demand-Generation | Peak Load–Installation Capacity

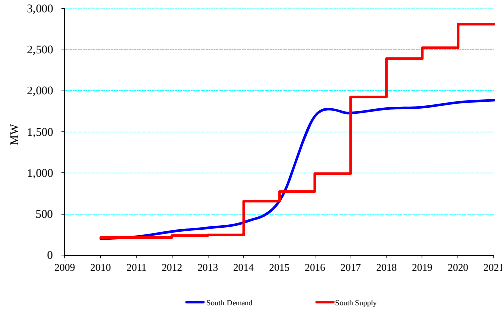
Case 1:



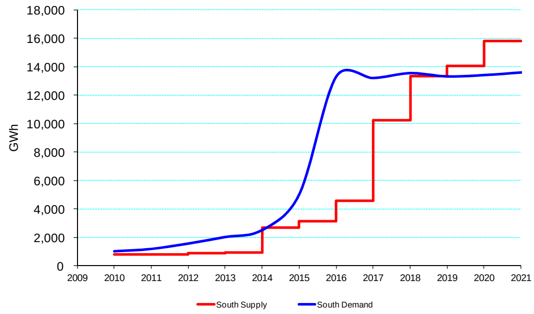


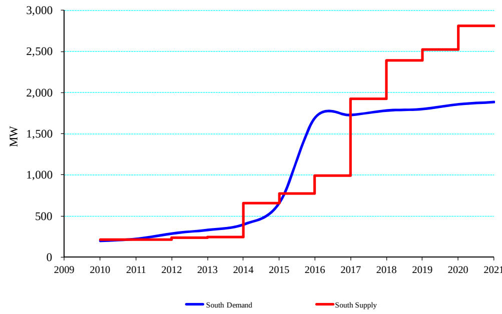
Case 2:



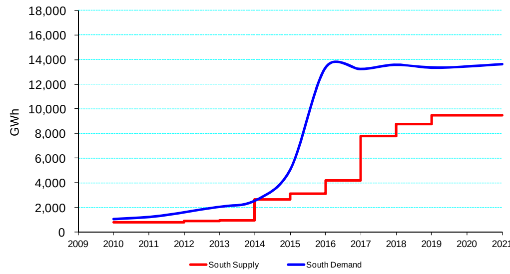


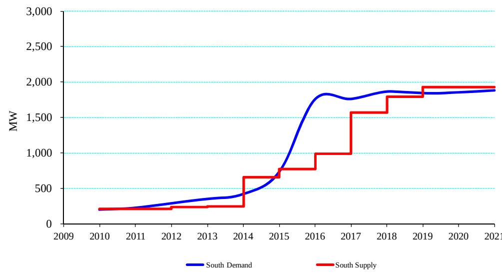
Case 3:





Case 4:





Data Source: PDPP 2010-2020 Revision -1, Prepared by the Study Team

Figure 3.3.3 Demand–Supply Balance for the Southern Area

As per demand–supply balance for Case 1 in Table 3.3.5 and Table 3.3.6, the annual power generation in the southern area from 2010 to 2016 is insufficient in the balance sheets. The supply capacity is also increasing a little bit slower as well, compared to that of the demand. The power generation for the southern area will exceed in 2017 after completion of some large-scale power developments, including M. Kalum. Accordingly, the power balance will be improved in 2017 and the surplus energy may be transmitted to the central or may be exported to neighboring countries. The surplus energy in the southern area is supposed to achieve 6143 GWh in 2021.

Table 3.3.5 Comparison of the Demand and Supply Energy for the Southern Area (Case 1)

South Unit: GWh

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Demand	1,048.0	1,209.0	1,590.1	1,946.4	2,369.3	3,337.6	5,013.9	5,077.9	5,526.6	5,634.8	6,003.1	6,172.3
Supply	798.6	798.6	894.6	948.6	2,671.6	3,132.1	4,196.2	6,396.2	9,461.3	10,199.3	12,315.3	12,315.3
Balance	-249.4	-410.4	-695.5	-997.8	302.4	-205.4	-817.7	1,318.3	3,934.7	4,564.5	6,312.3	6,143.0

Prepared by Study Team

Table 3.3.6 Comparison of the Peak Load and Supply Capacity for the Southern Area (Case 1)

South Unit: MW

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Demand	196.2	220.9	286.0	329.6	397.3	529.0	796.0	807.5	881.9	900.1	958.3	985.3
Supply	211.1	211.1	236.1	247.0	657.0	775.0	988.0	1,303.0	1,826.0	1,961.0	2,251.0	2,251.0
Balance	14.9	-9.8	-49.9	-82.6	259.7	246.0	192.0	495.5	944.1	1,060.9	1,292.7	1,265.7

Prepared by the Study Team

Demand – Supply Balance for Whole Country

Since the regional power system for the southern area will be integrated into the northern and central system in 2014, the analysis of demand-supply balance for the whole country is also important for the study on power trade with neighboring countries. The total demand-supply balance of all areas are summarized in the Table 3.3.7 and Table 3.3.8.

Table 3.3.7 Comparison of the Demand and Supply Energy for the Whole Country

Whole country Unit: GWh

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Demand	2,966.8	3,402.1	4,899.1	5,828.4	7,457.2	10,334.0	12,799.9	13,972.7	14,174.5	14,499.2	15,171.8	15,735.8
Supply	2,625.1	2,667.2	3,587.7	3,678.8	5,503.7	8,083.0	12,378.1	16,425.4	24,359.8	25,961.6	29,218.6	30,183.8
Balance	-341.6	-734.9	-1,311.4	-2,149.6	-1,953.5	-2,251.0	-421.8	2,452.7	10,185.3	11,462.4	14,046.8	14,448.0

Prepared by Study Team

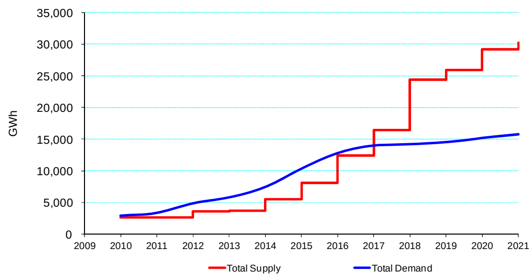
Table 3.3.8 Comparison of the Peak Load and Supply Capacity for the Whole Country

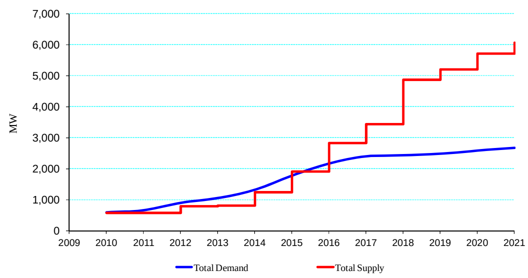
Whole country Unit: MW

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Demand	583.8	649.8	890.7	1,043.0	1,310.2	1,768.3	2,158.9	2,392.6	2,422.9	2,474.1	2,577.6	2,663.5
Supply	569.8	579.4	786.0	801.9	1,239.5	1,911.0	2,831.0	3,425.0	4,858.0	5,191.4	5,709.4	6,066.4
Balance	-14.0	-70.3	-104.6	-241.1	-70.7	142.7	672.2	1,032.5	2,435.2	2,717.3	3,131.8	3,402.9

Prepared by the Study Team

As shown in the balance sheet, the amount of annual power generation in the whole country from 2010 to 2016 warns a power shortage. However, the annual power generation will exceed the energy demand in 2017 onwards, and the balance will achieve 14,448 GWh in 2021.





Data Source: PDPP 2010-2020 Revision -1, Prepared by the Study Team

Figure 3.3.4 Demand–Supply Balance for the Whole Country

Special attention should be given to the annual balance analysis because the actual supply capacity of hydropower stations has to be reduced to one third to one fourth during dry season, following the seasonal water level on rivers. The load will also vary significantly with time during peak or off-peak each day. Therefore, such analysis of the annual demand-supply balance is used for unveiling an outline of the initial step, and further demand-supply analysis on monthly and daily basis are required for the central area.

3.4 POWER DEMAND–SUPPLY BALANCE ANALYSIS ON MONTHLY AND DAILY BASIS

Assumptions of Future Daily Load Curve Trend

The daily load curves were estimated for northern, central and southern area. The daily load curve of the central area for year 2017, 2020, and 2025 estimated in the study are shown in Figure 3.4.1.

Assumptions of the Future Monthly and Daily Power Generation

(1) General

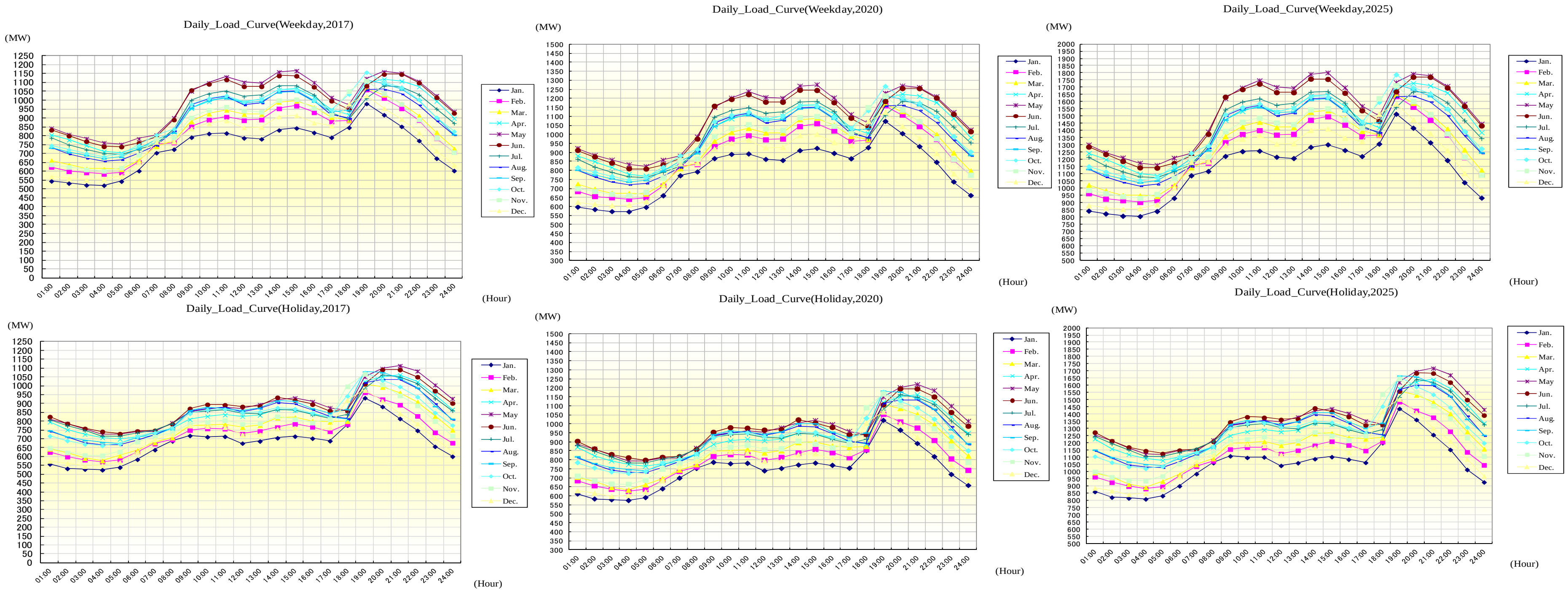
The power generation pattern of hydropower plants are estimated for existing and all planned hydropower stations listed in PDP 2010-2020 (Revision-1). The general methodology of estimation of each station is shown in Table 3.4.1.

Table 3.4.1 Method of Estimation of Power Generation Pattern

Type	Method
Existing Power Station	Existing power stations operation pattern is estimated from the past operation record.
Planned Power Project which PPA Made	The planned power project which PPA has signed and if PPA can be referred to the Study Team, the monthly capacity stated in PPA is used.
Planned Power Project with Study Level	1) If the study report is available and the power simulation result is presented, the monthly energy value will be used. 2) If the study report is not available for the Study, the power generation pattern will be estimated by the plant factor.

Prepared by the Study Team

For estimating the power generation pattern of the hydropower project (which has no PPA and no available study report for the Study Team), the Study Team first considered the hydropower operation role in the power system and the power generation pattern is estimated by reservoir size and owner type i.e., EDL-Gen's power stations or IPP(d).



Prepared by the Study Team

Figure 3.4.1 Daily Load Curves for the Central Area

(2) Operational Pattern of Planned Hydropower Projects Referred to PPA and Study Reports

- Planned hydropower project with PPA can be referred

The following hydropower stations are referred to as estimated monthly capacity stated in the PPA between IPP(d) and EDL.

Hydropower Plants Estimated by PPA	Nam Ngum 5, Nam Ngiep 2, Nam Ou 1-7, Xekaman1+Xanxai, Xenamnoy

- Planned Hydropower Project with PPA can NOT be referred, and the study reports can be referred

The following hydropower stations are referred in the study reports.

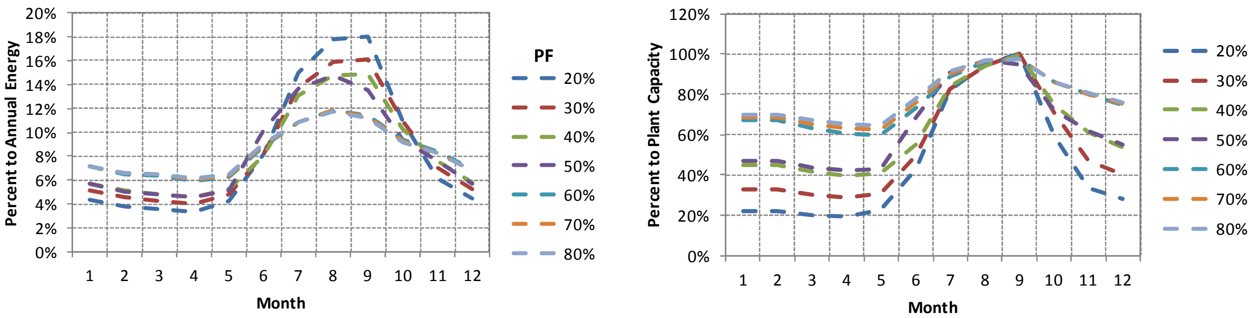
Hydropower Plant Output Referred in the Study Report	Nam Khan 2, Nam Lik1

(3) Estimation of Power Output by Plant Factor

The Study Team estimated the power generation of planned hydropower stations which have no PPA and study reports available for the Study. The objective hydropower plants are those located in the whole country of Lao PDR.

It was found that relation between plant factor and relative reservoir size to inflow is almost proportional in Laos, although it is not always the case. This means that reservoir size and the role of hydropower can be estimated if the PF value is known. The plant factor value is listed for all planned hydropower projects in PDP 2010-2020 (Revision-1). The power operation for all power stations can be estimated using the PF value in PDP 2010-2020 (Revision-1).

The power output of hydropower is simulated by mass curve method using the average specific discharge and adjusted to fit with the past operation records pattern. The estimated hydropower monthly energy and average power output for the plant factor varying from 20% to 80% is shown in Figure 3.4.2.

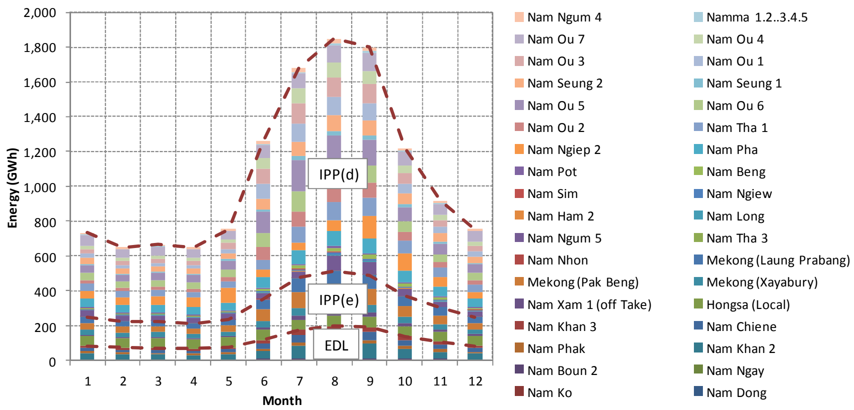


Prepared by the Study Team

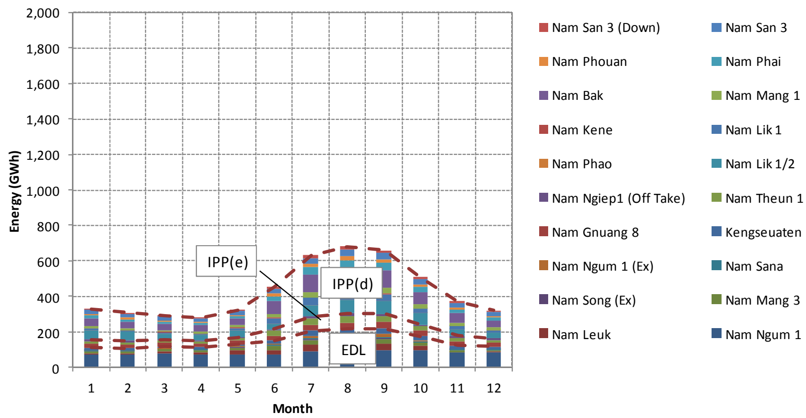
Figure 3.4.2 Percent of Monthly Energy to Annual Energy Simulated for Each Plant Factor

(4) Estimated Monthly Energy

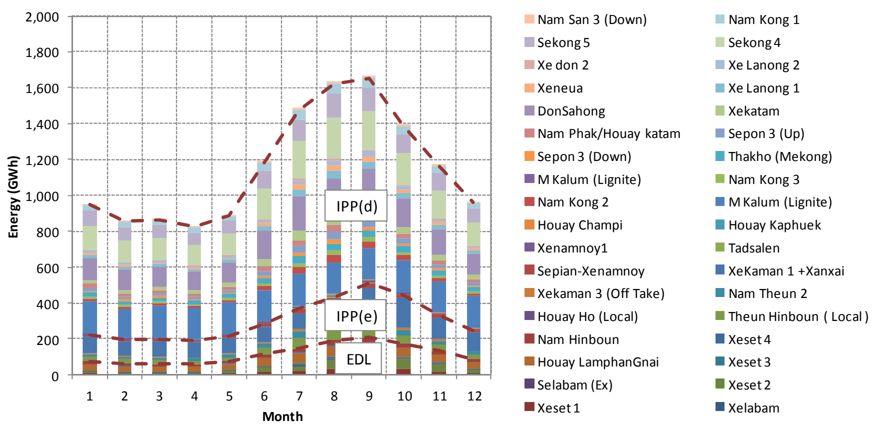
As discussed in the previous section, power output of all planned hydropower stations these were listed in PDP 2010-2020 (Revision-1), were estimated by referring to PPA, study reports, and by estimating by plant factor. The estimated monthly energy is shown in Figure 3.4.3.



Northern Area



Central Area



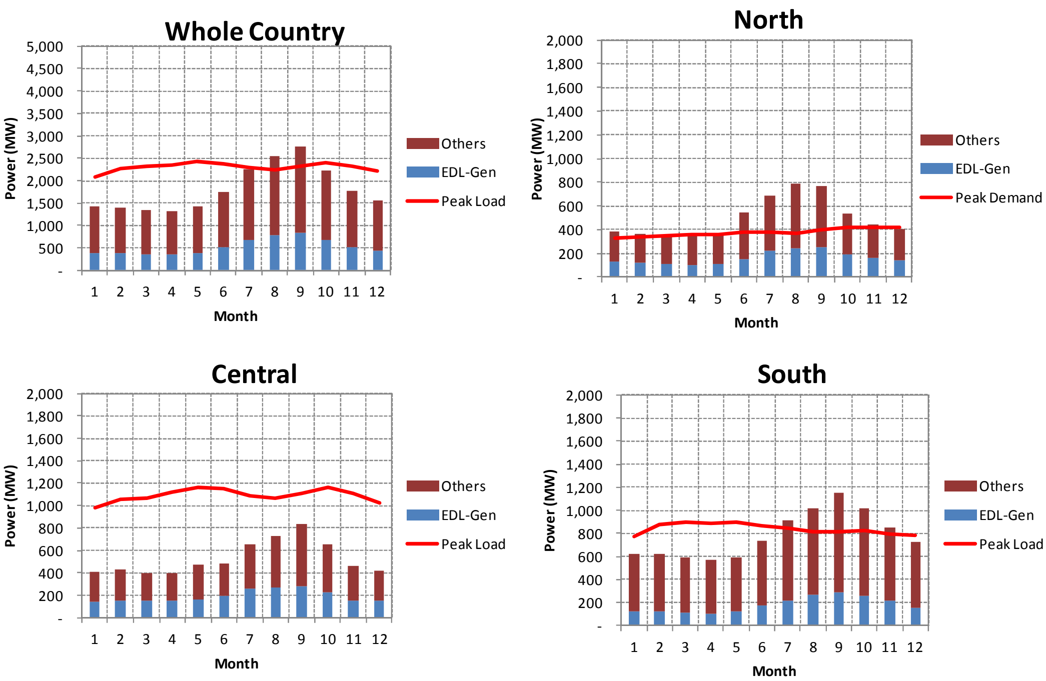
Southern Area

Prepared by the Study Team

Figure 3.4.3 Estimated Monthly Energy for the Northern, Central, and Southern Areas

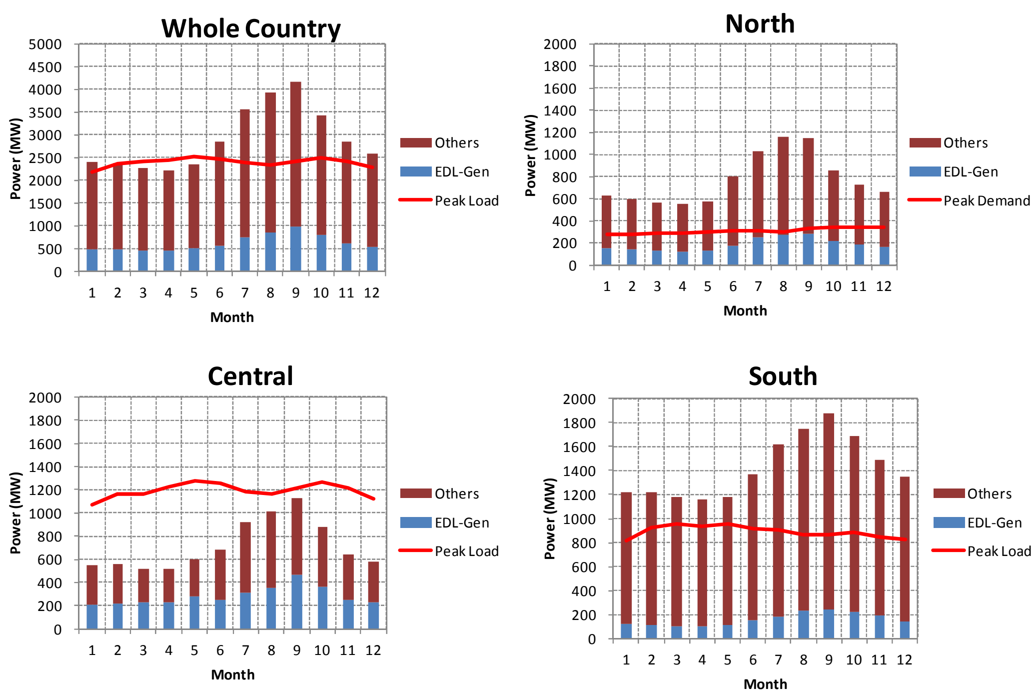
(5) Monthly Demand–Supply Balance

The monthly demand and supply balance for the whole country, northern, central, and southern areas for year 2017, 2020 and 2025 cases are shown in Figure 3.4.4, Figures 3.4.5 and 3.4.6, respectively.



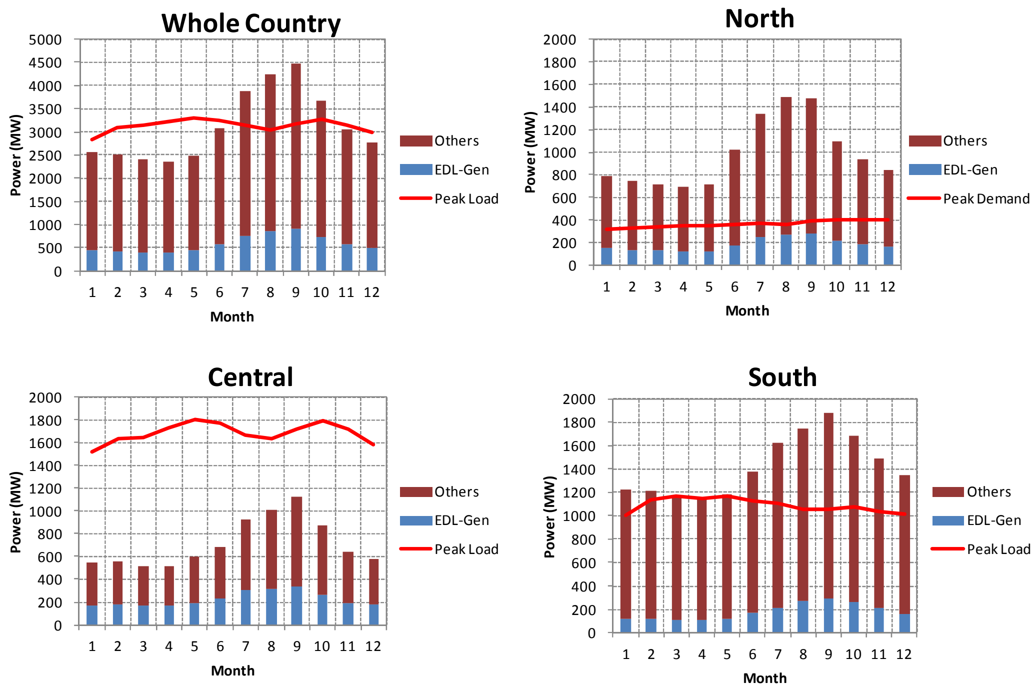
Prepared by the Study Team

Figure 3.4.4 Monthly Power Supply and Demand Balance (Year 2017)



Prepared by the Study Team

Figure 3.4.5 Monthly Power Supply and Demand Balance (Year 2020)



Prepared by the Study Team

Figure 3.4.6 Monthly Power Supply and Demand Balance (Year 2025)

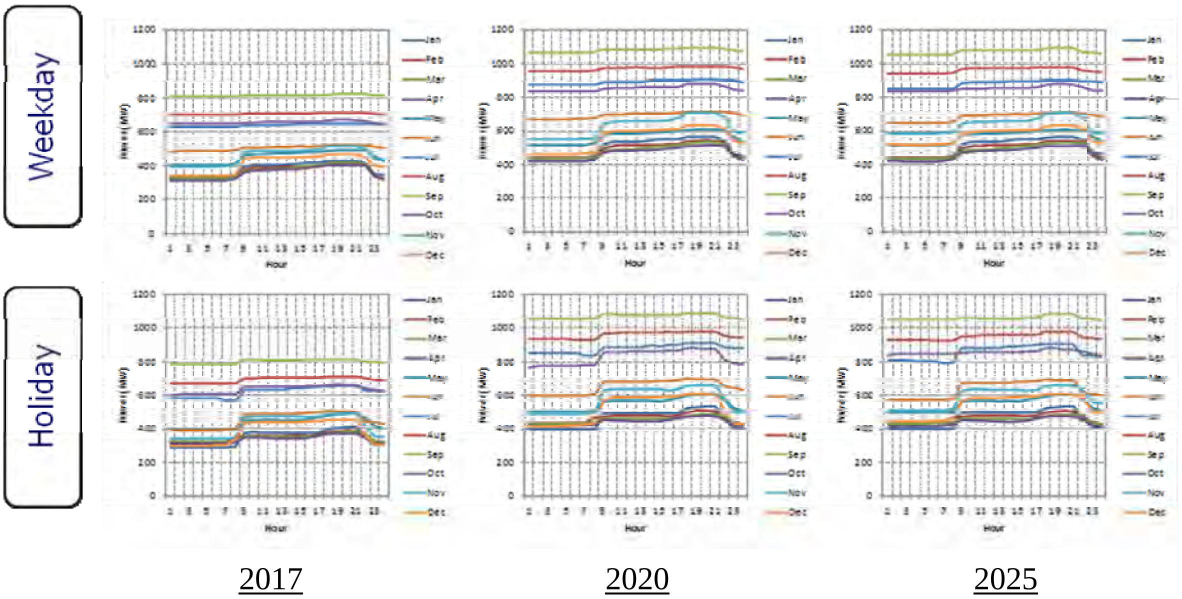
Figure 3.4.4 shows that the monthly power supply during dry season could not meet the demand aggregates of the whole country in 2017. The power supply in the northern area in dry season is almost the same to the peak demand, and the power supply is not enough to cover the demand in the southern area.

The power deficit in the southern area will be covered by importing power from EGAT. The power shortage in the central area is about 700 MW and this amount should also be imported from EGAT. The power shortage of 700 MW in the central area is difficult to be covered by domestic power plants even if the power operation of all EDL power generation plants change their operation to peak power supply. The power situation in 2017 will be severe for the power supply and demand balance.

Figure 3.4.5 shows that the power supply balance of the whole country is almost exceeding to the peak power demand in 2020. The power shortage in the central area will be covered by the power transferred from the northern and southern areas in 2020. In 2025, power demand will exceed the peak power demand during dry season, thus EDL will import power from EGAT during this season as shown in Figure 3.4.6.

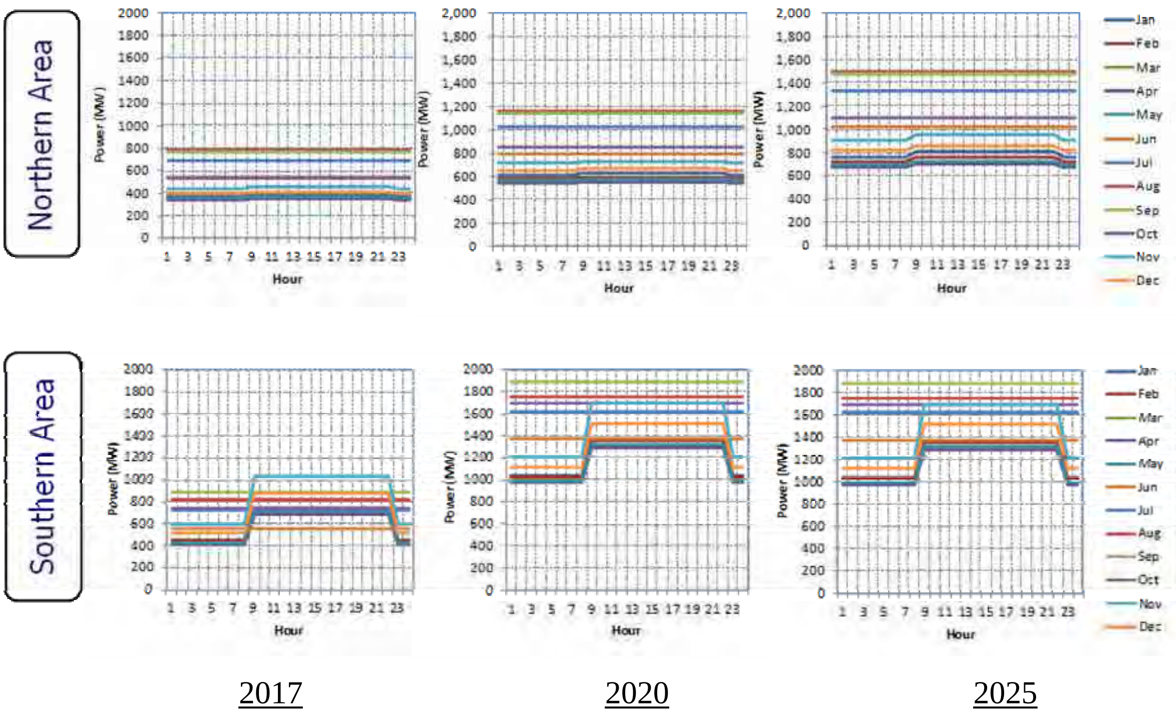
(6) Estimated Daily Operation

The daily operational pattern was estimated by considering the role of hydropower corresponding to the reservoir size and owner type. Then the monthly energy was allocated in the daily operation. The daily power operation in northern, central and southern area was estimated for year 2017, 2020, and 2025. The results are shown in Figures 3.4.7 and 3.4.8.



Prepared by the Study Team

Figure 3.4.7 Estimated Daily Power Generation in the Central Area



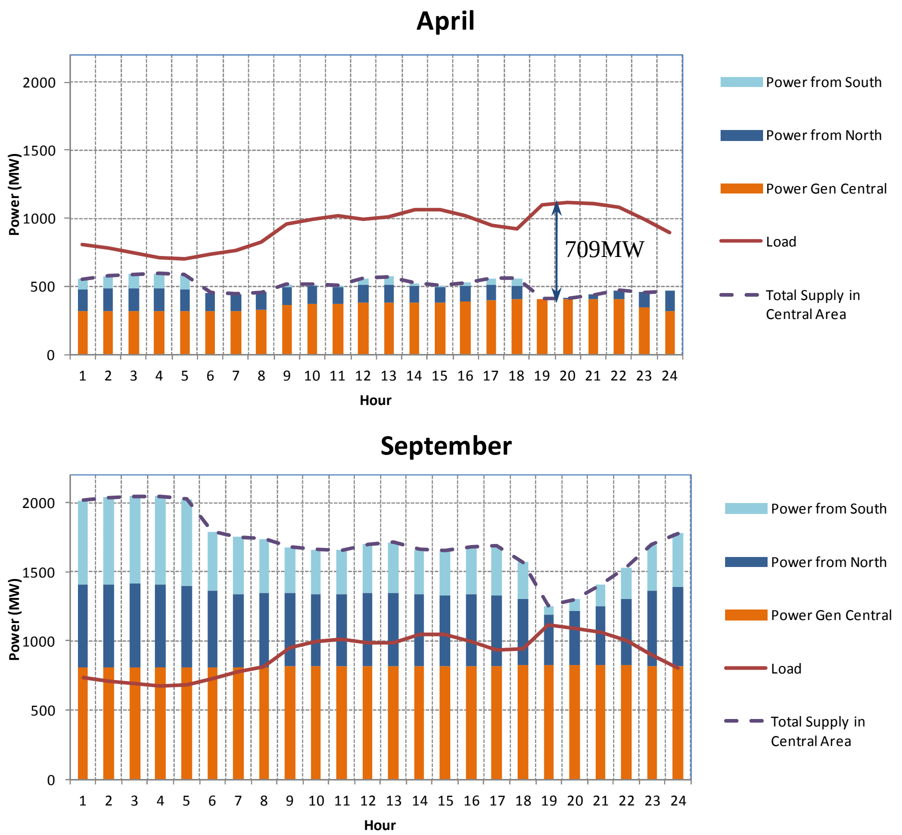
Prepared by the Study Team

Figure 3.4.8 Estimated Daily Power Generation in the Northern and Southern Area

<u>Daily Demand–Supply Balance in the Central Area of Lao PDR</u>

The daily power supply and demand balance for dry and wet seasons in the central area in 2017 is shown in Figure 3.4.9. The power supply to the central consists of power output of hydropower stations in central area and power delivered from the northern and southern areas by assuming a surplus power in northern and southern area going to the central area. As shown in the figure the power coming from the northern area and southern areas is limited especially during night peak hours as the power in the north and south is locally consumed before transferring to other area. The power shortage for peak hours in the central is estimated at 709 MW at maximum.

The power supply and demand balance in September (wet season) shows that the power supply will exceed the power demand in the central area with power delivered from the northern and southern area. However, the surplus of power supply for peak hours at night time is relatively small compared with the off-peak hours because the power in the northern and southern area are locally consumed at night time before transferred to other areas.



Prepared by the Study Team

Figure 3.4.9 Daily Power Supply and Demand Balance (Year 2017)

3.5 ISSUES OF POWER SUPPLY FOR PEAK POWER DEMAND IN THE CENTRAL AREA

As a result of the above analyses, the issues of power supply for peak power demand in the central area are summarized below.

(1) Reduction of Actual Power Generation during Dry Season

Most of the power consumed in Laos is currently provided by hydropower plants and shortage is compensated by power import from neighboring countries. It is well known that the actual power output of hydropower plants is extremely lower than the rated output of generators during dry season.

Power supply to the central area was assumed to have shortage during peak demand throughout 2017, whereas the north and south areas will have a surplus during wet season which will then be transferred to the central area. However, during dry season, even both northern and central areas will face shortage in power supply. The problem therefore will be the central area not receiving power from the northern or southern areas. During dry season, power import is the only way to compensate power shortage.

(2) Power Shortage for Peak Time Demand

It is observed in the demand–supply balance for 2017 that the expected 709 MW power shortage will be very sever during peak hours between 19:00 to 20:00 in April. EDL is required to secure a peak load power supply capacity against the peak demand during dry season.

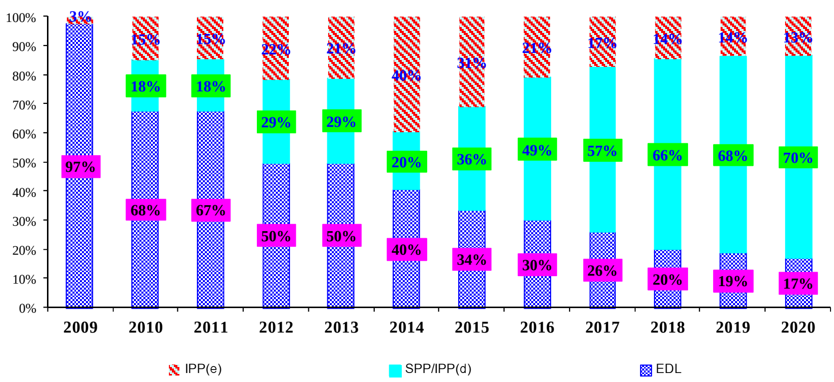
(3) Over Reliance on Power Import in the Future from View of Power Supply Security

If the shortage of electricity in Lao PDR is fully compensated by importing, it is projected that in the future, the proportion of power import to the demand in central area will vary approximately from 20% to 60% during dry season (November to May) in 2017. 60% power supply during peak time must especially depend on the importation of power from Thailand. The power system operation in Lao PDR relies on the power system of EGAT in Thailand.

The situation of overreliance on the EGAT system should be improved so as to reduce the proportion of power importation as much as possible from a viewpoint of power supply security.

(4) Low Proportion of Controllable Power Supply Capacity to the Whole Power Supply Capacity

The proportion of the installed generation capacity of EDL-owned power stations will reduce from 68% in 2010 to 17% in 2020.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total Supply by EDL	385	391	391	398	500	640	845	885	969	969	969	969	969	969	969	969
Total Supply by IPP(d)	100	104	225	233	247	679	1,394	1,948	3,185	3,518	3,976	4,286	4,286	4,286	4,286	4,286
Total Supply by IPP(e)	85	85	170	170	492	592	592	592	704	704	764	811	811	811	1,075	1,075
Whole Country	570	579	786	802	1,240	1,911	2,831	3,425	4,858	5,191	5,709	6,066	6,066	6,066	6,330	6,330

Prepared by the Study Team, updating PDP

Figure 3.5.1 Installed Generation Capacity by Ownership

EDL, as owner of the power plants has produced 391 MW of the 579 MW (67% generation capacity) in 2011. Many IPP domestic power generation projects will be completed in 2017 to 2018, although EDL-owned generation capacity will be 885 MW, the occupancy rate will decrease to 25% out of the rapidly growing generation capacity in the whole country of 3425 MW. In 2020, the proportion will be further decreased to 17%.

Generally, the IPP’s daily generation pattern is regulated under the conditions mentioned in the PPA between EDL and IPP. The operation cannot flexibly be controlled by EDL due to its intension to increase or decrease the generation according to the power network which changes from time to time.

EDL is recommended to secure more EDL-owned power stations for domestic supply in the future. At least the project of EDL power plants should be implemented on schedule as much as possible.

CHAPTER 4 COMPARATIVE STUDY FOR REINFORCEMENT OF PEAK POWER SUPPLY IN THE CENTRAL AREA

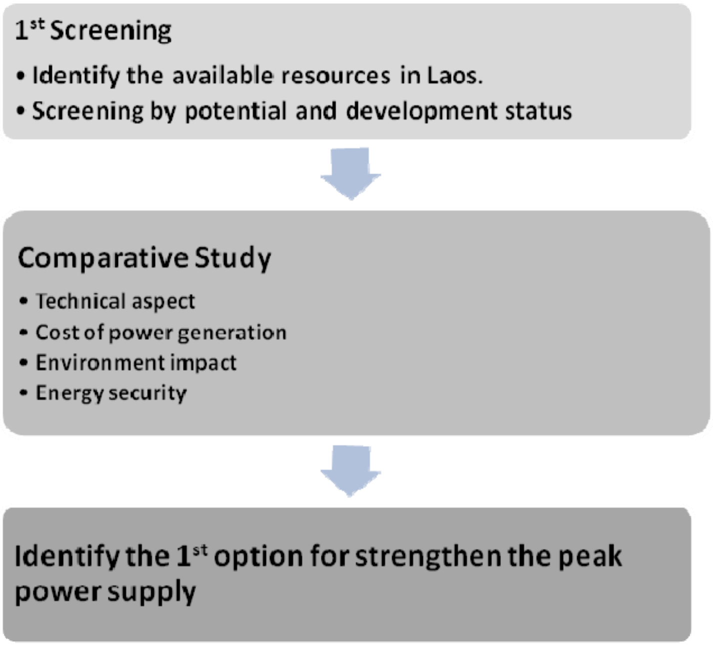
4.1 OBJECTIVE

In the previous chapter, it was identified that the central area of Laos will face a shortage of over 700 MW of power supply in the central area during peak hours at night in 2017. This shortage is anticipated five years after this study period, and hence, the power supply capability especially for peak hours should be urgently strengthened to secure a stable power supply.

In this chapter, countermeasure to strengthen the peak power capacity is examined considering the possible measures applicable to Lao PDR. A comparative study of options is carried out to select the most effective option for reinforcing the peak power supply.

4.2 METHODOLOGY

As this Study aimed to identify the power sources to physically reduce the power shortage of over 700 MW in 2017, a medium to large scale power source was considered for comparative study. Such bulk power sources were selected by screening applicable power sources in Lao PDR. Then, the options were compared in detail. The procedure for selecting the best option is as follows.



Prepared by the Study Team

Figure 4.2.1 Flow Chart for the Comparative Study for Reinforcement of Peak Power Supply in the Central Area

The criteria for screening the alternatives are shown in Table 4.2.1.

Table 4.2.1 Assessment Criteria for Screening Options

Item	Assessment Criteria
(1) Potential	Examining the potential or resource of options. If potential or resource is not available for peak power supply, the option will be eliminated.
(2) Exploitation/Development Status	Examining the development status of the option. If the potential or resource is not exploitable or the technology to harness the energy is not available in Laos, then it is not a realistic option. In this case, the option will be eliminated from the list.

Prepared by the Study Team

As this Study seeks the bulk capacity of power sources, mini or micro hydropower is not considered.

After 1st screening of the options, remaining options were compared considering the items shown in Table 4.2.2.

Table 4.2.2 Assessment Criteria for Comparative Study

Item	Assessment Criteria
(1) Technical Aspect	Options are evaluated for technical aspects like technical difficulties.
(2) Energy Security	The options are compared for energy security i.e. increasing self-sufficiency rate and ensuring power supply stability.
(3) Cost of Power Generation/Purchase	The cost comparison is performed for the preliminary survey level.
(4) Environmental Issue	The environmental issues are studied for each option.

Prepared by the Study Team

After the comparative study, each option was prioritized considering the future power generation plan.

4.3 SCREENING OF ALTERNATIVE POWER SOURCES

Prospective Power Sources

(1) Outline of Alternative Energy Sources

The energy sources used or applicable to Lao PDR is shown in Table 4.3.1.

First Screening of Options

This Study sought for a power source to mitigate the large shortfall during peak hours, such power source should be exploitable and realistic for use as power generation in Lao PDR. The criteria involved in the first screening of options are potential and exploitation status. The result of the evaluation is described below:

(1) Criteria 1: Potential

Coal thermal was eliminated since the exploitable coal reserve is limited in Lao PDR. In addition, coal thermal was regarded as base power supply, which lacked flexibility to meet operation for peak power supply. Therefore, coal thermal was not appropriate for peak power supply. Other resources may not have significant problems in potential aspects.

Table 4.3.1 Energy Sources and Energy Production Methods for Selection of Options

Energy Source	Energy Production Method
Hydropower (Large scale hydro; NN1 Expansion*1)	The electric energy is produced by converting the hydraulic potential energy to electric energy using turbine and generators. The large scale hydro capacity is more than 15MW in Lao PDR. Nam Ngum 1 (NN1) expansion is the first candidate as hydropower exploitable source (See note *1).
Hydropower (Small scale hydro)*2	Hydropower plants with capacity of less than 15 MW are categorized as small scale hydropower.
Coal Thermal	Electric energy is produced by converting heat energy to mechanical energy (steam turbine). Heat energy is produced through coal combustion.
Diesel Engine (Heavy Oil)	Diesel engine is used to drive electric generator. The scale of generator ranges from several kW to MW.
Renewable Energy	Renewable energy comes from natural resources that are replenished at a faster rate than they are consumed. Solar, biomass, wind, and hydro are common renewable energy sources.
Power Import	Power import from neighboring countries is considered as energy source since this option involves directly receiving energy in the form of electricity.

Note;) In the above table, natural gas is not imported from neighboring country in Lao PDR; therefore natural gas is eliminated since its use is not a realistic option.
*1: Since economically and financially viable hydropower potential sites have already been identified, and development rights are held by project owners, NN1 expansion is considered as the first candidate for large scale hydropower since such expansion includes EDL's power station where environmental issues are cleared.
*2: Small scale hydro is normally considered as a form of renewable energy. However, in Lao PDR, small scale hydro involves an installed capacity of less than 15 MW, which can also be considered as medium scale power plant. Therefore, small scale hydro is separated from the renewable energy group.
Prepared by the Study Team

(2) Criteria 2: Exploitation/Development Status

Renewable energy such as biomass, biofuel, solar, etc. were eliminated since renewable energy other than small hydropower was not a realistic option for bulk power supply. Laos has a biomass potential of 938 MW; however, its used as a biomass power scheme is still under the trial stage.

Large scale and small scale hydropower, and power import were not eliminated since these power serve as substantial power sources in Lao PDR. The diesel engine generators remained as these are still being used in Laos despite its small scale and heavy oil being transported using vehicles. Further, diesel engine generator option may be necessary as an urgent back up for power supply when importing power was not available.

(3) Result of 1st Screening

In summary, the coal thermal and renewable energy, except small scale hydro, were eliminated from the candidate list. The remaining options for comparative study are as follows:

- Large scale hydro (NN1 expansion);
- Small scale hydro;
- Power import; and
- Diesel engine.

4.4 COMPARATIVE STUDY OF OPTIONS

Technical Assessment of Options

Options are evaluated to 3 grade rating, A is highest and C is lowest. The options are assessed with the technical aspects for technical difficulties, survey maturities, lead time to construction, life span of the options. A comparative study for the technical aspects are shown in Table 4.4.1.

Table 4.4.1 Summary of Technical Assessment of Options

Options	Technical Difficulties	Survey Maturities	Lead Time	Life Span	General Rating for Technical Assessment
Large Scale Hydropower (NN1 Expansion)	B	A	A	A	A
Small Scale Hydropower	B	C	B	A	B
Diesel Power Plant	A	B	A	C	B
Power Import	N/A	N/A	A	A	A

Prepared by the Study Team

Comparison of Energy Security of Options

In this Study, the Study Team considered energy security for self-sufficiency, power supply stability, and availability of energy source for long term span. A comparative study on energy securities is shown in Table 4.4.2.

Table 4.4.2 Summary of Energy Security Comparison for Each Option

Options	Self-sufficiency	Power Supply Stability	Long Term Availability	General Rating for Energy Securities
Large Scale Hydropower (NN1 Expansion)	A	A	B	A
Small Scale Hydropower	A	B	B	B
Diesel Power Plant	C	A	C	C
Power Import	C	A	B	B

Prepared by the Study Team

Cost Comparison of Options

The costs data of each option were considered in this assessment. For power sources which do not have precedents in Lao PDR such as those from diesel power plants, available cost in neighboring countries were used as reference in this Study. The cost was evaluated considering price range due to variety of unit size, fuel materials, and so on.

The result of cost comparison of the options is shown in Table 4.4.3.

Table 4.4.3 Cost Comparison of Options

	Development Cost (USD/kW)	O&M Cost (USD/kW/year)	Unit Cost of Power Generation (USD/MWh)	Rating
Large Scale Hydro (NN1 Expansion)	1620	7.5	40-80	B
Small Scale Hydro[*2]	2500-4700	4-90	40-80	C
Diesel Engine	960	-	148	C
Power Import	Peak (THB/kWh) 1.74	Off Peak (THB/kWh) 1.34		A[*1]

Note;) *1: Rating "A" is conditional as power import tariff is set to a quite low rate, which assumes mutual interchange.
*2: Referred from "Renewable Energy Development Strategy in Lao PDR", 2011, MEM.
Prepared by the Study Team

Among other power source options, power import from EGAT was apparently the most cost-efficient option. As analyzed in Section 5.6, NN1 expansion's benefit-cost (B/C) ratio was estimated at 0.47 by taking the power trade surplus as an economic benefit. However, the power trade between EDL and EGAT was regarded as mutual interchanges under the international cooperation; and the export and import tariff may not fully represent the actual cost of power supply. In fact, EGAT charged much more expensive rates (Peak: THB 3.8376/kWh, Off-peak: THB 2.3966/kWh) to domestic customers. If said economic analysis applies these EGAT domestic tariff rates as benefits, the B/C ratio of the expansion project will go up to around 1.1, which indicates that the expansion has more economic viability than the power trade option.

<u>Assessing from the Natural and Social Environmental Aspects</u>

(1) Natural Environment

Negative impacts on the natural environment from each electricity generation option were studied from the viewpoint of air quality, eco-system and consumption of natural resources. Consequently, the option of "Increased Capacity on Existing Hydropower" has the least impact on the natural environment followed by the option of "Power Import", "Small Hydro" and "Diesel Engine". A summary of the comparative study from natural environment is shown in the Table 4.4.4.

Table 4.4.4 Summary of the Comparative Study from the Natural Environmental Point of View

Options	Description	Rating
Increased Capacity on Existing Hydropower	-Not increase energy thus no emission of CO_2, SO_2, or NOx -Negative impact is expected on water flow -Negative impact is site-specific -Type of energy resource is renewable	A
Small Hydro	-Very low emission of CO_2, SO_2, and NOx -Negative impact is expected on water quality and ecosystem -Emitted waste is mostly organic -Negative impact is site-specific -Type of energy resource is renewable	C
Diesel Engine (Heavy Oil)	-Emission of CO_2, SO_2, and NOx are expected -Negative impact is expected on water quality and ecosystem -Emitted waste includes toxic chemical compounds -Negative impact is not site-specific -Type of energy resource is nonrenewable	C
Power Import (Natural Gas)	-Not increase energy thus no emission of CO_2, SO_2, or Nox in Laos - Emission of CO_2, SO_2, or Nox is expected in Thailand -Type of energy resource is non renewable	B

Prepared by the Study Team

(2) Social Environment

Negative impacts on the social environment from each electricity generation option were studied from the viewpoint of resettlement, agriculture, fishery, tourism and human health. Consequently, the options of “Increased Capacity on Existing Hydropower” and “Power Import” have the least impact on the social environment followed by the option of “Small Hydro” and “Diesel Engine”. A summary of the comparative study from the social environment is shown in the Table 4.4.5.

Table 4.4.5 Summary of the Comparative Study from the Social Environmental Points of View

Options	Description	Rating
Increased Capacity on Existing Hydropower	-No land acquisition -No negative impact on agriculture, fishery, tourism or human health	A
Small Hydro	-Land acquisition is expected -Negative impact is expected on agriculture, fishery, tourism	C
Diesel Engine (Heavy Oil)	-Land acquisition is expected -Negative impact is expected on agriculture, fishery, tourism	C
Power Import (Natural Gas)	-No land acquisition -No negative impact on agriculture, fishery, tourism or human health	A

Prepared by the Study Team

<u>Comparison Result of Options</u>

The comparison results of the options are summarized below.

Table 4.4.6 Comparison Results of Options

Options	Technical Assessment	Energy Securities	Cost	Environment	General Rating by Score
Large Scale Hydropower (NN1 Expansion)	A	A	B	A	11
Small Scale Hydropower	B	B	C	C	6
Diesel Power Plant	B	C	C	C	5
Power Import	A	B	A	B	10

Note) General rating by score is aggregates of points by assuming A = 3 pts, B = 2 pts, and C = 1 pt.
Prepared by the Study Team

According to the above comparison table, power import and large scale hydro (NN1 expansion in this case) have almost the same rating. NN1 expansion however has a slightly better score. The NN1 expansion is advantageous in terms of energy securities, but the cost comparison has lower score than that of power import option. However, as it is noted in previous section, this result was due to the low tariff rate determined under mutual interchanges as well as international cooperation. EGAT charged much more expensive rates (Peak: THB 3.8376/kWh, Off-peak: THB 2.3966/kWh) to domestic customers. If said economic analysis applies these EGAT domestic tariff rates as benefits, the B/C ratio of the expansion project will go up to around 1.1, which indicates that the expansion has more economic viability than the power trade option.

Therefore, it was concluded that the large scale hydropower development considering NN1 expansion was the first priority project to strengthen the peak power supply capacity. Subsequently, the power import, small scale hydropower and diesel power plant followed.

Although the power import is ranked in second, power import from EGAT is still important for power supply of EDL. Importing from EGAT is important with respect to the power supply reliability for EDL. The detail of role of power import to EDL is described in Chapter 7.1.

4.5 CONCLUSION OF COMPARATIVE STUDY OF OPTIONS

A comparative study was carried out among the possible candidate options in Lao PDR. After the screening and subsequent comparative study, it was concluded that NN1 expansion was the first option to strengthen the peak power supply in the central area.

However, it does not mean that the power import option should be abandoned as it still takes a substantial role in power supply in the central area. In 2017, over 700 MW power should be imported although the NN1 expansion scheme is implemented. It is noted that the power supply capacity should be developed continuously to meet the increasing power demand in Lao PDR.

CHAPTER 5 CONFIRMATION OF THE ROLE OF NAM NGUM 1 HYDROPOWER EXPANSION IN UPDATED POWER SUPPLY AND DEMAND

5.1 PRESENT CONDITION OF NN1 HYDROPOWER STATION

History of NN1 Hydropower Development

The Nam Ngum 1 (NN1) hydropower station was constructed having a capacity of 7 billion m^3, which is the largest reservoir size in Laos. The NN1 Hydropower Station started generating electricity with an initial 30 MW power capacity in 1971. The NN1 hydropower station has been expanded twice to produce 110 MW in 1978, and 150 MW in 1984 in order to meet the increasing power demand in the central area. The present installed capacity is 155 MW. The plant factor of the power station was at 66% in the beginning of its operation. Plant factor further was increased to 74% due to the increase of inflow to the reservoir from the Nam Son diversion which was constructed in 1995 and the Nam Leuk Hydropower Project that was developed in 2000. The increment of inflow to the NN1 reservoir by Nam Son diversion and Nam Leuk hydropower station are at 65 m^3/s and 15 m^3/s, respectively. The principal features of NN1 hydropower station are shown in Table 5.1.1.

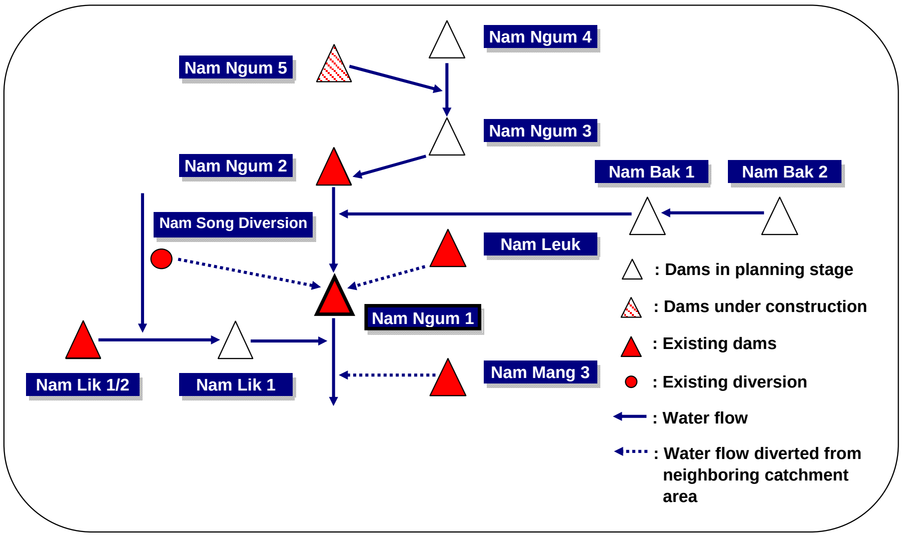
Table 5.1.1 Principal Features of the Nam Ngum River Basin and NN1 Hydropower Station

Feature	Data	Description
River Basin Area	8,460 km^2	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	155 MW	Unit 1, 2 : 17.5 MW x 2, Unit 3, 4, 5 : 40 MW x 3
Max. Plant Discharge	465.3 m^3/s	57m^3/s x 2, 117.1 m^3/s x 3
Reservoir Capacity	7.03 billion 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 the Study Team

Development of Water Resource in the Upstream of NN1

The upstream of NN1 dam is intensively developed and is used mainly for hydropower project. The hydropower development in the Nam Ngum River basin is shown in Figure 5.1.1.



Prepared by the Study Team

Figure 5.1.1 Hydropower Development in the Nam Ngum River Basin

The principal feature of the planned/existing hydropower development in the upstream of NN1 is shown in Table 5.1.2.

In 2010, the Nam Ngum 2 (NN2) Hydropower declared its initial operation day (IOD) and started operation for hydropower generation. So far, NN2 has not declared a commercial operation day (COD), therefore, NN2 operation does not meet operation requirements stipulated in the PPA. It is expected that the operation of NN2 will be changed after the COD which is expected by the end of 2012 or January 2013. The actual operation of the NN2 in compliance with the PPA is still unknown during this study unless NN2 states COD. Therefore the impact of the NN2 operation to NN1 reservoir cannot be determined yet.

Table 5.1.2 Principal Features of Planned Hydropower Station in Upstream of NN1

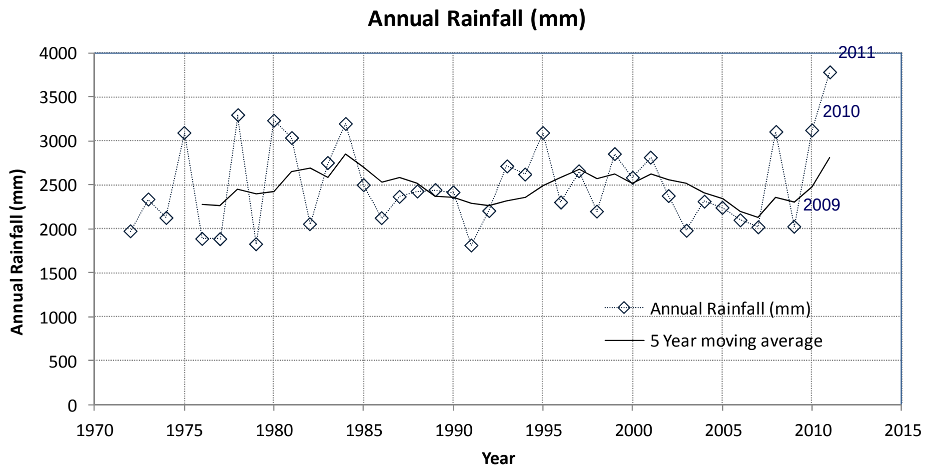
Items \ Project	Nam Ngum 2	Nam Ngum 3	Nam Ngum 4	Nam Ngum 5	Nam Bak 1	Nam Bak 2
Purpose	IPP (Export)	IPP (Export)	IPP (Export)	IPP (Domestic)	IPP (Export)	IPP (Domestic)
Status	Existing	PPA Signed	Pre-F/S	Under construction	Pre-F/S	Pre-F/S
Main Developer	Southeast Asia Energy Limited (Thailand)	GMS Power	Saigon Invest Group	NN5PC	Southeast Asia Energy Limited (Thailand)	Southeast Asia Energy Limited (Thailand)
Planned Commencement of Power Generation	December 2010	-	-	2012	-	2015
Principal Feature						
Catchment area (km_2)	5,640	3,888		483	597	320
Storage at FSL (MCM)	2,617	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 the Study Team

Updating Hydrology

(1) Annual Precipitation

The annual rainfall observed in the NN 1 hydropower station is shown in Figure 5.1.2.



Prepared by the Study Team

Figure 5.1.2 Observed Annual Rainfall at NN1 Hydropower Station

It is noted that the annual rainfall observed in 2011 recorded the highest amount since NN1 commenced its operation in 1972. The annual rainfall in 2010 and 2011 were higher than the average of 2500 mm a year.

(2) Inflow Update

The inflow data is received from the NN1 Power Station. The inflow collected into the NN1 reservoir for the past five years is shown in Figure 5.1.3.

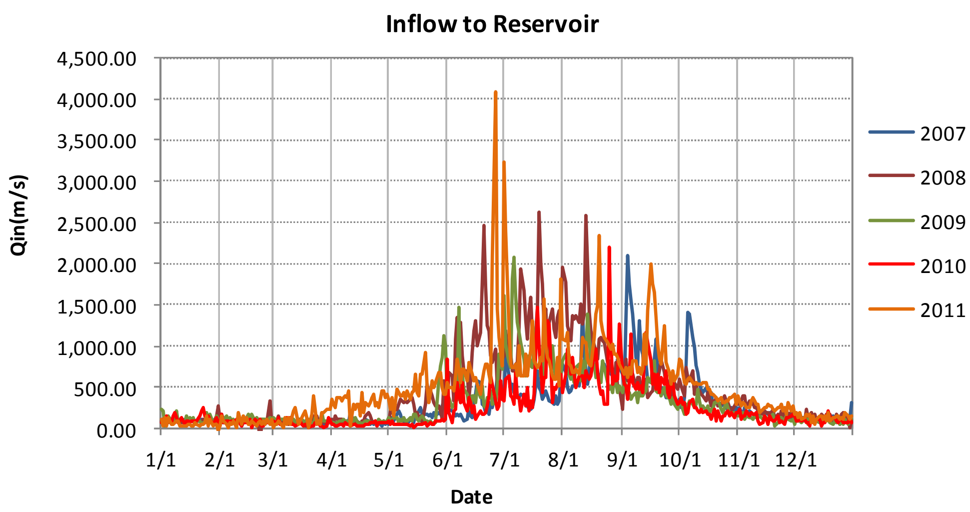


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Figure 5.1.3 Observed Inflow into NN1 Reservoir

Reservoir Operation and Power Generation

(1) Reservoir Operation

The reservoir operation record of NN1 is shown in Figure 5.1.4.

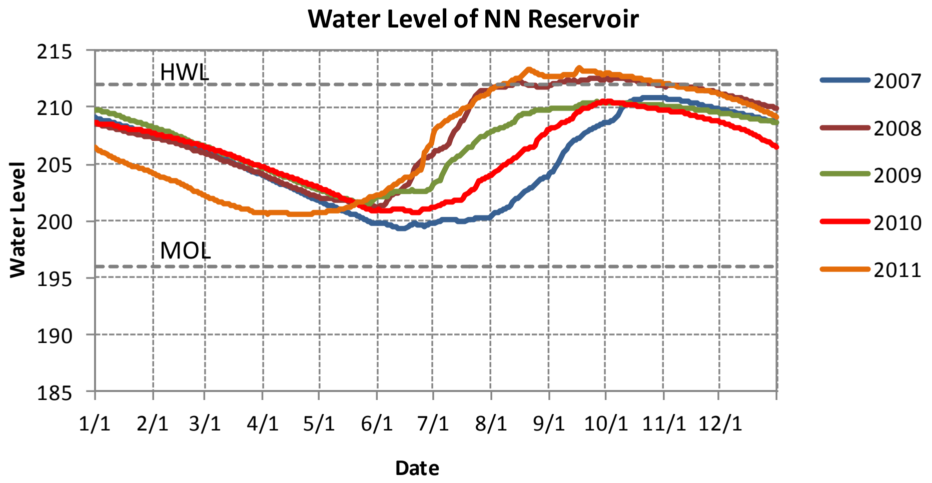

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Figure 5.1.4 Reservoir Operation Record of NN1 Reservoir

It is noted that the water level in wet season in 2010 was relatively lower than those of the other years due to the impounding done at NN2 reservoir. In 2011, the starting water level is lower than other years since the water level could not be recovered during the year 2010 due to impounding of NN2. However, the water level was quickly recovered to HWL in 2011, due to the largest rainfall ever recorded that year.

(2) Power Generation

The power generation for the past five years are shown in the table below.

Table 5.1.3 Monthly and Annual Energy Production

(Unit; GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2007	72	71	83	80	73	58	76	63	58	63	80	72	852
2008	68	66	80	80	89	96	117	122	125	129	88	86	1,146
2009	84	82	83	76	71	78	109	121	105	93	58	57	1,017
2010	61	58	72	66	72	63	49	56	79	84	71	100	832
2011	85	73	72	68	68	68	116	128	125	128	112	110	1,154
Avergae	74	70	78	74	75	73	93	98	98	100	82	85	1,000

Prepared by the Study Team

As shown in the Table 5.1.5 above, the annual energy was largest in 2011 and the annual energy was smallest in 2010 due to the NN2 impounding.

5.2 OUTLINE OF NN 1 HYDROPOWER STATION EXPANSION

In this chapter, the contents of the preparatory survey on the Nam Ngum 1 hydropower station expansion in 2010 is briefly explained.

(1) Selection of Optimum Scale of Expansion

In the preparatory survey on NN1 expansion in 2010, the eight alternative plans varying installed capacity from 40 MW to 120 MW were considered. Among the eight alternative plans, four options were selected, namely, A1-A2, A4, B2, and D2. These four options are compared, and the 40 MW expansion plan (A1) was selected as the most optimum expansion scale considering the economical and financial B/C ratios, stability analysis of load flow, environmental impacts, and construction method. In the preparatory survey, basic design was conducted for the expansion plan. The plan and section of the 40 MW expansion plan is shown in Figure 5.2.1.

(2) Role of NN1 Expansion in Power Supply in the Central Area

The role of NN1 hydropower station expansion in power supply in the central area is;

1) To enable to meet the increasing power demand especially during night peak hours, the expansion of NN1 hydropower station enables to shift off peak energy during peak hours by utilizing the massive NN1 reservoir capacity.
2) To enable NN1 power plants with low cost maintenance as the operation hours per unit is decreased.
3) To enables EDL to export surplus power to EGAT during rainy season. The capacity of interconnection between the EGAT and EDL grid is planned to be reinforced from 100 MW to 600 MW in 2016.

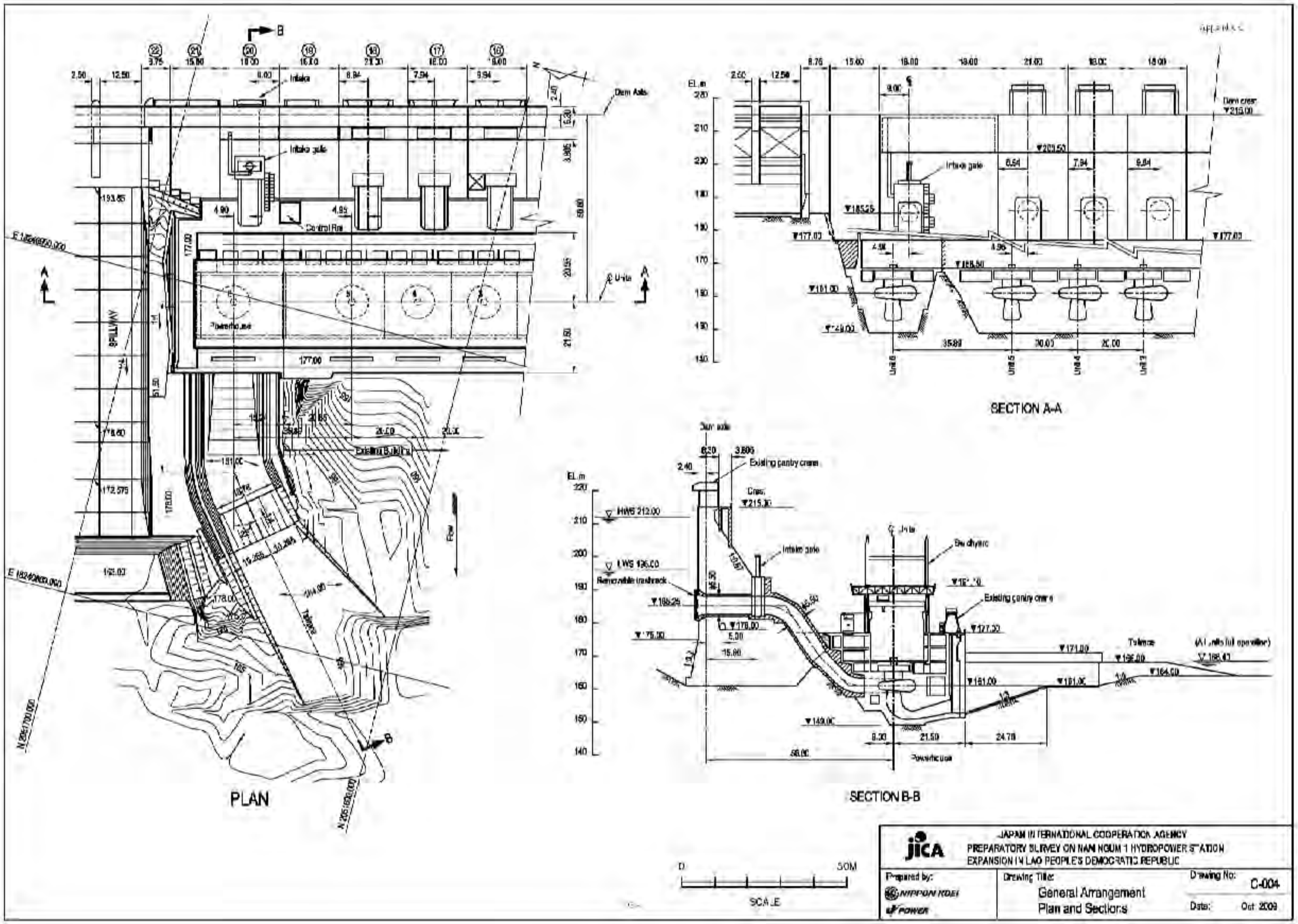
(3) Reservoir Operation Plan

The expansion of NN1 hydropower station increases the flexibility of reservoir operation. The current annual energy production of NN1 is 1012 GWh and is expected to increase to 1071 GWh (59 GWh increase) after the NN2 completion. Also, the NN1 expansion will produce annual energy of 1127 GWh (56 GWh increase with NN2 case without expansion).

(4) Environmental and Social Considerations

Unlike the new hydropower scheme, the expansion of the existing NN1 Hydropower station will have no significant environmental and social impact. This is because no additional reservoirs or transmission lines by the expansion.

The influence to the downstream environment due to the expansion would be the change in the water level fluctuation before and after expansion. The preliminary hearing survey for local inhabitants, and the hydraulic calculation was conducted in the preparatory survey. Results showed that the water level fluctuation was within the allowable level. The IEE was prepared and Environmental Compliance Certificate (ECC) was issued upon the completion and approval of IEE.



Source; Preparatory Survey of the Nam Ngum 1 Hydropower Station Expansion (2010)

Figure 5.2.1 Nam Ngum 1 Expansion Plan (Additional Unit No.6) in the Preparatory Survey in 2010

(5) Project Cost and Implementation Schedule

The project cost for the expansion was estimated to JPY 7006 million on the currency basis and price level as of August 2008. The construction period was estimated at 36 months (3 years), and commercial operation is expected in 2015.

(6) Economic and Financial Analysis

The economic analysis of expansion plan assumed the thermal power plant as an alternative power source. EIRR was calculated at 17.68% thus, it was economically feasible. However, the financial analysis resulted in that the FIRR of 2.75%. This is due to that the electricity tariff in Lao PDR was set to low level. Therefore, the survey concluded that expansion of NN1 is financially feasible only when the project was given a soft loan with low interest rate.

5.3 ROLE OF EXPANDED NN1 HYDROPOWER STATION IN UPDATED POWER SUPPLY AND DEMAND IN THE CENTRAL AREA

In this chapter, the expanded NN1 hydropower station operation is simulated using its updated inflow series up to 2011. The purpose of the simulation is to confirm the role of expanded NN1 station in the updated power supply and demand balance. The added inflow series are described in Section 5.1. The reservoir operation rule for the Study is the one applied in the Preparatory Survey in 2010. The power generation simulation was conducted using the inflow series from 1972 to 2011.

The construction of the NN1 expansion is considered to be completed in 2017. In 2017, the following supply and demand balance conditions are anticipated:

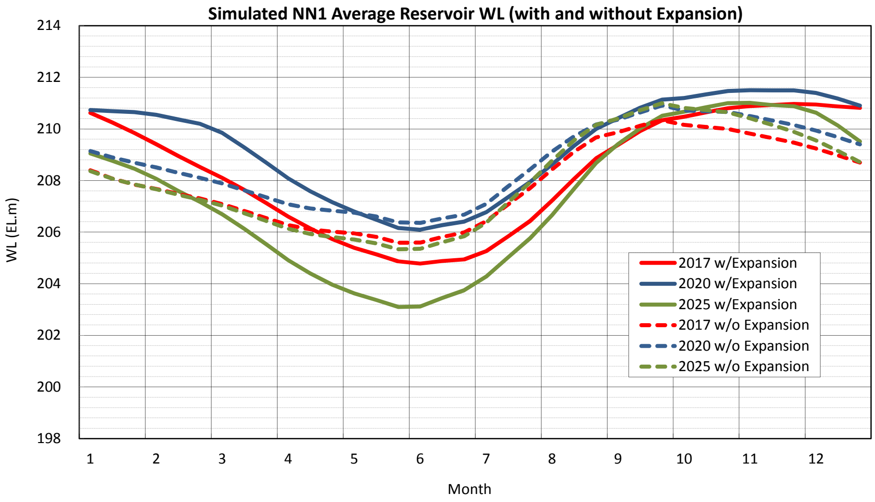
- The large scale IPP(d) hydropower will be developed in the northern area.
- Estimating power generation pattern in the northern area shows that the power generation will be 24-hour base load power supply. Thus, the power coming from the northern area forms as the base load supply in the central area.
- Importing power from the northern area will be reduced during peak hours due to consumption in the northern area. This will also be the case to the power coming from the southern area.

The power generation simulation is carried out for the NN1 Power Station for the years 2017, 2020 and 2025. For the simulation of 2017, the operation rule for 2015 which was developed in the preparatory survey was tentatively used.

Power Generation Simulation

(1) Reservoir Operation

The power generation simulation was carried out using the inflow series from 1972 to 2011 for the case with a 40 MW expansion and without a 40 MW expansion. The simulated reservoir water level for with and without the expansion for the year 2017, 2020, and 2025 is shown in Figure 5.3.1.

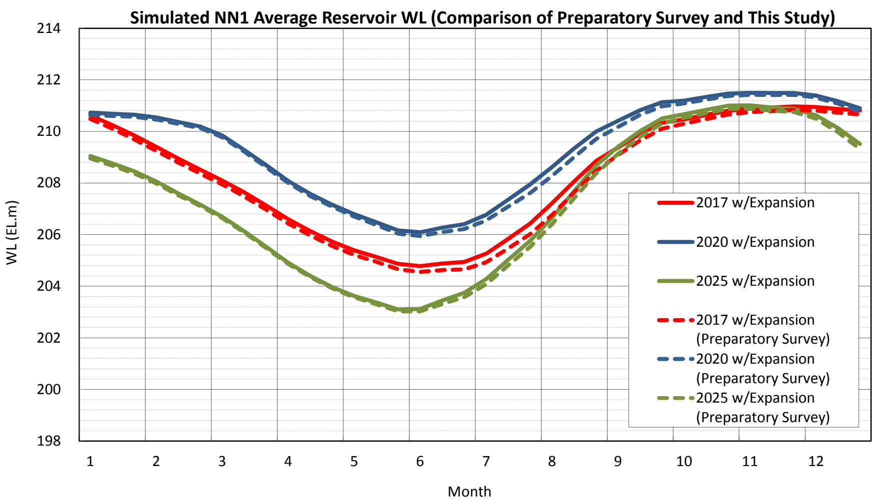


Prepared by the Study Team

Figure 5.3.1 Simulated Reservoir Water Level of NN1 with and without Expansion

The figure shows that the NN1 reservoir operation with 40 MW expansion case changes to lower the water level during the dry season so as to generate power in that season. By the end of the wet season, the water level is higher for the without expansion case to keep the water for the dry season.

The result of the water level was compared to the previous preparatory survey in 2010. The results of the Study on the reservoir water level of NN1 reservoir with expansion case and preparatory survey are shown in Figure 5.3.2.



Prepared by the Study Team

Figure 5.3.2 Comparison of Reservoir Water Level between This Study and Previous Preparatory Survey

The water level in this Study was slightly higher than those in the preparatory survey. This was due to including the 2011 flood event.

(2) Hourly Power Output

The daily power output pattern on weekdays and holidays is shown in Figure 5.3.3.

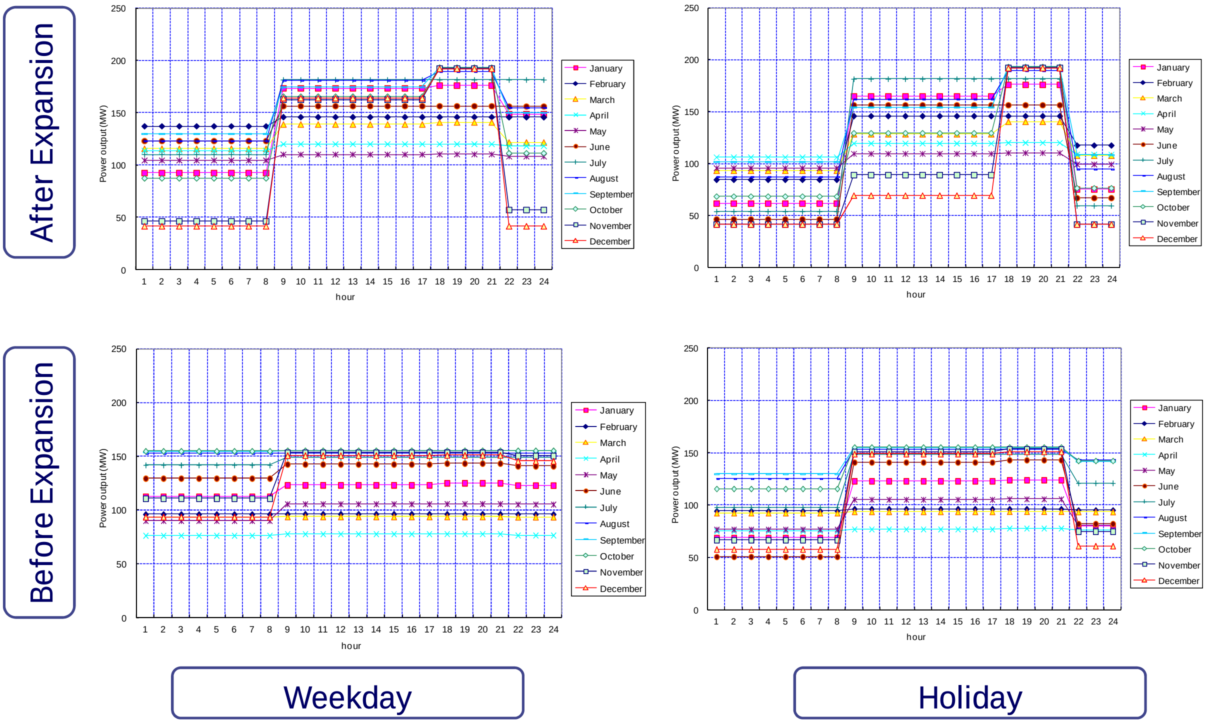


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Figure 5.3.3 Hourly Average Power Output of the NN1 Hydropower Station

As shown in the figure, the NN1 operation is change to peak power supply especially during dry season. The off-peak power output is decreased to 40 MW. The 40 MW generation is required by environmental aspect to release water equivalent to 40MW during the off-peak hours.

(3) Annual Energy

The power and energy output for with and without 40 MW expansion are shown in Table 5.3.1.

As shown in the table, the annual energy without expansion is 1064 GWh and 1130 GWh with expansion. The difference in energy is 66 GWh. In the previous preparatory survey in 2010, the increment of energy due to NN1 expansion was estimated at 54 GWh. The increase in the energy was due to the inclusion of the 2011 hydrology. The increment in the annual energy was 5% in the previous preparatory survey and 6% in this study. The difference is only 1% of the total energy.

In summary, it can be said that the increment of energy due to expansion to 40 MW will increase the annual energy from 5% to 6% .

Table 5.3.1 Calculated Annual Energy and Dependable Power

Before Expansion with NN2

Year	Anual Energy (GWh)	Average Energy: in Peak hours (GWh)	Average Energy: in Off-Peak hours (GWh)	Dependable Energy Weekday: Night Peak (GWh)	Dependable Energy Weekday: Daytime Peak (GWh)	Dependable Capacity (MW) (95%) Weekday 18:00-22:00	Weekday 9:00-18:00	Weekday 22:00-0:00	Weekday 0:00-9:00	Holiday 18:00-22:00	Holiday 9:00-18:00	Holiday 22:00-0:00	Holiday 0:00-9:00
2017	1,063	441	622	102	166	70	65	57	42	69	60	29	29
2020	1,066	450	616	115	200	79	78	60	38	79	72	31	31
2025	1,062	441	621	114	199	78	78	38	37	78	60	32	32
Average	1,064	444	620	110	188	76	74	51	39	75	64	31	31

After Expansion with NN2

Year	Anual Energy (GWh)	Average Energy: in Peak hours (GWh)	Average Energy: in Off-Peak hours (GWh)	Dependable Energy Weekday: Night Peak (GWh)	Dependable Energy Weekday: Daytime Peak (GWh)	Dependable Capacity (MW) (95%) Weekday 18:00-22:00	Weekday 9:00-18:00	Weekday 22:00-0:00	Weekday 0:00-9:00	Holiday 18:00-22:00	Holiday 9:00-18:00	Holiday 22:00-0:00	Holiday 0:00-9:00
2017	1,125	540	585	163	254	111	99	37	37	111	38	36	36
2020	1,146	553	593	170	281	116	110	38	38	116	39	37	37
2025	1,119	536	583	151	238	103	93	37	36	103	37	31	31
Average	1,130	543	587	161	258	110	101	37	37	110	38	35	35

Note: "Dependable Capacity (MW) (95%) is the power output at 95% of power duration curve. This value is equivalent to the capacity that is available at 95% of chance in a year.

Prepared by the Study Team

(4) Power Output in Updated Power Supply and Demand in the Central Area

The difference of the power supply and demand balance in the central area due to NN1 expansion is shown in Figure 5.3.4.

In the figure, the orange dotted line represents the power supply with 40 MW expansion of NN1 and the blue dotted line represents the power supply without 40 MW expansion. The figure shows the increment in power supply during dry season especially during peak hours.

Prepared by the Study Team

Figure 5.3.4 Hourly Power Supply and Demand in Central Area in 2017

The difference of power supply capacity between with and without NN1 expansion in the central area is shown in Table 5.3.2.

Table 5.3.2 Difference of Aggregate Power Output in Central Area between with and without Expansion of 40MW at NN1 Hydropower Station

Diffrence in power output for before and after expansion of 40MW												(Unit:MW)
	Month											
Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.0	-20	41	22	37	14	-6	-32	-30	-24	-68	-65	-52
2.0	-20	41	22	37	14	-6	-32	-30	-24	-68	-65	-52
3.0	-20	41	22	37	14	-6	-32	-30	-24	-68	-65	-52
4.0	-20	41	22	37	14	-6	-32	-30	-24	-68	-65	-52
5.0	-20	41	22	37	14	-6	-32	-30	-24	-68	-65	-52
6.0	-20	41	22	37	14	-6	-32	-30	-24	-68	-65	-52
7.0	-20	41	22	37	14	-6	-32	-30	-24	-68	-65	-52
8.0	-20	41	22	37	14	-6	-32	-30	-24	-68	-65	-52
9.0	50	50	45	42	4	14	33	28	19	10	9	13
10.0	50	50	45	42	4	14	33	28	19	10	9	13
11.0	50	50	45	42	4	14	33	28	19	10	9	13
12.0	50	50	45	42	4	14	33	28	19	10	9	13
13.0	50	50	45	42	4	14	33	28	19	10	9	13
14.0	50	50	45	42	4	14	33	28	19	10	9	13
15.0	50	50	45	42	4	14	33	28	19	10	9	13
16.0	50	50	45	42	4	14	33	28	19	10	9	13
17.0	50	50	45	42	4	14	33	28	19	10	9	13
18.0	51	50	47	42	5	13	33	36	38	38	39	41
19.0	51	50	47	42	5	13	33	36	38	38	39	41
20.0	51	50	47	42	5	13	33	36	38	38	39	41
21.0	51	50	47	42	5	13	33	36	38	38	39	41
22.0	26	50	28	42	3	15	33	2	-5	-44	-93	-104
23.0	26	50	28	42	3	15	33	2	-5	-44	-93	-104
24.0	26	50	28	42	3	15	33	2	-5	-44	-93	-104

Prepared by the Study Team

A negative sign "-" in the table (marked in red) shows that the power supply with expansion case is decreased compared to the power supply without expansion case. A positive figure shows that the power supply with expansion case increased . The table also shows that the power supply during off peak hours from June to January is decreased. The power generation simulation shows off-peak power is shifted to peak hours and dry season generation. This may be one of the effects of the expansion, as the expansion of the existing power plant increases the flexibility of power generation operation. The role of NN1 in the power supply system of the central area will be changed more to peak power supply. Due to this shift from off-peak energy to peak energy, the power shortfall during peak hours will be improved by 12% in 2017 if the NN1 hydropower station expansion is implemented.

5.4 UPDATE OF ENVIRONMENTAL AND SOCIAL CONDITION OF NN1 HYDOROPOWER STATION EXPANSION

(1) Environmental Compliance Certificate

In the case of Extension of NN1 hydropower station Project, an initial environmental examination (IEE) was required to conduct for obtaining an environmental compliance certificate (ECC) by the project developer before starting construction works. The ECC is valid through the operation period of the project. The ECC, however, will automatically expire and cannot be used if the project does not start to operate within two years from the date of issuance. It may be extended if the project developer makes a request to the MoNRE unless there is no change in the project design and/or planning. In the case of NN1 extension project, the ECC was issued in April 2010 to EDL. In March 2012, EDL issued a request to MoNRE for the extension of the ECC and the ECC was extended on 9 July, 2012.

(2) Reconfirmation on Environmental and Social Condition

Based on the result of the previous study in 2010, information regarding natural and social environments within the project area was reconfirmed and updated, taking into account any possible affects from newly operated two hydropower plants, namely, Nam Lik Hydropower Plant and Nam Ngum 2 Hydropower Plant. The following is the main findings through the field observation and village level hearings (ten out of 24 villages) in the downstream of the NN1 where the affect of water fluctuation from expansion of the NN1 is expected as well as information collection at authorities concerned.

(3) Riverbank Gardening

Planting vegetables at riverbank emerged due to the decrease of river water level during dry season is called riverbank gardening. In the project area, it was confirmed that farmers have accustomed to plant their vegetables in secured areas at least 1 m (5 m as the maximum) from the edge of the lowest water level during dry season as a buffer zone. Through the water fluctuation depends on the cross section topology of the river, it is considered that at least 1 m of increase from the present level is within the range of buffer zone, thus it will be no negative impact on the riverbank garden.

As for the ownership of the riverbank, it is assigned in the Land Law (2003) that the Ministry of Agriculture and Forestry is the responsible ministry of the management (the task has been taken by the MoNRE since its establishment in 2011). The use of the riverbank area can be allocated to individuals or organizations for appropriate protection and use in case the village administration, where the riverbank area is located, make a request to the concerned authority (district or municipal administration). As for the surveyed villages, it was found that both the defined status and area on river bank area varied among villages.

(4) Water Quality

During May until August 2011, it was reported that massive fishes bred in fish farming cages of the Nan Ngum River died and eight fish farmers were affected by the incident. After the investigation conducted by the Institute of Natural Resources and Environmental Research (INRER) together with the district and provincial officers, it was concluded that the water with low rate of dissolved oxygen (DO) released from the NN2 Hydropower Plant was the cause of the incident. Accordingly, the Vientiane Province made recommendation on operation improvement to the NN2 Hydropower Plant. The water quality monitoring including the rate of DO in the Nan Ngum River started at seven sites including the Nam Lik River before the confluence point to the Nam Ngum River, Thalat Bridge, and Ban Keun Kang on a monthly basis by the INRER since January 2012. Nothing abnormal has been detected up to the present.

(5) Water Fluctuation

With the newly operated hydropower plants taken into account, information on daily water fluctuations from previous study was updated. Any significant change on maximum water level difference were found before and after construction of the two hydropower plants.

(6) Tasks for further study

The following tasks are recommended to be carried out in further study:

- Assess impact on the downstream of the Nan Ngum River resulting from the Extension of the Nan Ngum Hydropower Plant, taking the data of daily water fluctuation after the commencement of operation of Nam Lik ½ and Nam Ngum 2 into account;

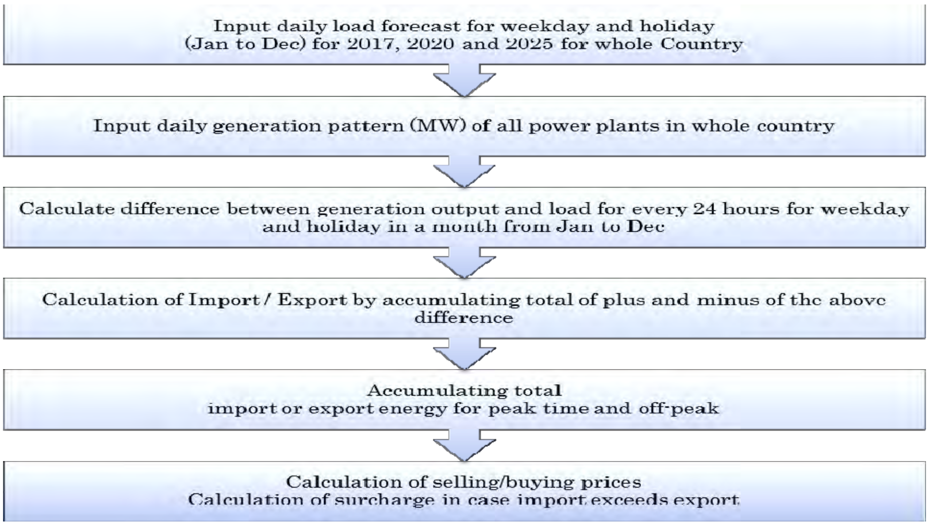
- Collect monitoring result on water quality after construction of Nam Lik ½. Moreover, monitoring plan of Nan Ngum 2 needs to be reviewed and updated for the extension of the Nam Ngum Hydropower Plant prepared in the previous study; and

- Collect information regarding on-going monitoring program on management of the Nam Ngum River basin such as responsible agency for monitoring, monitoring items, and existing monitoring scheme, in order to update the monitoring plan on the extension of the Nam Ngum Hydropower Plant prepared in the previous study.

5.5 PROSPECTIVE POWER IMPORT/EXPORT WITH THAILAND AFTER NN 1 HYDROPOWER STATION EXPANSION

For the estimation of prospective import and export energy in cases with and without expansion of NN1, the difference of load and generation output (with and without NN1 expansion) for the whole country were calculated at hourly intervals to estimate the imported and exported energy to Thailand. This simulation analysis was extended on weekdays and holidays of each month, because the unit price (THB/kWh) of import/export differ between peak and off-peak hours, and the daily load curve and generation pattern change in trend on weekdays or holidays. Finally, the result of the import and export of energy in the above simulation were converted to the selling and buying prices of electricity to Thailand.

The flow of this simulation is summarized in Figure 5.5.1 below.

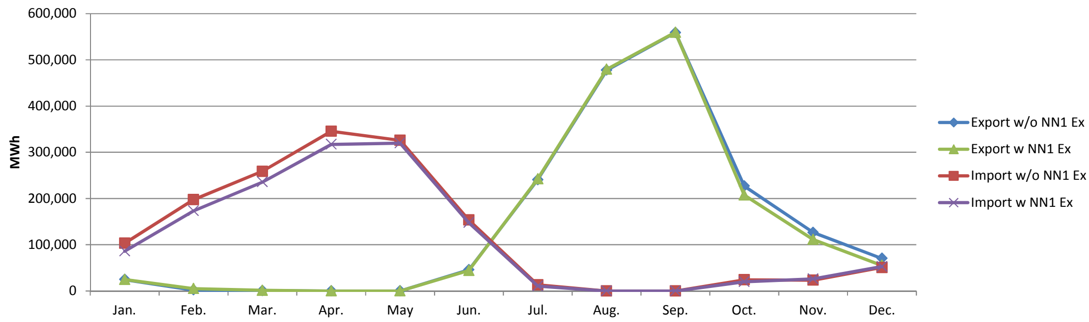


Prepared by Study Team

Figure 5.5.1 Flow of Method for Simulation of Power Import or Export

Estimation of Import and Export Energy in 2017

Table 5.5.1 and Figure 5.5.2 show the result of simulation of power import and export in 2017.



Prepared by Study Team

Figure 5.5.2 Comparison Import/Export With and Without NN1 Expansion (2017)

Table 5.5.1 Prospective Export/Import Energy in 2017

	w/o NN1 Expansion					(MWh)	40MW Expansion					(MWh)
	Export			Import			Export			Import		
	Off-peak	Peak	Total	Off-peak	Peak	Total	Off-peak	Peak	Total	Off-peak	Peak	Total
Jan.	24,565	0	24,565	45,293	57,886	103,179	24,580	0	24,580	42,514	43,460	85,974
Feb.	1,874	0	1,874	88,106	109,564	197,670	4,950	0	4,950	76,591	96,685	173,276
Mar.	443	0	443	114,656	144,203	258,858	1,242	0	1,242	105,076	130,544	235,620
Apr.	0	0	0	190,891	154,498	345,389	0	0	0	173,415	143,511	316,926
May	0	0	0	157,671	168,233	325,904	0	0	0	152,724	166,893	319,617
Jun.	45,515	0	45,515	48,954	104,576	153,530	44,277	0	44,277	46,957	100,709	147,667
Jul.	216,372	24,092	240,464	4,139	8,982	13,122	211,402	30,895	242,297	3,592	6,878	10,470
Aug.	362,030	115,388	477,417	0	0	0	354,871	124,472	479,343	0	0	0
Sep.	417,012	141,556	558,568	0	0	0	410,999	148,438	559,436	0	0	0
Oct.	204,199	22,624	226,823	5,189	18,843	24,032	182,548	24,624	207,172	4,263	15,509	19,771
Nov.	88,261	38,205	126,465	11,397	11,947	23,344	70,292	40,858	111,150	16,602	9,388	25,990
Dec.	62,733	7,353	70,085	28,425	22,415	50,839	45,843	9,279	55,122	34,317	18,422	52,739
Total	1,423,003	349,218	1,772,221	694,720	801,146	1,495,866	1,351,004	378,566	1,729,571	656,050	731,999	1,388,048

Prepared by Study Team

In 2017, the power import and export are nearly balanced on an annual basis. During dry season, the import exceeded the export. On the contrary, during wet season the export exceeded the import.

Table 5.5.2 Comparison of Power Import/Export With and Without NN1 Expansion in 2017

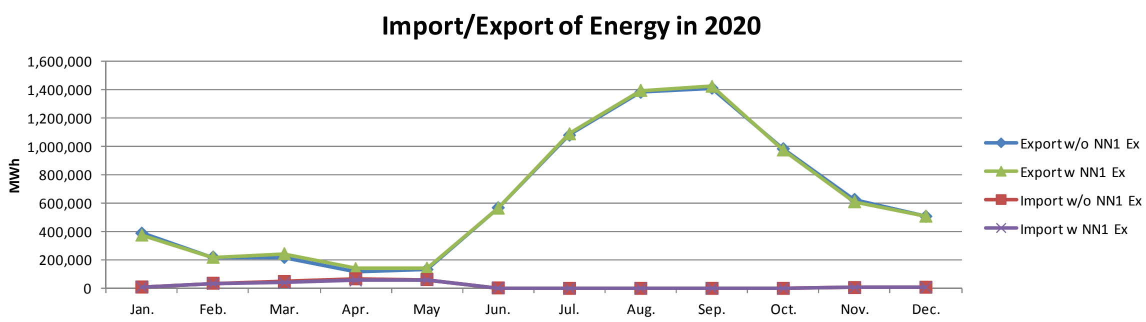
2017		Off-Peak	Peak	Total
w/o NN1 Ex	Export	1,423,003	349,218	1,772,221
	Import	694,720	801,146	1,495,866
	Balance	728,283	-451,929	276,354
w NN1 Ex	Export	1,351,004	378,566	1,729,571
	Import	656,050	731,999	1,388,048
	Balance	694,955	-353,433	341,522
Difference	Export	-71,999	29,348	-42,650
between	Import	-38,671	-69,148	-107,818
with and w/o	Balance	-33,328	98,496	65,168
Note: Balance : Export-Import				

Prepared by Study Team

When NN1 is expanded, the reduction of power import is larger than that of the power export by 65.2 GWh. This means that the export of energy in power trade will relatively grow by 65.2 GWh with the expansion of NN1.

Estimation of Power Import and Export in 2020

Table 5.5.3 and Figure 5.5.3 show the result of simulation of power import and export in 2020. As indicated in Figure 5.5.3, if all power plant projects are completed as scheduled, power import will not be required. The power export will rapidly increase from June to December of 2020.



Prepared by Study Team

Figure 5.5.3 Comparison Import/Export With and Without NN1 Expansion (2020)

Table 5.5.3 Prospective Export / Import Energy in 2020

	w/o NN1 Expansion					(MWh)	40MW Expansion					(MWh)
	Export			Import			Export			Import		
	Off-peak	Peak	Total	Off-peak	Peak	Total	Off-peak	Peak	Total	Off-peak	Peak	Total
Jan.	216,184	172,807	388,991	9,409	0	9,409	197,465	177,932	375,397	9,912	0	9,912
Feb.	136,373	84,050	220,423	34,530	1,341	35,870	122,266	96,009	218,275	32,498	348	32,846
Mar.	142,806	75,109	217,915	46,670	1,495	48,165	156,232	88,253	244,485	39,214	400	39,614
Apr.	74,014	43,159	117,173	56,997	10,249	67,246	85,914	53,298	139,212	48,921	7,216	56,137
May	87,656	45,658	133,314	56,616	5,526	62,142	94,719	46,820	141,539	54,230	5,195	59,425
Jun.	368,967	199,289	568,255	3,151	0	3,151	361,979	203,577	565,556	3,015	0	3,015
Jul.	680,057	399,351	1,079,408	0	0	0	680,295	408,883	1,089,177	0	0	0
Aug.	900,022	481,403	1,381,425	0	0	0	904,201	491,271	1,395,472	0	0	0
Sep.	896,664	514,084	1,410,749	0	0	0	901,825	522,513	1,424,338	0	0	0
Oct.	616,144	367,683	983,827	0	0	0	601,390	373,777	975,167	0	0	0
Nov.	336,072	290,604	626,676	5,245	0	5,245	312,995	297,512	610,506	4,361	0	4,361
Dec.	285,625	222,054	507,679	7,729	0	7,729	275,985	232,842	508,826	6,544	0	6,544
Total	4,740,584	2,895,250	7,635,834	220,347	18,611	238,959	4,695,264	2,992,687	7,687,951	198,696	13,158	211,854

Prepared by Study Team

Table 5.5.4 Comparison of Power Import/Export With and Without NN1 Expansion in 2020

2020		Off-Peak	Peak	Total
w/o NN1 Ex	Export	4,740,584	2,895,250	7,635,834
	Import	220,347	18,611	238,959
	Balance	4,520,237	2,876,639	7,396,875
w NN1 Ex	Export	4,695,264	2,992,687	7,687,951
	Import	198,696	13,158	211,854
	Balance	4,496,568	2,979,529	7,476,097
Difference	Export	-45,320	97,437	52,117
between	Import	-21,651	-5,453	-27,104
w and w/o	Balance	-23,669	102,890	79,221
Note: Balance : Export-Import				

Prepared by Study Team

The benefit of energy in power trade with Thailand will relatively be 79.2 GWh after the 40 MW expansion of the NN1 hydropower station.

Charge on Power Import and Export

According to the tariff for power trade with Thailand shown below, the electricity prices for power import and export were calculated under the conditions with and without NN1 expansion.

Table 5.5.5 Unit Price for Export and Import with Thailand

Unit: Bath/kWh

Tariff	Export	Import
Peak	1.6	1.74
Off-Peak	1.2	1.34

Source: EDL

(1) Prices for 2017

Since the unit rate of EDL's buying unit price was higher than selling unit price (see Table 5.5.5), although the annual energy of export was a little higher than import in 2017, EDL is still required to pay THB 58.57 million to EGAT in 2017 as shown in Table 5.5.6 in case of no NN1 expansion. On the contrary, after expansion of NN1, EDL is not required to pay the electricity expense to EGAT. Meanwhile, EGAT has to pay the amount of THB 74.13 million to EDL.

Table 5.5.6 Electricity Prices for Import and Export of Power to Thailand (2017)

Without NN1 Expansion (2017)

	Export			Import			Payment
	Off-peak	Peak	Total	Off-peak	Peak	Total	(*1000Baht)
Jan.	29,478	0	29,478	60,693	100,721	161,414	131,937
Feb.	2,248	0	2,248	118,062	190,641	308,703	306,454
Mar.	532	0	532	153,638	250,913	404,552	404,020
Apr.	0	0	0	255,794	268,827	524,621	524,621
May	0	0	0	211,279	292,725	504,004	504,004
Jun.	54,618	0	54,618	65,598	181,962	247,560	192,942
Jul.	259,646	38,548	298,194	5,547	15,629	21,176	-277,018
Aug.	434,436	184,620	619,056	0	0	0	-619,056
Sep.	500,414	226,490	726,905	0	0	0	-726,905
Oct.	245,039	36,198	281,237	6,953	32,786	39,739	-241,498
Nov.	105,913	61,128	167,040	15,272	20,787	36,059	-130,981
Dec.	75,279	11,764	87,043	38,089	39,001	77,090	-9,953
Total	**1,707,604**	**558,748**	**2,266,352**	**930,925**	**1,393,994**	**2,324,920**	**58,568** (Pay to EGAT by EDL)

With NN1 Expansion (2017)

	Export			Import			Payment
	Off-peak	Peak	Total	Off-peak	Peak	Total	(*1000Baht)
Jan.	29,496	0	29,496	56,968	75,621	132,589	103,092
Feb.	5,940	0	5,940	102,632	168,232	270,863	264,923
Mar.	1,491	0	1,491	140,801	227,146	367,948	366,457
Apr.	0	0	0	232,376	249,710	482,086	482,086
May	0	0	0	204,651	290,393	495,044	495,044
Jun.	53,132	0	53,132	62,923	175,234	238,157	185,025
Jul.	253,683	49,432	303,115	4,813	11,967	16,780	-286,335
Aug.	425,845	199,155	625,000	0	0	0	-625,000
Sep.	493,198	237,500	730,699	0	0	0	-730,699
Oct.	219,058	39,399	258,457	5,712	26,985	32,697	-225,760
Nov.	84,350	65,373	149,723	22,246	16,335	38,581	-111,142
Dec.	55,011	14,847	69,858	45,985	32,055	78,039	8,181
Total	**1,621,205**	**605,706**	**2,226,911**	**879,106**	**1,273,678**	**2,152,784**	**-74,127** (Pay to EDL by EGAT)

Note) Payment: positive amount means payment of EDL to EGAT, negative amount means payment of EGAT to EDL
Prepared by the Study Team

(2) Prices for 2017

In simulation of power import and export for 2020, since the power export is growing and far exceeded the import, EDL is not required to pay any buying cost to EGAT. Whereas, EGAT pays electricity cost to EDL on actual consumption of EGAT. If EGAT purchases all surplus power from EDL, the price was estimated at THB 9.99 billion in case of no NN1 expansion, and THB 10.13 billion in case NN1 expansion is constructed, as shown in Table 5.5.7.

Table 5.5.7 Electricity Prices for Import and Export of Power to Thailand (2020)

Without NN1 Expansion (2020)

	Export			Import			Payment
	Off-peak	Peak	Total	Off-peak	Peak	Total	(*1000Baht)
Jan.	259,421	276,491	535,911	12,609	0	12,609	-523,303
Feb.	163,647	134,481	298,128	46,270	2,333	48,603	-249,525
Mar.	171,368	120,175	291,542	62,538	2,602	65,140	-226,402
Apr.	88,817	69,054	157,871	76,376	17,834	94,209	-63,661
May	105,188	73,053	178,240	75,865	9,615	85,481	-92,760
Jun.	442,760	318,862	761,622	4,222	0	4,222	-757,400
Jul.	816,068	638,961	1,455,029	0	0	0	-1,455,029
Aug.	1,080,027	770,244	1,850,271	0	0	0	-1,850,271
Sep.	1,075,997	822,535	1,898,532	0	0	0	-1,898,532
Oct.	739,373	588,292	1,327,665	0	0	0	-1,327,665
Nov.	403,286	464,966	868,252	7,029	0	7,029	-861,224
Dec.	342,750	355,287	698,037	10,357	0	10,357	-687,679
Total	**5,688,701**	**4,632,400**	**10,321,101**	**295,265**	**32,384**	**327,649**	**-9,993,452**
							(Pay to EDL by EGAT)

With NN1 Expansion (2020)

	Export			Import			Payment
	Off-peak	Peak	Total	Off-peak	Peak	Total	(*1000Baht)
Jan.	236,958	284,692	521,650	13,283	0	13,283	-508,367
Feb.	146,719	153,615	300,334	43,548	605	44,153	-256,181
Mar.	187,478	141,204	328,683	52,546	696	53,242	-275,440
Apr.	103,097	85,277	188,374	65,555	12,556	78,110	-110,264
May	113,663	74,912	188,575	72,668	9,039	81,707	-106,868
Jun.	434,374	325,723	760,097	4,041	0	4,041	-756,057
Jul.	816,354	654,212	1,470,566	0	0	0	-1,470,566
Aug.	1,085,041	786,034	1,871,075	0	0	0	-1,871,075
Sep.	1,082,189	836,021	1,918,211	0	0	0	-1,918,211
Oct.	721,668	598,043	1,319,711	0	0	0	-1,319,711
Nov.	375,594	476,019	851,612	5,844	0	5,844	-845,768
Dec.	331,182	372,547	703,728	8,769	0	8,769	-694,959
Total	**5,634,316**	**4,788,299**	**10,422,616**	**266,253**	**22,895**	**289,148**	**-10,133,468**
							(Pay to EDL by EGAT)

Note) Payment: positive means EDL payments to EGAT, negative means EGAT payments to EDL
Prepared by the Study Team

5.6 UPDATE ON THE ECONOMIC AND FINANCIAL ANALYSES OF NN1 HYDROPOWER STATION EXPANSION

(1) Update of Project Cost Estimation

The present analysis has updated the project cost estimated by the previous preparatory survey through price adjustment in the consumer price index (CPI) to acquire 2012 price. The updated project cost was JPY 7,212 million in total. Compared to the estimates of the previous survey (JPY 7,006 million), the cost was increased by 2.9%.

(2) Economic Analysis

The increase in energy supply and shift to peak energy were regarded as the primary benefits of the expansion project. EIRR was calculated based on the international trade tariff with EGAT revised in August 2011. Table 5.6.1 summarizes the EDL trade balance projection. Surcharge payments were not anticipated because import amount will not exceed the export in any case.

Table 5.6.1 EDL Trade Deficit (Surplus) Projection

Year		EDL Trade Deficit (Surplus) with EGAT		
		A. Without Project	B. With Project	C. Benefit (A-B)
2017	THB 1,000	58,568	(74,127)	132,695
	USD 1,000	*1,828*	*(2,314)*	*4,142*
2020	THB 1,000	(9,993,452)	(10,133,468)	140,016
	USD 1,000	*(311,905)*	*(316,276)*	*4,370*

Source: JICA Study Team

EIRR was calculated at 4.04%, which was lower than the discount rate of 10%. NPV with 10% discount rate was USD -31.4 million. The low IRR in this analysis was primarily because of the low tariff level and small difference between peak and off-peak energy values. It is questionable if the current cross-border trade tariff reflects the actual economic values of energy supply.

EIRR taking the cost of alternative thermal power as economic benefit was also calculated in the analysis. In this analysis, the economic benefit was measured by the capacity benefit (kW value) and the energy benefit (kWh value) increased by the expansion project through valuation of alternative thermal power. In reference with the previous preparatory survey, the data for a middle-speed diesel power plant were updated to estimate the economic value. The kW value and the kWh values of this type of thermal power were estimated as USD 144.14/kW per year and USD 0.148/kWh respectively. The EIRR was calculated at 15.06% and NPV at USD 29.7 million with 10% discount rate indicating the project's economic viability.

(3) Financial Analysis

It was confirmed that EDL would be responsible for the construction of NN1 expansion and the debt service of the ODA loan. Operation of the power station will be undertaken by EDL-Gen under the ownership of EDL, who will be also responsible for the transmission and distribution of the energy generated. Thus the FIRR in the present analysis was calculated in the viewpoint of EDL and its increased electricity tariff revenue was recognized as the financial benefit of the project. The calculation applied the average domestic tariff as of 2017 (LAK 741/kWh or USD 9.39 cents) increased from the current level (LAK 559/kWh). The FIRR was calculated at 5.50% and NPV with 4.20% discount rate (WACC) was USD 15.6 million. Compared to the previous JICA survey results in 2010 (2.75%), the FIRR was improved mainly because of the increased tariff. The FIRR slightly higher than the WACC of 4.20% indicates its marginal profitability and necessity of a concessional ODA loan to implement the project. A low tariff level compared to a large investment cost was considered a major factor for low FIRR. Since EDL has flat-rate tariff system and does not apply TOD rates, the results cannot reflect the increase in peak capacity enabled by the project. In case the off-take tariff between EDL-Gen and EDL was taken as the financial revenue, The FIRR would be calculated at 2.15% showing low profitability of the project to EDL-Gen. The off-take agreement between EDL and EDL-Gen does not apply TOD rates either.

CHAPTER 6 REVIEW OF TRANSMISSION LINE NETWORK IN THE CENTRAL AREA

6.1 TRANSMISSION LINE NETWORK IN LAO PDR

Figure 6.1.1 and Figure 6.1.2 show the current power network system of Lao PDR enclosed in the PDP 2010-2020 (Revision-1).

The north and central systems are currently connected by 115 kV single circuit transmission line with a conductor (1 x 117 mm^2), at an estimated capacity limited to 30 to 40 MW.

The construction of 115 kV double circuit transmission line (conductor size: 1 x 240 mm^2) from Takhek to Pakbo was completed in the beginning of 2011 while Pakxan to Thakhek in June 2011, so as to connect the power system from central to northern part in southern regions.

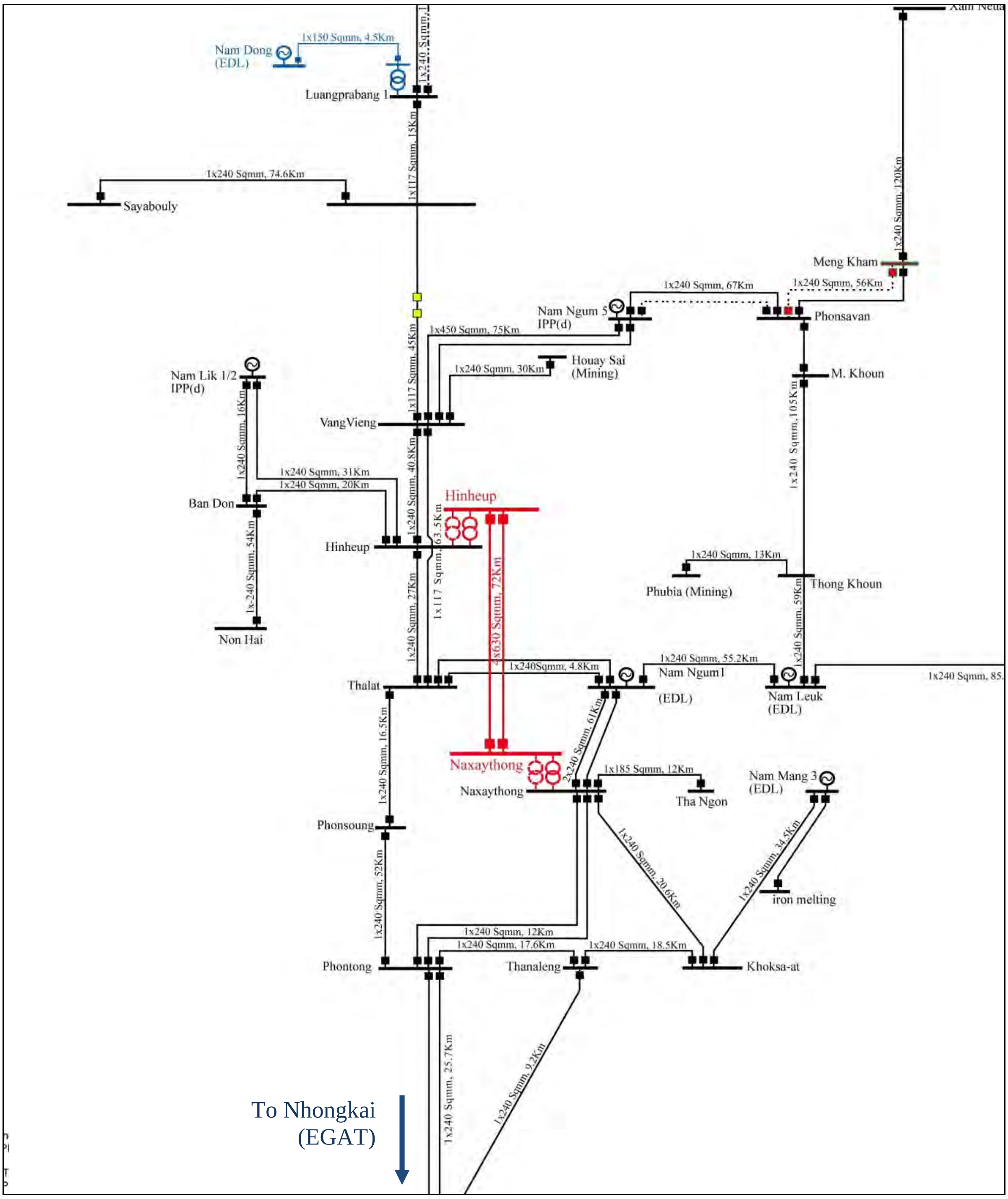
Under such circumstance, the power system of Lao PDR is still separated into two parts, namely: i. north and central system up to Pakbo and Kengkok in the south, and ii. Xeset system in the southern area.

North and central system does not connect to Xeset system in the south yet. It is planned that the 115 kV transmission line between Pakbo and Xeset will be constructed and commence operation in 2016 under the finance of JICA. Thus, the power systems in Lao PDR will be integrated into one network.

6.2 TRANSMISSION LINES IN THE CENTRAL AREA

(1) Existing Transmission Lines in Central

The existing transmission lines in the central area (PDP 2010-2020 Revision 1) are illustrated in Figure 6.2.1. A 230 kV double circuit transmission line from Hinheup to Naxaythong was installed in 2011 with a single conductor of 630 mm^2 per phase at 365 MW capacity for each circuit.



Note: Because this single line diagram is excerpted from the PDP 2010-2020 (Revision 1) without any change, Nam Ngum 5 Hydropower Station (NN5) is already indicated as originally scheduled although it is still under construction . NN5 is expected to start operation in 2012.

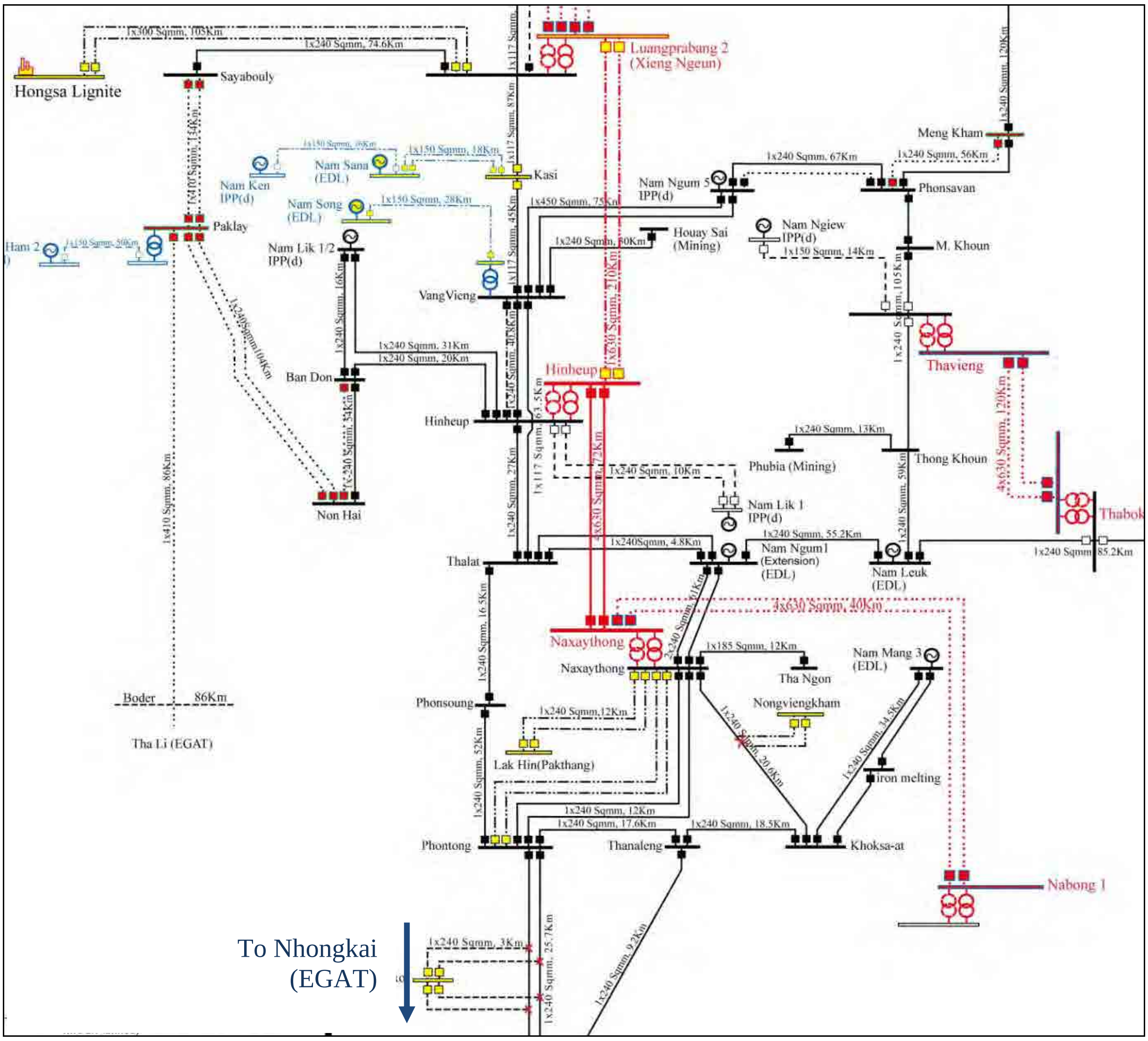
Source : PDP 2010-2020 Revision 1

Figure 6.2.1 Current Transmission Line Network in the Central Area

(2) Future Transmission Lines in Central in 2014

The transmission system in the central area in 2014 is pictured in Figure 6.2.2. The 230 kV double circuit transmission line is extended to Luangprabang 2 in the northern area, and also extended to Nabong 1 in the southern area. Nabong 1 Substation is expected to connect to the EGAT system in Thailand through 230 kV double circuit interconnection transmission line.

At an intermediate point on existing 115 kV transmission line from M. Khoun to Thong Khoun, 230 kV Thavieng Substation will be established. The 230 kV double circuit transmission line will be extended from Thavieng to Thabok, which will be newly constructed between Nam Leuk and Pakxan.



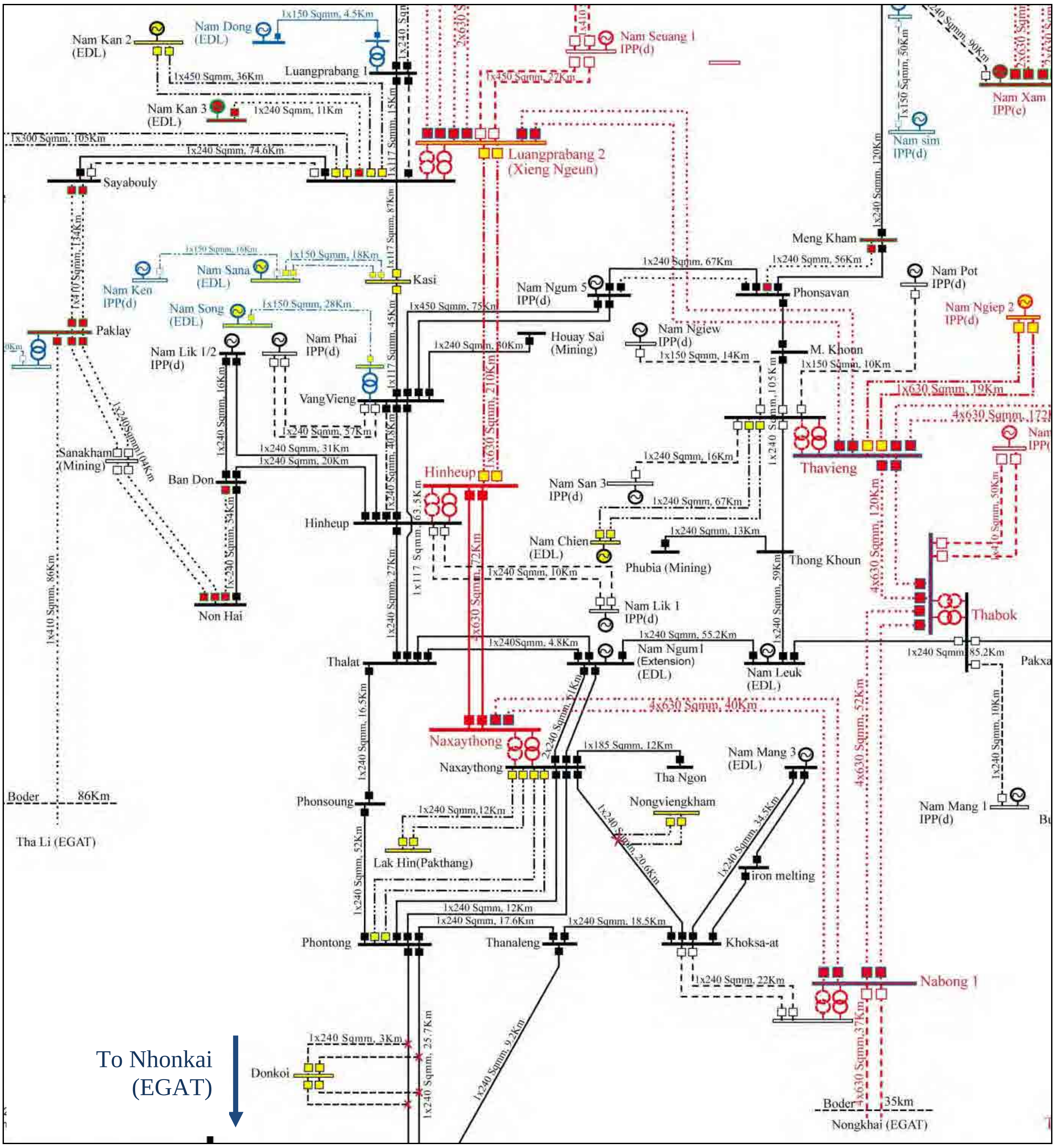
Source : PDP 2010-2020 Revision 1

Figure 6.2.2 Transmission Line Network in the Central Area in 2014

(3) Future Transmission Lines in the Central in 2017

The transmission system in the central area in 2017 is pictured in Figure 6.2.3. In this stage, the 230 kV double circuit transmission lines will consist of a ring-line with grid substations, including Luangprabang 2–Hinheup–Naxaythong–Nabong 1–Thabok–Thavieng.

The Nabong 1 Substation is expected to connect the 230 kV international interconnection transmission line for power trade with EGAT, as shown in PDP 2010-2020 (Revision 1). The transmission line is designed as a double circuit with four conductors of ACSR 630 mm^2 per phase.



Source : PDP 2010-2020 Revision 1

Figure 6.2.3 Transmission Line Network in the Central Area in 2017

6.3 REVIEW OF LOAD FLOW ANALYSIS

In the previous JICA's Preparatory Survey, it was reported that no overload was found on the transmission lines around NN1 P/S after 40MW NN1 expansion in the year of 2016. On the contrarily, some issues of overload of bus conductors in Thalat S/S and NN1 Switchyard were pointed out. The Study Team checked whether such recommended actions for upgrading bus conductors were taken by EDL.

<u>EDL's Action for 115kV Bus Conductors in Substations</u>

(1) Bus conductors in Thalat Substation

It was pointed out that 115kV bus conductors in Thalat substation did not have enough capacity for calculated load. It was however confirmed that the replacement of said bus conductors has been completed to upgrade to an adequate size.

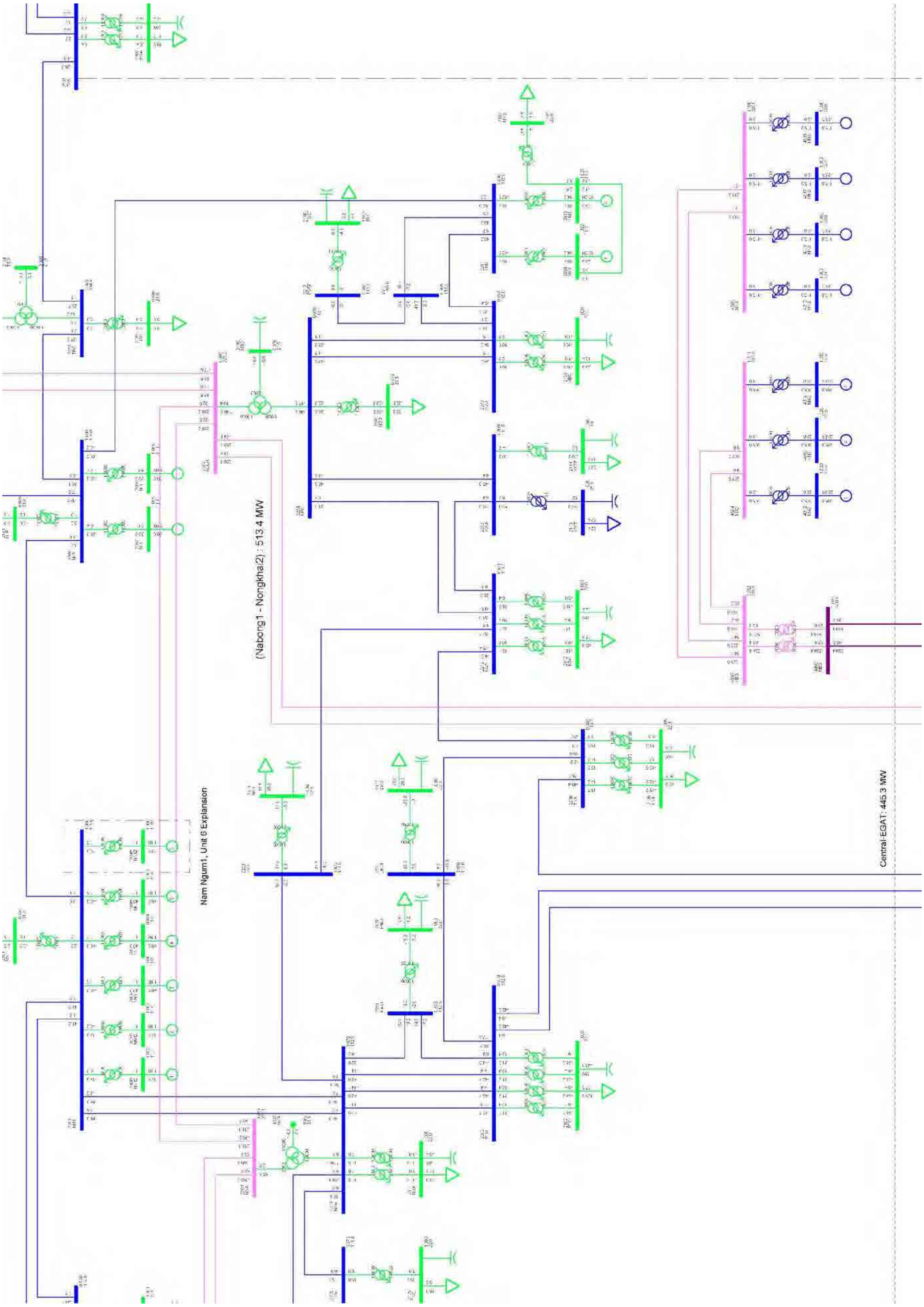
(2) Bus conductors in Nam Ngum 1 Power Substation

It was also pointed out that 115kV bus conductors in switchyard did not have enough capacity in case of NN1 expanded. The replacement of bus conductors has not yet been completed.

<u>EDL's Load Flow Analysis</u>

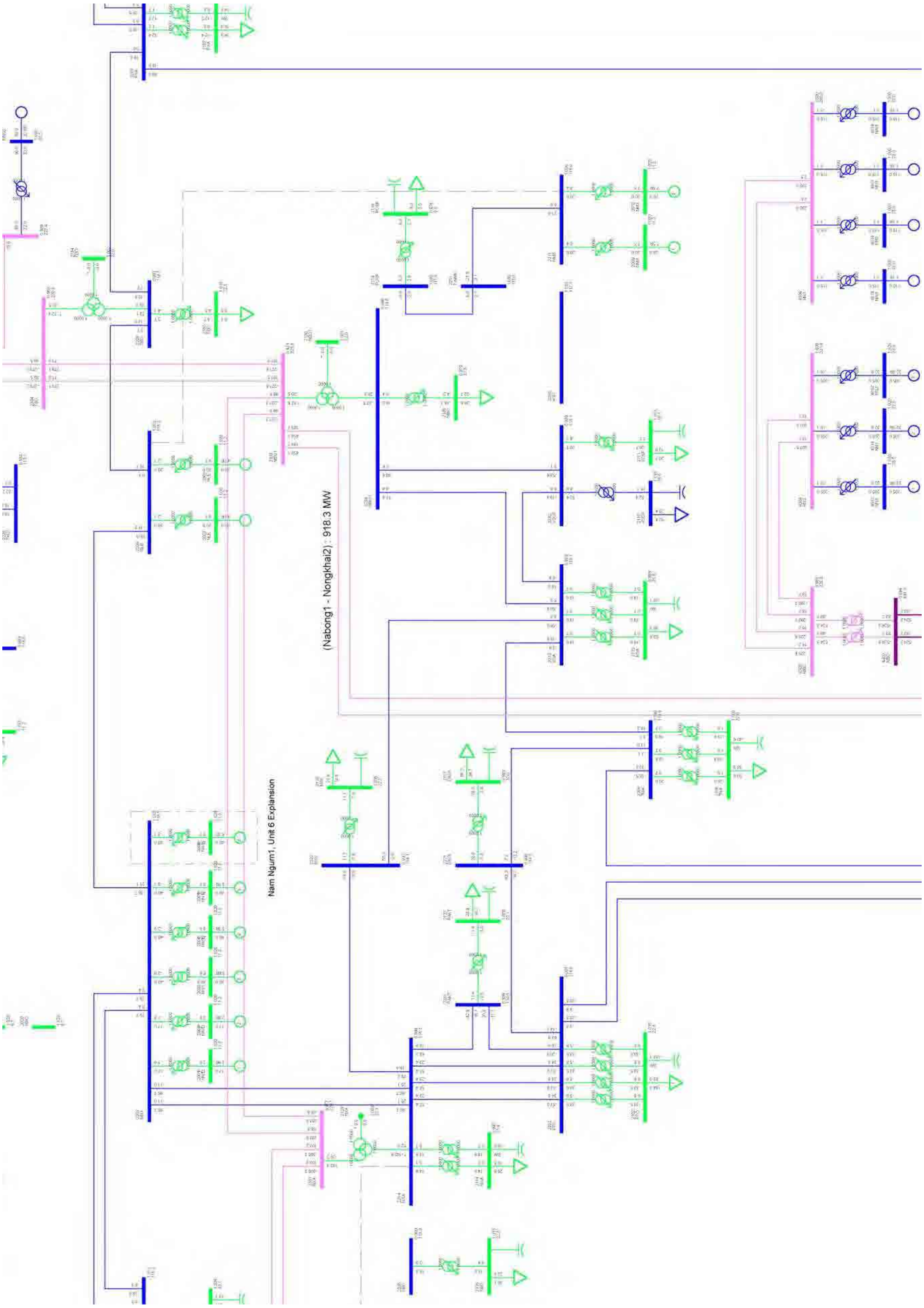
The result of EDL's load flow analysis on the power system in PDP 2010-2020 Revision 1 with consideration of 40MW expansion of NN1 Power Station in 2017 and 2020 was focused on 115 kV transmission network around NN1 in Figures 6.3.1 and 6.3.2.

According to review of this analysis, there was neither overload nor abnormal voltage on the transmission lines in the Nam Ngum system under normal conditions with 40 MW expansion. There seems to be no needs for installation of a new transmission line or upgrading the existing transmission line in case 40MW expansion. However, as reported in the previous JICA Study, it is still recommended that the size of 115kV bus conductors in NN1 switchyard should be upgraded.



Source; EDL

Figure 6.3.1 EDL's Load Flow Analysis (2017)



Source; EDL

Figure 6.3.2 EDL's Load Flow Analysis (2020)

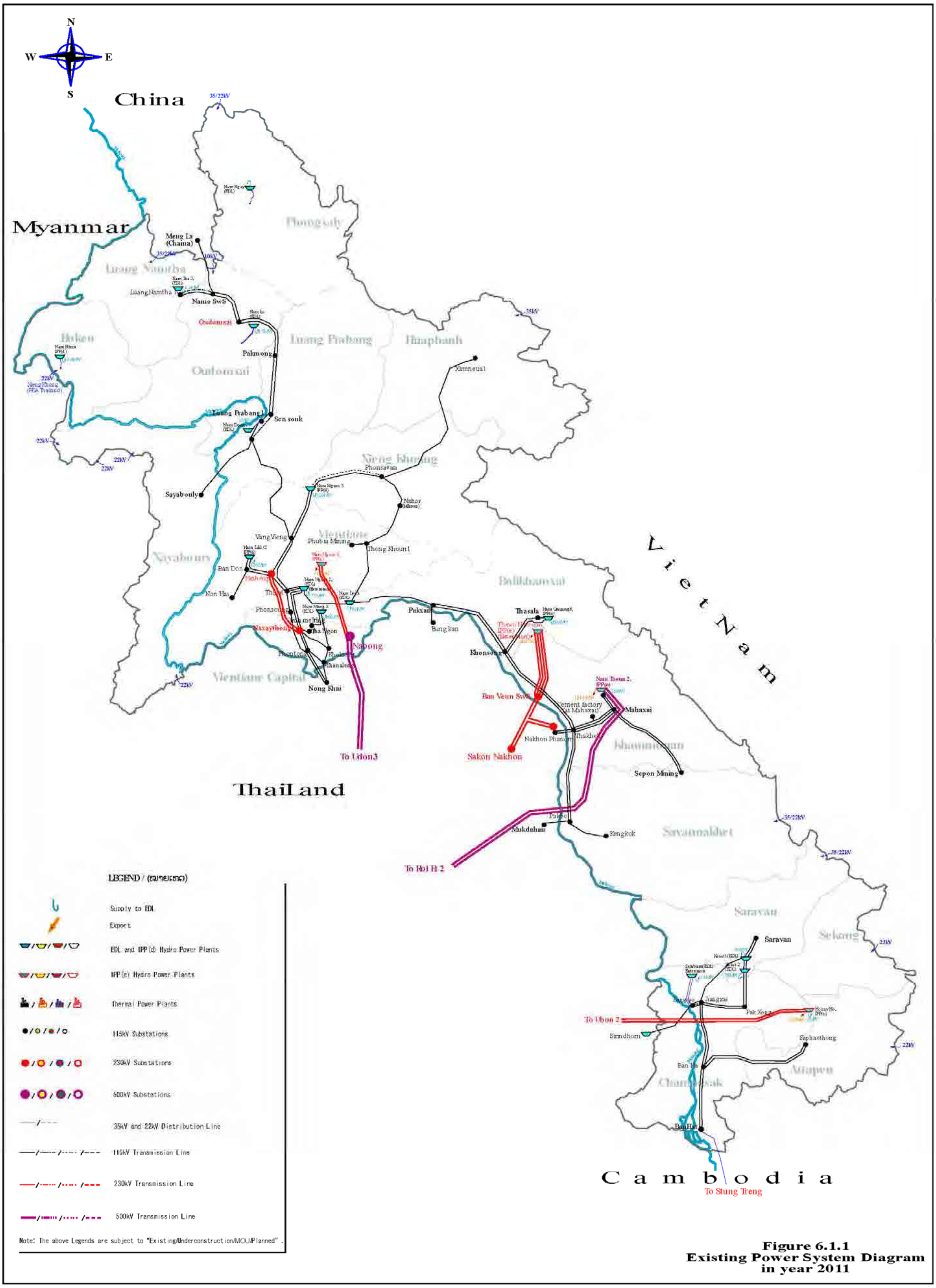


Figure 6.1.1
Existing Power System Diagram in year 2011

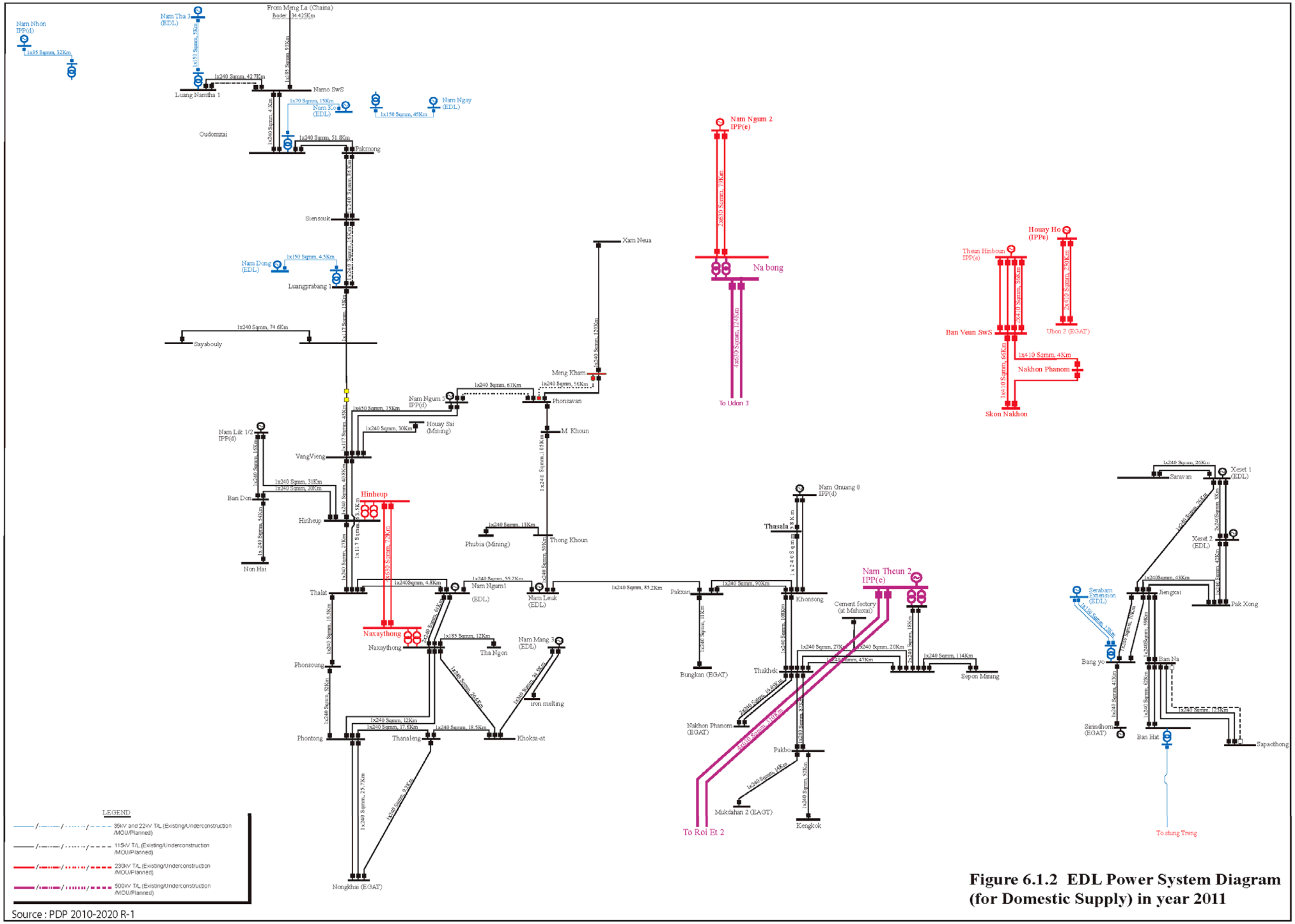


Figure 6.1.2 EDL Power System Diagram (for Domestic Supply) in year 2011

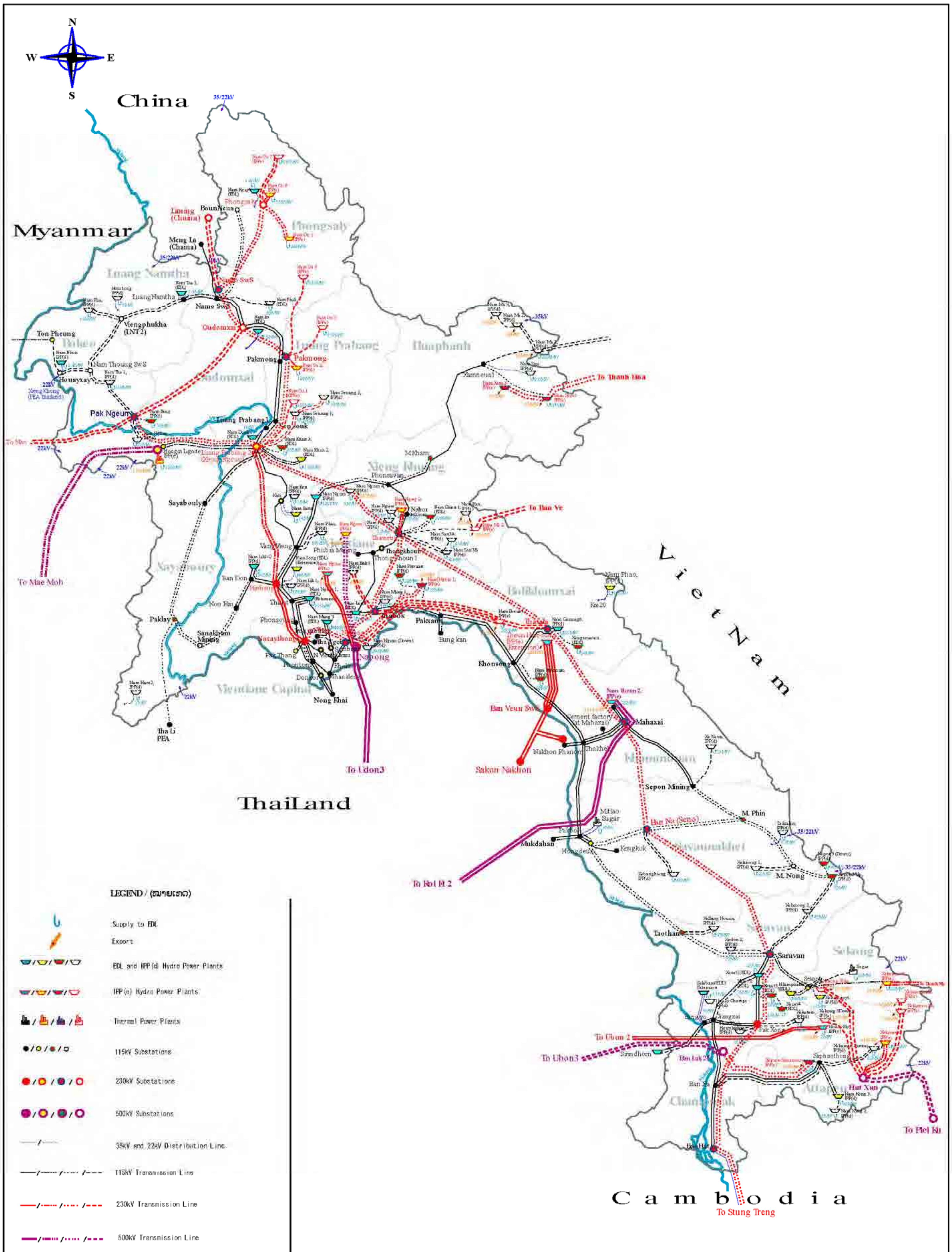


Figure 6.1.3
Planned Power System Diagram
in Year 2020

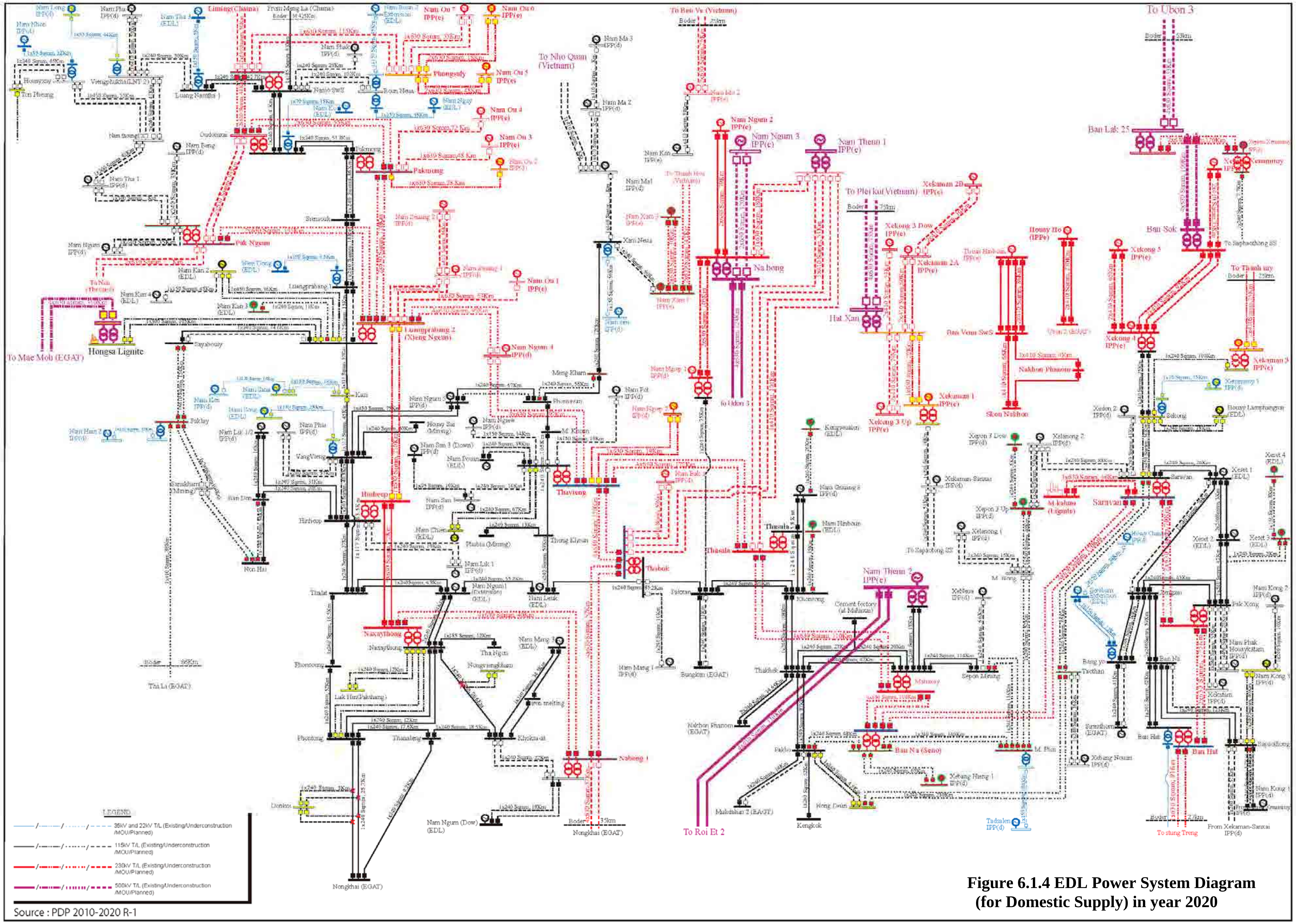


Figure 6.1.4 EDL Power System Diagram (for Domestic Supply) in year 2020

Source : PDP 2010-2020 R-1

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Issue on Power Supply in the Central Area

(1) Summary on Power Supply and Demand Analysis

In Chapter 3, the Study Team examined PDP 2010-2020 (Revision-1) and updated the power supply and demand projection. The power supply plan was updated considering the current development status and possible future development of the power plants. The power demand was also reviewed considering the loads of the large industries such as railway construction. The power supply and demand balance was compared in daily basis for the year 2017, 2020, and 2025. As a result, the Study Team found that the peak power supply in the central area of Laos PDR will be insufficient to meet the power demand especially during peak hours at night. The deficit of power supply in the central area was estimated to be over 700 MW at peak time, which should be covered by importing from neighboring country such as Thailand.

(2) Issue of Power Supply in the Central Area

Issue of power supply for peak power generation in the central area is discussed in Chapter 3 and summarized below.

- Reduction of Actual Power Generation during Dry Season

As majority of power source for domestic power supply in Lao PDR is hydropower, the energy and power output of those hydropower plants are affected by the hydrologic seasonal fluctuation. In the dry season, especially from March to May, the power output of hydropower plants is significantly lower than that in wet season.

- Power Shortage for Peak Time Demand

In the study of demand and supply balance for the year 2017, it is observed that power shortage will be more severe during night peak hours from 19:00 to 20:00 in April. EDL is required to secure a reliable power supply for peak load in the dry season at a maximum of additional 709 MW.

- Low Proportion of Controllable Power Capacity to the Total Power Supply

The installed capacity of EDL-owned power stations will reduce its proportion to the total capacity from 68% in 2010 to 17% in 2020. While, as many IPP domestic power generation projects will be completed in 2018, although EDL-owned generation capacity also increases to 885 MW, the proportion will decrease to 25% out of 3,425 MW capacity for the whole country. In 2020, this proportion will further decrease to 17%. This low rate of proportion of controllable capacity in EDL power system impedes the mobility and flexibility of power generation to follow the daily load fluctuation.

In addition to the above issues, as bulk power should be imported from EGAT for peak hours in 2017, the following concerns are anticipated:

- Interconnection Capacity

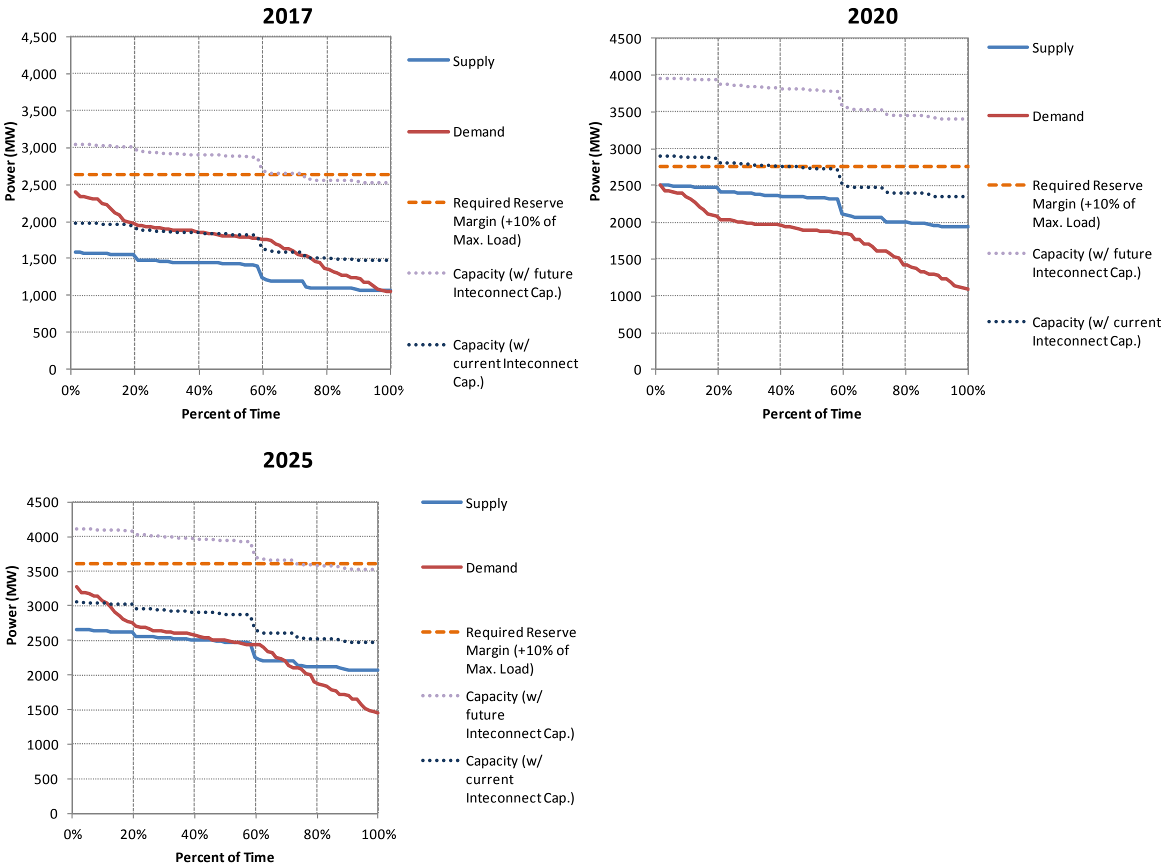
The current present interconnection capacity with Thailand is approximately 800 MW including all existing interconnection transmission lines without N-1 criteria. Thus, importing 709 MW is close to the physical capacity of interconnection, and the marginal capacity of the interconnection is quite limited considering the instantaneous load fluctuation. At present EDL plans to construct the additional interconnection lines between Nabong 1 to Nongkhai 2 for 1460 MW capacity with N-1 criteria. This additional interconnection line may resolve the limitation of capacity; however, any delay of this additional interconnection will worsen the power supply reliability.

- EGAT Capability for Power Export

According to Chapter 5, the reserve capacity of EGAT to the maximum power demand is estimated to be approximately 7000 MW. If this reserve capacity of 7000 MW is presumed in 2017, exporting additional 700 MW to EDL will reduce the 10% reserve margin of EGAT power supply, which is deemed to be generated by combined cycle gas turbine with rather expensive imported natural gas. Thus, this increment of power export of EGAT is not negligible with respect to the cost and power capacity. Although power exchange tariff between EGAT and EDL is set to be lower than the electricity tariff in Thailand, it is necessary for EDL to reduce the power import from EGAT, so as not to deteriorate the power supply reliability of EGAT.

(3) Necessary Reserve Margin of Power Supply

In general, the power supply reliability is visually understood from the comparison of duration curve of power generation and hourly loads. The load duration curve of the whole country combined, and the power generation duration curve for the whole country during the most severe dry months from March to May, are estimated and presented in Figure 7.1.



Prepared by the Study Team

Figure 7.1.1 Duration Curve of Load and Power Generation with Power Supply Capacity and Required Reserve Margin

As shown in the figure, power demand exceeds power supply capacity during most of the time in 2017. The power supply capability, which includes the interconnection capacity, is less than the power demand with the current interconnection capacity in 2017. If the interconnection capacity is strengthened to 1460 MW as planned, power supply capacity will exceed the estimated power demand. The required reserve margin is assumed to be 10% of the maximum load as presented in the figure. It shows that the power supply capability for domestic use cannot be achieved to meet the capacity with reserve margin in 2017 and 2025, if the strengthening the interconnection capacity is not implemented.

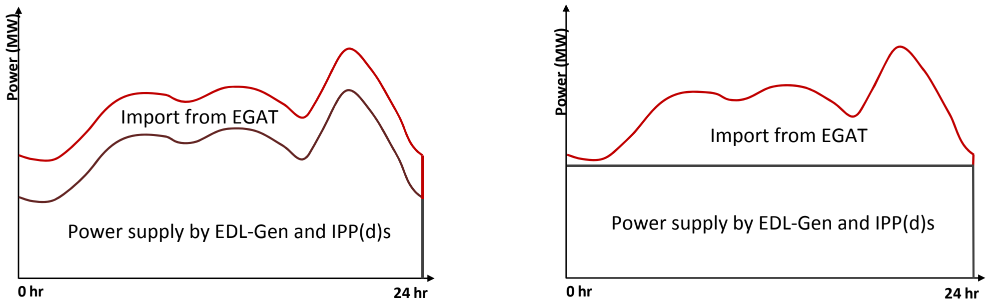
The interconnection capacity can be assumed as the reserve capacity for EDL power system; therefore, power import takes an important role for power supply in Lao PDR for power supply reliability. In summary, power import is indispensable for reliable power supply in Lao PDR. The strengthening the interconnection capacity should surely be implemented.

(4) Efficient Power Generation between EDL-EGAT System

If the power system of EDL and EGAT is considered as a whole, the system is considered as the mix of power sources of hydropower and thermal power plants. Such hydro-thermal system is generally optimum in operation for generation cost aspects when the thermal power plants generate power at constant output, and fluctuation of the daily load shape is covered by the hydropower generation.

Ideally, if the power plants in Laos generates the power plants to follow the daily load shape, the power import from EGAT becomes constant. This situation will be preferable for EGAT to avoid generates increment power with expensive imported natural gas. If the power plants in Laos generates at constant output, EGAT must generate power by combined cycle with imported natural gas to follow the load shape of Laos. Such mode of power generation is shown in Figure 7.1.2.

In this context, it would be preferable that the power plants in Laos should generates the power to follow the daily load shape to minimize the cost of power generation of EGAT for power exporting, thus the peak power supply capacity should be improved in Laos.



(Constant Power Import) Thermal Generation Cost of EGAT for Exporting to EDL Grid	<	(Variable Power Import) Thermal Generation Cost of EGAT for Exporting to EDL Grid

Total importing energy is assumed to the same for both cases.

Prepared by the Study Team

Figure 7.1.2 Concept of Load Shape Following and Constant Power Output

<u>Reinforcement of the Peak Power Supply in the Central Area</u>

(1) Comparative Study for Options for Strengthening Peak Power Supply

In Chapter 5, the options for strengthening the peak power supply were studied among all possible peak power sources available in Laos, which includes renewable energy such as biomass. After the screening of potential and availability of peak power source, the following options were selected:

a. Large scale hydropower development;

b. Small scale hydropower development;

c. Diesel power plant; and

d. Power import.

Among those selected for peak power source, the options were assessed based on four criteria, which consist of 1)Technical assessment, 2) Energy securities, 3) Cost, and 4) Environment. As a result of the comparison of options based on these criteria, large scale hydropower development was selected as the first option for strengthening the peak power supply.

Table below shows the result of comparison extracted from Table 4.4.8 in Chapter 4.

Comparison Result of Alternative Options

Options	Technical Assessment	Energy Securities	Cost	Environment	General Rating by Score
Large Scale Hydropower (NN1 Expansion)	A	A	B	A	11
Small Scale Hydropower	B	B	C	C	6
Diesel Power Plant	B	C	C	C	5
Power Import	A	B	A	B	10

Note) General rating by score is aggregates of points by assuming A = 3 pts, B = 2 pts, and C = 1 pt.
Prepared by the Study Team

It is noted that large scale hydropower development assumed implementation of the existing NN1 hydropower station expansion, as this option was the most exploitable power peak power source available for EDL. Although the power import is ranked in second, power import from EGAT is still important for power supply reliability of EDL.

(2) NN1 Expansion as Urgent Peak Power Development and Renewal of Existing Dam

As NN1 expansion was selected as the first option for strengthening the peak power supply, the power development through the expansion of existing power plants has been implemented also in Japan. Since this type of expansion has minimal impact to the environment, it has been implemented as an urgent power development to meet the increasing peak power demand in Japan.

Further, it also noted that renewal of existing dams by piercing dam body is generally accepted to improve release capability in Japan. Examples of power plants expansion utilizing existing dams and renewal of existing dams in Japan are shown in Table 7.1.1.

Table 7.1.1 Example of Dam Renewal and Power Plant Expansion Projects Utilizing Existing Dams in Japan

Name of Dams	Akiba Dam	Okutadami Dam	Nanairo Dam	Kuki Dam	Katsukomi Dam
Height of dam	89.0m	157m	61m	28m	34m
Height of dam at piercing point	32.5m	61m	18.4m	26m	18m
Depth of water at piercing point	28m	56m	14.4m	23.5m	16.5m
Piercing diameter	D=6.5m	D=6.2m	D≒2.6m	D≒1.3m	D≒2.4m
Piercing length	L=21m	L=32m	L≒6m	D≒3m	D≒4.5m
Method of piercing	Slot Drilling	Slot Drilling	Diamond Wire Sawing	Diamond Wire Sawing	Abrasive Waterjet
Purpose of the piercing	Hydropower plant expansion	Hydropower plant expansion	Dam renewal	Dam renewal	Dam renewal
Increment Power/Energy	46.9MW/ 96GWh/year	200MW/ - GWh			

Source: J-Power, Preparatory Survey on NN1 Expansion (2010)

It is noted that the Okutadami dam power plants expansion does not expect energy increase by the expansion. As it is generally accepted that expansion of existing hydropower plants usually does not increase the annual energy[1], the Okutadami dam hydropower plant expansion is an example to valuate

1 U.S. Army Corps of Engineers: Engineering and Design Hydropower. EM1110-2-1701, 1985, USA

the expansion with respects to the capacity benefit.

NN1 expansion is similar to Okutadami case as it will be developed as an urgent peak power development to cover the bulk power supply shortage anticipated in the near future. It is inevitable that the increment of energy is limited; however this situation is exemplified by Okutadami dam hydropower plants expansion.

Role of Expanded NN1 in Updated Power Supply and Demand

(1) Increment of Energy

In this study, the inflow time series data is updated and prepared until 2011. Then, the power generation simulation was conducted for NN1 hydropower station with an expansion of 40 MW. The result of the power generation simulation showed that the annual energy will increase to 66 GWh if NN1 is expanded. In the previous study, the increment energy was calculated to be 56 GWh. The increase in incremental energy was due to the 2011 hydrology. However, the difference was less than 1% of the annual energy of NN1 hydropower plant. It can be said that NN1 expansion will increase the annual energy from 5% to 6%.

(2) Contribution to Peak Power Supply

The expansion scale of 40 MW is just 4% of the total installed capacity in the central area in 2017, which is 940 MW. However, by utilizing the massive reservoir storage capacity, expansion of NN1 will improve the flexibility of operation. Thus the off-peak energy is shifted to peak energy.

The power from the northern area to central area is expected to stabilize base power. Therefore, NN1 is allowed to concentrate on peak power operation while keeping a minimum power output to meet the environmental requirement during off-peak hours. This shifting of energy from off-peak to peak hours caused the peak energy deficit in 2017 to decrease to 12% in the central area. Therefore, NN1 expansion is an effective method to decrease power import from EGAT.

(3) Reduction of O&M Cost for Existing Generation Units

As discussed in the preparatory survey in 2010, the expansion project will improve the operational efficiency of the whole power station. Thus, it is envisaged that the project will result to the reduction of the O&M cost of the existing generation units. This study estimated that the saving of operation time was updated to 11% from 12.4% in the previous preparatory survey in 2010.

Environmental Study for Nam Ngum 1 Hydropower Station Expansion

In the case of Extension of NN1 Hydropower Station Project, an initial environmental examination (IEE) was required to conduct for obtaining an environmental compliance certificate (ECC). The result of the IEE was submitted to the Water Resources and Environment Administration (now Ministry of Natural Resources and Environment or MoNRE), and the ECC was issued in April 2010 to EDL. In March 2012, EDL issued a request to MoNRE for the extension of the ECC because its validity is limited only for two years. The request was accepted and the ECC was extended on 9 July, 2012.

The ECC needs to be extended every two years until the commencement of the operation, unless there is no change in the project design and/or planning.

Based on the result of the previous study in 2010, information regarding natural and social environments within the project area was reconfirmed and updated, taking into account any possible affects from newly operated two hydropower plants, namely, Nam Lik Hydropower Plant and Nam Ngum 2 Hydropower Plant. Consequently, any significant effects were found on water fluctuation. As for water quality, the low rate of dissolved oxygen water was observed in the downstream of the Nam Ngum Hydropower Plant after the commencement of the Nam Ngum 2 Hydropower Plant; however, the water quality has returned to normal at present.

Economic and Financial Analyses for Nam Ngum1 Hydropower Expansion

The project cost estimated in the previous preparatory survey was adjusted to the present price with recent inflation rates. The project cost was updated to JPY 7,212 million (increased by 2.9% from the preparatory survey estimates).

In the economic analysis, EIRR estimated with effects on international electricity trade balance was as low as 4.04%, which was lower than the discount rate of 10%. The low IRR was primarily because of the low tariff level and small difference between peak and off-peak energy values. It is questionable if the current cross-border trade tariff level reflects the actual economic values of energy supply. Surcharge payment, imposed in case EDL has excess import from EGAT, is not anticipated in both with- and without-project cases in 2017 and 2020. Taking the alternative thermal power as economic benefit, EIRR was calculated as 15.06%, and NPV was USD 29.7 million with 10% discount rate. Thus the project is economically viable.

In the financial analysis, the increased tariff revenue of EDL was considered as the project's financial benefit. FIRR was calculated as 5.50%, showing marginal profitability of the project. Low tariff level compared to the large investment cost was considered as a major factor of the low FIRR. The tariff system of EDL does not apply TOD rates; thus, the increase in peak capacity cannot be reflected in the financial benefit calculation. Because of the very marginal financial viability of the project, a concessional ODA loan is considered necessary for implementation.

Review of Transmission Line Network in the Central Area

(1) Present Transmission Line in Lao PDR

Presently, the power system of Lao PDR is still separated into two parts, namely, (i) north and central system up to Pakbo and Kengkok in the south, and (ii) Xeset system in the southern area. It is planned that the 115 kV transmission line between Pakbo and Xeset will be constructed and commence operation in 2016 under finance of JICA.

Nabong 1 Substation is expected to connect to EGAT system in Thailand through a new 230 kV transmission line for power trade, which was designed as a double circuit with four conductors of

ACSR 630 mm^2 per phase.

(2) EDL's Action for Bus Conductors in Substations

In the previous JICA's Preparatory Survey, it was reported that no overload was found on the transmission lines around NN1 P/S after 40MW NN1 expansion in the year of 2016. Contrarily, some issues of overload of bus conductors in Thalat S/S and NN1 Switchyard were pointed out. The Study Team checked whether such recommended actions for upgrading bus conductors were taken by EDL.

a. Bus conductors in Thalat Substation

It was pointed out in previous study that 115kV bus conductors in Thalat substation did not have enough capacity for calculated load. It was however confirmed that the replacement of said bus conductors has been completed to upgrade to an adequate size.

b. Bus conductors in Nam Ngum 1 Power Substation

It was also pointed out in previous study that 115kV bus conductors in switchyard did not have enough capacity in case of NN1 expanded. The replacement of bus conductors has not yet been completed as of August 2012.

(3) EDL's Load Flow Analysis

According to result of this analysis, there was neither overload nor abnormal voltage on the transmission lines in the Nam Ngum system under normal conditions with 40 MW expansion. There seems to be no needs for installation of a new transmission line or upgrading the existing transmission line in case 40MW expansion.

Since some modifications on the power system were made after issue of PDP 2010-2020 Revision 1, EDL's load flow analysis may accordingly need to be updated. It is recommended that further detailed study on overload of transmission lines and bus conductors in consideration of N-1 conditions be carried out in the continued Preparatory Study on Expansion of NN1 Hydropower Station (Phase-2).

7.2 RECOMMENDATIONS

Recommendations on Future Power Supply in the Central Area

The domestic power supply of Lao PDR is composed of power generation by domestic power sources and power import from EGAT. Power import takes significant role on reliable power supply for Lao PDR. However, considering the power demand and balance in EGAT, anticipated power import for over 700 MW from EGAT will consume 10% of their reserve margin, if the current reserve margin of EGAT is kept. Thus it is deemed that such situation is not preferable for EGAT power supply system. EDL is required to develop their own power source in Lao PDR, and schedule their power generation to secure the power capacity especially during dry season. Power development in own resources for domestic power supply is the first priority in the power supply sector of Lao PDR. In this context, NN1 expansion is selected as the first option for peak power capacity development as a result of the comparative study.

However, as reliable power supply is endorsed by the power import from EGAT, and power import is indispensable for power supply of EDL, it is recommended that the planned reinforcement of interconnection line should be implemented.

In addition, it is preferable to change some of IPP(d)s power generation operation from base power operation to peak power operation. Many of Power Purchase Agreement (PPA) signed between EDL and IPP(d) does not specify the operation hours or operation period per day. On the contrary, PPA between EGAT and IPP(e) hydropower specify the generation hours to meet the peak hours in load curve in Thailand. It is recommended to change the form of PPA, to focus on peak power supply by splitting current flat tariff to time of use (TOU) tariff, which consists of peak and off-peak tariff or simply specifying the operation period to meet peak hours. As it is anticipated that controllable power capacity for EDL will be very limited to the total capacity in the near future, the increment of peak power supply by IPP(d)s will help the peak power operation of EDL power generation scheduling.

Recommendations on Environmental Issue

The following tasks are recommended to be carried out in further study:

- Assess impact on the downstream of the Nan Ngum River resulting from the Extension of the Nan Ngum Hydropower Plant, taking the data of daily water fluctuation after the commencement of operation of Nam Lik 1/2 and Nam Ngum 2 into account;

- Collect monitoring result on water quality after construction of Nam Lik 1/2 and Nam Ngum 2 in order to review and update as appropriate the monitoring plan on the extension of the Nam Ngum Hydropower Plant prepared in the previous study; and

- Collect information regarding on-going monitoring program on management of the Nam Ngum River basin such as responsible agency for monitoring, monitoring items, and existing monitoring scheme, in order to review and update as appropriate the monitoring plan on the extension of the Nam Ngum Hydropower Plant prepared in the previous study.