Department of Electricity, Ministry of
Energy and Mines
Electricité du Laos
Lao People's Democratic Republic

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

Final Report
(Summary)

January 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

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IDD
JR
09-092

S-1. Background and Objective of the Study

The national power network system of Lao PDR is divided into four systems (North, Central 1, Central 2 and South) and the domestic power consumption of Lao PDR is supplied individually as separated areas. Department of Electric Ministry of Energy and Mines and Electricité du Laos have been struggling to optimize and stabilize their power network systems by connecting them of four regions in Laos. The transmission line project between Central 1 and Central 2 regions that was planned in collaboration with “The Study on Master Plan of Transmission Line and Substation System in Lao PDR (2001-2002)” has been advanced through the Japanese Government Loan. The project will make it possible to supply power to Central 2 power consumers from Central 1 power generation and the amount of the imported energy from Thailand with high price is expected to be reduced.

On the other hand, there are no interconnections of the power systems between Central region and South region. The completion of the national power grid by urgent expanding the bulk power network system to the south region is strongly expected. It is expected not only to improve the management of electric power industries by the national power interchange, but also to contribute the realization of the energy policy such as to vitalize the national economy, to fulfill the Basic Human Needs and to preserve the environment by converting the fuels required for living.

Government of Laos proposed to the Government of Japan a request for this study because Japan has a plenty of experiences in cooperation with Lao PDR regarding the transmission line and substation system of Laos. To examine the request, Japan International Cooperation Agency (JICA) carried out the preliminary surveys in July 2008. After JICA discussed details of the request and agreed with officials of the Lao PDR, both parties signed S/W in August 28, 2008.Carrying out this study is based on this S/W.

The purposes of the study were to make an optimal plan of the national power network system from 2011 for 20 years, to carry out the basic design of the prioritized project adopted through the aforementioned plan and to do the technology transfer to the counterpart staff regarding the power network system plan.

S-2. Outline of Power Sector

Electricity Consumption in Lao PDR reached 100GWh in 2006 and the growth rate during the period 1996-2006 hit more than 11%.

Regarding electricity consumption by sector after 2004, that in industrial, service, residential have been growing steadily. Particularly, in residential and service sector those have been increasing at 10% and 20%, respectively.

Meanwhile, the peak power recorded 369MW in 2007 and the growth rate showed 12% during the period 1999-2007.

Electric System Standards

24-hour of Loss-of-Load Expectation (LOLE) is adopted in Lao PDR system as system reliability criterion. Through “JICA Lao Electric Power Technical Standards Preparation Project” (2000-2003), Lao Electric Power Technical Standards (LEPTS) were prepared with Lao counterparts in DOE and EDL. LEPTS consists of articles to maintain the safety for Civil and Electric Hydropower Plant Facilities, Substation Facilities, Transmission Line Facilities, Distribution Line Facilities and User’s Sites Electrical Facilities. LEPTS were enforced as a ministerial ordinance in February 2004. “JICA

LEPTS Promotion Project" (2005-2008) was commenced continuously, and then preparation of necessary documents, training for DOE and EDL staff, establishment of regulatory organization in DOE, and public relations activities were carried out.

Law on Electricity

The Law on Electricity is the basis of electricity business in Laos. The law was promulgated in 1997, consisting of 11 chapters and 81 articles. It stipulates electricity-related matters such as approval of electricity business and electricity trade. The existing Law on Electricity is now under amendment procedure to be in line with nowadays reality, finally facilitating growth in Laos' electricity sector. It is said that a gap between the existing law and rapidly-changing socio-economic circumstance have been widening. The revision work is almost finalized and has been promulgated.

Electricity Tariff System

The Law on Electricity stipulates that electricity tariffs for domestic customers and for export/import business should be approved by the Government of Lao (GoL) periodically. Lao PDR's electricity tariff system is largely classified into three systems, namely retail tariff for domestic customers, export/ import tariff, and wholesale tariff by Independent Power Producers (IPP). The level of EDL's retail tariff for domestic customers has been set politically low. Specifically the tariff for Residential and Agriculture customers are set lower than the others. Tariffs for energy export and import have been determined through regular negotiations with the related authorities of the partner countries. In general, the import tariffs are set higher than export tariffs. In Lao PDR, two independent power producers (IPPs), Theun-Hinboun Power Company Limited (THPC) and Houay Ho Power Company Limited (HHPC) sell electricity to EdL. Power rates for IPP projects are determined through negotiation between EdL and correspondent IPP.

Power Sector

In the Power Sector Policy Statement issued on March 15th 2001, the Government of Lao PDR has the basic policies as stated below.

Stable and continuous domestic power supply at a reasonable price is maintained and expanded to promote the economic and social development.

Power sources developments for power export are promoted to derive enough income to meet the policy for governmental development.

The Departments of Electricity (DOE) of Ministry of Energy and Mines (MEM) governs the power sector of Lao PDR. Electricité du Laos (EDL) is the power utility owned by the Government of Lao PDR governed by DOE covering the power generation, transmission and distribution managing the domestic power supply and the power import and export. The joint management of the foreign companies and Lao PDR organizes the IPPs shouldering the large scaled power export through the export-oriented power transmission lines.

In Lao PDR, all development projects required to obtain Environmental Compliance Certificate (ECC) before starting construction activities. Environmental Assessment (EA) needs to be implemented in order to obtain the ECC. Water Resources and Environment Administration (WREA), the principal Government agency for formulating and guiding environmental policy, is responsible for reviewing EA report and issuing ECC to project owner. The IEE report is to be developed by a project owner, Electricité du Laos (EdL), in which Environmental Office under Department of Technology is in charge. Subsequently, the report is to be reviewed by Ministry of Energy and Mines in which Social and Environmental Division under Department of Electricity is in charge, and to be submitted to WREA for approval. Based on the Environmental Protection Law, the

Environment Assessment Law stipulates uniform requirements and procedures for environmental assessment. Decree on the Compensation and Resettlement of the Development Project defines principles, rules, and measures on compensation and resettlement resulting from development project.

Financial Analysis of EDL

The electricity demand in year 2016 is estimated to become four times as much as the one of year 2006. The challenge is how to finance such vast investment. EDL's financial statements show that its capital investment mostly relies on long-term borrowing from multilateral/ bilateral development donors. Therefore, it is essential for EDL to keep its financial status solid. The fact, however is that the loss which domestic electricity supply business has posted consistently has been offset by profits from export business and dividend income from IPP. In order to improve such financial structure, three parties of EDL, the government of Lao (GOL) and International Development Association (IDA) have agreed to "The Action Plan for Financial Sustainability of the Power Sector" in 2005. The Plan includes the action to increase tariffs to cost-recovery levels and the one to settle government areas owed to EDL. EDL's financial statements demonstrate that EDL is eligible for further loan from the institutes of overseas assistance: the past-five-year figures of equity ratio, which measures the long-term solvency, and current ratio, which measures the short-term solvency, have cleared the concern of EDL's financial capability.

Multilateral creditors like IDA have requested EDL to keep its loan policy as shown below when EDL takes out a loan from them.

- Self Financing Ratio $\geq$ 30%
- Debt to Equity Ratio $\leq$ 1.5
- Debt Service Coverage Ratio $\geq$ 1.5

The investment plan in EDL's Power Development Plan (2007-16) generally follows the above policy. EDL's financing plan in PDP is concluded to be viable.

S-3. Existing Facilities of Transmission Lines and Substations

Power System Configuration

Domestic electric power in Laos is separately supplied to four regions, North, Central 1, Central 2 and South.

The Central 1 grid supply power to Capital Vientiane with three hydropower stations, Nam Ngum 1 (155 MW), Nam Leuk (60 MW) and Nam Mang3 (40 MW) and 115 kV interconnection between Thailand and Laos. The Central 2 grid consists of two systems. Each system imports power from Thailand through the interconnections. The South grid has Xeset1 hydropower station (45 MW) and Selabam hydropower station and a 115 kV interconnection with a single circuit. There are no 115 kV substations in North region. The North region has power supply from distributed power stations or through the distribution lines from Central 1 grid, China and Vietnam.

The four transmission systems are operated by EDL for domestic energy supply and partially for export to Thailand. There are 28 115/22 kV substations/switching stations on those systems and the transformer capacity is 873 MVA in total.

There are no central dispatching centers in Laos to manage the domestic power supply system.

O & M of Transmission System

The Distribution Department of EDL in the head office has responsible to manage and control the existing 115 kV transmission lines, substations and distribution lines of each province dividing the whole country into three areas, i.e. Northern Area (9 provinces except Vientiane Capital), Vientiane Capital (6 districts) and Southern Area (7 provinces). Operators and maintenance staffs of each substation are responsible daily O&M including routine checks and inspections and minor repairs of substation facilities. EDL's branch offices in each province are responsible for operation and maintenance of local HV (High Voltage), MV (Medium Voltage) and LV (Low Voltage) networks including inter-connection MV lines with the neighboring countries. It is noted that province-owned MV and LV networks are managed by the Department of Electricity (DOE) of each province.

Through the team's interview to various O & M sections of EDL, following issues are found.

a) Periodical patrol and maintenance for the lines should be performed strictly following O & M manuals to prevent avoidable faults.

b) Since computer operated Distributed Control Systems (DCS) are introduced in some substations and operation records such as voltage, current, power factor, load, etc. are automatically logged at the substations, log sheets are recorded in handwriting at most of the substation and the mistakes by human error are sometimes observed. Introducing the automatic log system and training for accurate meter reading to understand the functions of equipment and meters in substations by operators are promptly necessary.

c) Spare parts for the facilities, in particular, for distribution equipment are not sufficient for proper repair. Common parts from other damaged equipment are used for parts of another equipment in repairing.

d) EDL's official O&M manuals for transmission lines, substation and distribution line are to be prepared promptly.

e) Tools and meters necessary for repair shop are insufficient in accordance with responsible persons of EDL's repair shop.

f) Capability of person in charge of operation and maintenance of all fields of the power sector is necessary to be upgraded.

S-4. Conceptual Designs

Basic Design Criteria

Climatic conditions applied for the conceptual design of the national transmission system are as mentioned below.

- Atmospheric Temperature, Air Density, Wind Velocity, Wind Pressure, Stringent (the most severe design) Condition and EDS (Every Day Stress) Condition, Annual Rainfall, Isokeraunic Level (IKL), Seismic Condition, and Other conditions assumed.

LEPTS and IEC standards are applied to the design of new and/or reinforcement of substation equipment.

This preliminary design is carried out for the planning of new 230 kV and 115 kV substations and reinforcement/augmentation of the existing substations of the Optimum Transmission System.

The following design concepts are applied for the preliminary design.

- Reliability Concept, Type of Substations, Connection of Substation Equipment, Earthing System, Countermeasures for Disasters, and Consideration for Environment.

The busbar systems for 115 kV and 230 kV substations are selected in coordination with the related existing network in respect of supply reliability, operation and maintenance, and other factors.

115 kV and 230 kV main power transformers are to be of three phase, oil immersed type with on load tap changer (OLTC). ONAF (Oil Natural Air Forced) and ODAF (Oil Directed Air Forced) cooling systems are applied for 115 kV and 230 kV main transformers, respectively. 115 kV main power transformers are to be three-winding star-star-delta (Y-Y-Δ) connection transformer type. 230 kV main power transformers are to be three-phase auto-transformer type. The unit capacity and number of units of main transformers in a substation are determined, taking into comprehensive account demand forecast, economic feasibility, system reliability, voltage regulation, land acquisition, plan of equipment shift, etc. In addition, the preliminary design is also carried out for the following switchgear and substation equipment.

- Circuit Breakers, Standard Constitution of Equipment, Static Capacitors and Shunt Reactors, Protective Relay System, Communications System, and Distributed Control System

S-5. Power Demand Forecast

Power Demand Forecast by Macroscopic Methods

In this study, power demand forecast during the period until 2030 is required for the transmission development planning. The figure below shows the implementation flow of the forecast. First microanalysis on correlation between economic indices and electricity consumption has been carried out and based on the results power demand in Lao PDR was forecasted in this study.

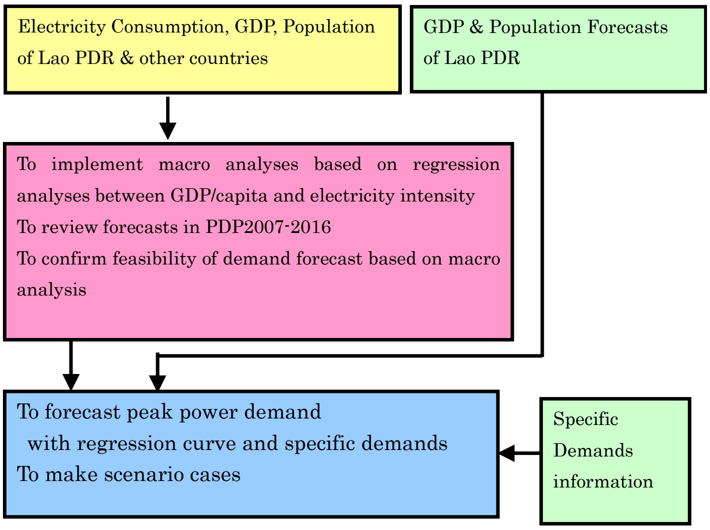

Figure S-5.1: Analysis Flow of Demand Forecast

For this study three scenario cases shown in the table below were to be assumed. Base case and Base case + SLACO were based on 7% of GDP growth rate and High case was based on 9%. In Base and High Case, demand forecasts consist of the calculation by macro analyses with the GDO growth rates and specific power demands except SLACO that is an aluminum-processing factory, in Base+SLACO Case, it comprised the calculation by macro analyses and all specific power demands.

Macro analysis on correlation between GDP/capita and electricity intensity of Lao PDR and neighboring countries using regression analysis gives us a formula.

Main assumptions for our demand forecast were as follows;

- GDP growth rate: 9% in High Case, 7% in Base Case
- Population prospect: 7.3 million person in 2020, 7.9 million person in 2030
- Line losses:

Year	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20-30
Line Loss Rate (%)	21.4	20.8	20.4	19.8	19.3	18.7	18.2	17.7	17.1	16.6	16.1	15.5	15.0

(Source: PDP2007-2016 EDL)

- System load factor:

Year	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19
Load Factor (%)	44.3	45.6	46.9	48.2	49.5	50.8	52.1	53.4	54.8	56.1	57.4	58.7
Year	'20	'21	'22	'23	'24	'25	'26	'27	'28	'29	'30	
Load Factor (%)	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0	68.0	69.0	70.0	

(Source: PDP2007-2016 EDL)

Specific demand: to take into consideration of specific demands identified as of Feb. 2009. the specific demand may increase by 1,000MW totally in 2013 & 2014. This is to be caused by commissioning of aluminum processing factory, SLACO. Since this demand is very huge, this study would not deal with this load in Base & High Case but Base + SLACO Case.

Figure below shows peak power demand forecasts calculated for this study. This figure illustrates that the peak power in Base Case shall reach 1,852MW in 2020 which shall be 4 times more than the current demand and 3,065MW in 2030 which shall be 7times more than the current one. The peak power in High Case and Base+SLACO Case shall grow to 2,272MW and 2,851MW in 2020, and 4,951MW and 4,065MW in 2030. This means that the peak power in High Case shall have left that in Base+SLACO Case behind.

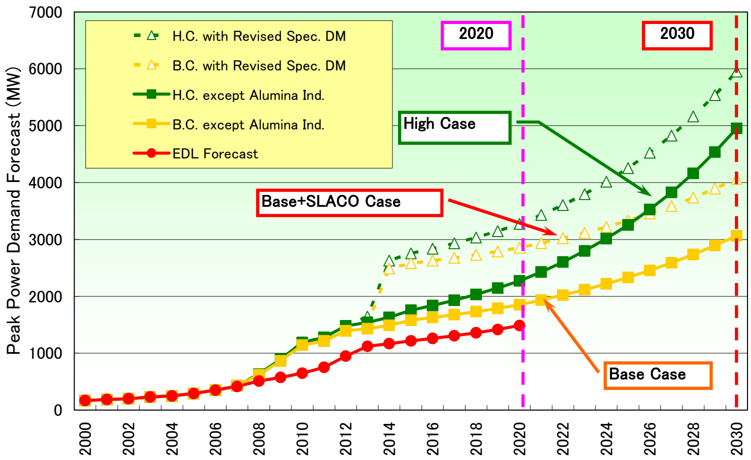

Figure S-5.2: Peak Power Demand Forecasts by Case

Table S-5.1: Peak Power in 2020, 2030 by Case

Case Name	2020	2030
Base Case (MW)	1,852	3,065
High Case (MW)	2,272	4,951
Base+SLACO Case (MW)	2,851	4,065

Power Demand Forecast for Substations

The power demand of the whole of Laos supplied from 115 kV substations has been forecasted assuming that the residential power consumption was correlated with population, power consumption per capita and its electrification rate and the the commercial and the industrial power consumption were correlated with the GDP based on the methodology taken in JICA in 2002. The power demand for each 115 kV substation in provinces was forecasted based on the predicted provincial population and power consumption for per capita. The power demand of all the special power consumers that could be identified has been included and the difference between the macroeconomic demand forecast and the total amount of the power demand after 2026 was supposed to be the special consumers latter appearing.

S-6. Review of Power System Plans

The adequacy of the latest Power Development Plan prepared by EDL (March 2008) approved by DOE was confirmed from the technical viewpoints thorough demand-supply simulation and power system analysis.

Outline of Balancing Supply and Demand Simulation

The latest power development plan was reviewed in the basic balancing supply and demand simulation. The series of simulation has been conducted in 2016 on the most likely to be realized interconnected systems based on the latest power development plan and interconnection plan in the Indochina region.

In the detail balancing supply and demand simulation, the best mix for power generation in 2030 is analyzed reflected the results of basic simulation and based on the adopted demand forecast and scenarios.

Plans for interconnection to neighboring country project are clarified power import projects and power export from IPP generation projects. Some projects could be suspended due to problems of fund raising or negotiation of PPA. The situation of each interconnection project will be comprehended from existing reports, interview of counterpart personnel, private investor, the World Bank and ADB. The information for interconnection projects has been reflected in the balancing supply and demand simulation.

The postulation for basic simulation of balancing supply and demand in order to review the authorized power development plan is described in the following section.

1) Power System Configuration

The power system configuration in 2016 for the basic simulation is selected as three (3) systems in the Lao PDR and two (2) systems in the Thailand in considering present system constrain, interconnection with Thai system and system expansion plan.

- Lao PDR (Three (3) systems): North + Central 1, Central 2, South

- Thailand (Two (2) systems): Northeast, Central + South

2) Demand Forecasts

Demand forecasts by systems are listed in the Figure below. Peak demands in Lao PDR are distributed depended on the records in the year of 2005. Energy by systems is calculated by each peak demand and EdL estimation of load factors.

Table S-6.1: Demand Forecasts for Analysis (2016)

System	Peak Demand (MW)	Energy (GWh)	Load Factor (%)
Laos North+Central1	847	4,971	67%
Laos Central 2	168	986	67%
Laos South	110	578	60%
Thai Northeast	3,468	17,547	57.8%
Thai Central+South	28,974	201,792	79.5%

Power development plan by 2025 for the basic simulation of balancing supply and demand is prepared by the consultant based on the information form the Department of Energy, Ministry of Energy and Mines (DOE, MEM). The plan is hydropower plant development oriented. Hongsa lignite thermal power plant (100MW, Lignite) is planned in 2013. Viengphukha thermal power plant (60MW, Coal) is planned in 2019. The power development plan for detail simulation will be developed based on results of basic simulation, the least cost generation composition and considering potential of primary energy in the Lao PDR especially coal deposit.

3) System Interconnection

Interconnected system for reviewing is selected in 2016 based on the latest power development plan. The capacities of interconnection are adopted from the latest power development plans of EdL and neighboring countries. The capacities of interconnection for the study are described in the table below.

Table S-6.2: Capacities of Interconnection (2016)

System interconnection	Capacity (MW)
Lao North + Central 1 - Lao Central 2	90
Lao Central 2 - Lao South	180
Lao North + Central 1 - Thai Northeast	600
Lao Central 2 - Thai Northeast	120
Lao South - Thai Northeast	120
Thai Northeast - Thai Central + South	1,300

Simulations of System Reliability

Situations of system reliability of authorized power development plan are illustrated in the Figures below. The reserve margin, 241MW, is required to secure the system reliability criterion (LOLE=24 hour). After interconnection, the necessary reserve margin will decrease to 88MW.

The supply capacity can secure to meet each peak demand in every system when the power plants are developed on schedule. The surplus energy would be in the Loa North + Central1 system and the South system from monthly energy balance. The energy balance in Lao central2 system could be insufficient especially in dry season when the power exchange is added through interconnection. The power export to Cambodia is not considered.

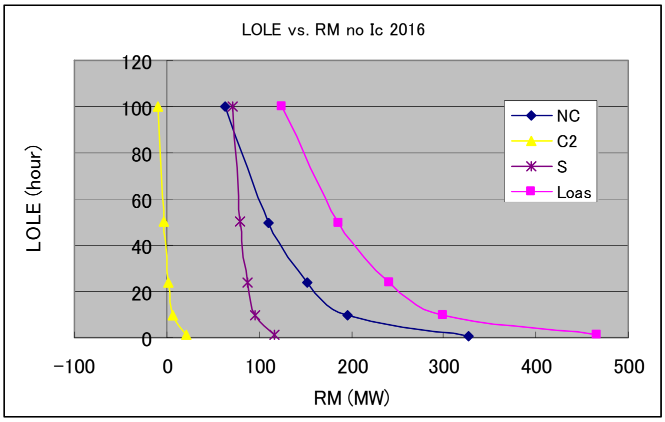

Figure S-6.1: Relation LOLE vs. Reserve Margin in Isolated system

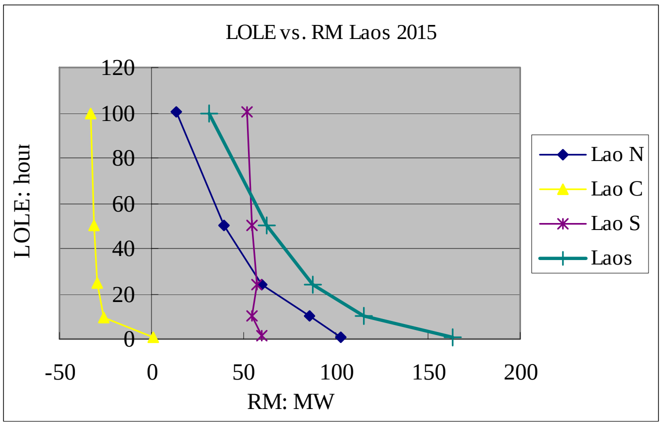

Figure S-6.2: Relation LOLE vs. Reserve Margin in Interconnected system

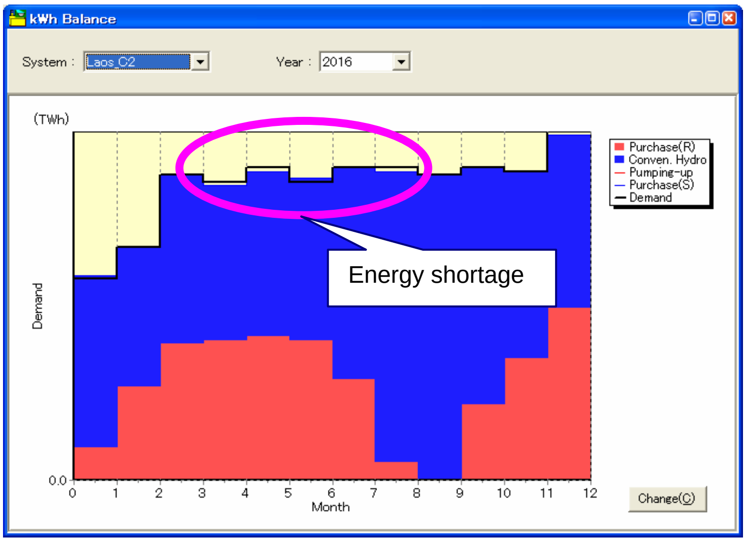

Figure S-6.3: Monthly Energy Balance in Lao Central2 system (2016)

Basic System Analysis

PSS/E (Power System Simulator for Engineering) Ver.31, which EDL also owns, was used for the series of system analysis works for the power system as of 2016, the final year of the PDP 2007-16 both for the peak demand periods of time in dry and wet seasons following the Fundamental Technical Criteria and Study Conditions described below.

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

- Under normal operation, loads of transmission lines and transformers must be within their rated capacities.
- In case of a single circuit fault for the section with more than double circuits, the power flow of remaining facilities must be within the rated capacities.
- Power transmission from the generators with single circuit transmission lines is allowed when the generator rejection is not significant in case of a single circuit fault.
- In case of a single fault of an 115/22kV transformer, the loads of the remaining transformers must be within 110% of the rated capacities.
- In case of a single fault of a 230/115kV transformer, the loads of the remaining transformers must be within the rated capacities after reducing power export to Thailand by restricting the specified power outputs of generators.
- Under the normal operation condition, bus voltages in the transmission system must be within the range from 95% to 105% of the nominal voltage. In the case of a single contingency, bus voltages must be within the range from 92% to 108% of the nominal voltage.
- The power factors of generators must be within the range from 90% (leading) to 85% (lagging).
- The fault currents of the transmission system must not exceed the maximum fault currents shown in the table below.

Table S-6.3: Maximum Fault Current

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

- Power system stability must be maintained without restricting the generation output of principal power plants or interrupting the power supply to the demand in case of a permanent three-phase short circuit fault, after clearing the fault by main protection relays, not considering any reclosing operations.
- Fault clearing times by main protection relays were shown in the table below.

Table S-6.4: Fault Clearing Times by Main Protection Relays

Voltage Level	Fault Clearing Time
230kV	100ms
115kV	140ms

- PSS/E data of the power system as of 2008 to 2016 were provided by EDL and line constants in the data were basically applied.
- Either 230kV or 115kV is applied to the transmission system for domestic power supply.

- For newly planned substations which were not considered in the PDP 2007-2016, the following conditions are assumed.

  - As a 230kV bus configuration, one-and-a-half (1+1/2) method is basically applied. Application of double bus arrangement is also considered if higher supply reliability is required.

  - 115/22kV Transformers
    - 30MVA, 3 banks in maximum in a substation
    - Maximum load target is 60MVA

  - 230/115kV Transformers
    - The capacities of primary and secondary sides are determined with predicted power flow.
    - The voltage of 22kV and the delta winding are applied to the tertiary sides. The capacity of the tertiary side is basically 30% of that of primary and secondary sides.
    - On-load tap changers are applied.

  - Standard Impedance

    The impedances of power supply transformers are as shown in the table below.

Table S-6.5: Standard Impedance of Power Supply Transformer

Voltage	Impedance between Primary and Secondary Sides
230/115kV	12.5%
115/22kV	8.5%

- The rated capacities of the conductors are shown in the table below.

Table S-6.6: Standard Conductors

		MW	A	MVA
115kV	477 MCM ACSR	100	600	120
	795 MCM ACSR	140	818	163
	2 x 795 MCM ACSR	280	1636	326
230kV	1272 MCM ACSR	365	1,078	429
	2 x 1272 MCM ACSR	730	2,156	859
	4 x 1272 MCM ACSR	1,460	4,312	1,718
500kV	4 x 795 MCM ACSR	2,300	3,272	2,834
	4 x 1272 MCM ACSR	3,200	4,312	3,734

477 MCM ACSR is equivalent to240mm^2 (Hawk).
795 MCM ACSR is equivalent to 410mm^2 (Drake).

- The dry season outputs in “Estimated Generation in Dry Season / Year, ADB “Preparing the Greater Mekong Subregion Northern Power Transmission Project”, October 2008, for dry season generator outputs. As generator outputs in the dry season, 70% of the installed capacities are applied for the generators whose firm capacities are unknown. In the wet season, power outputs of the generators in southern area are restricted to 80% of the installed capacities to maintain system stability under normal operation condition.

- Under normal operation condition, 500/115kV transformers in Hongsa Lignite thermal power station are opened.

Analysis Results

- Dry Season: Under normal operation condition, no overloading of transmission lines or abnormal voltage at substation buses occurs.

- Wet Season: Under normal operation condition, no overloading of transmission lines or abnormal voltage at substation buses occurs.

Under single contingency conditions, over voltages occur at some substations in the north region. Switching operations and/or installation of shunt capacitors can solve the voltage violation problems.

Under the single contingency cases of 115kV Saravan SS – Sekong SS (1Ckt Open), overloading occurs to the remaining circuits of the same sections. This situation is due to calculation condition that all of the generation outputs of the generators in Southern Area are restricted to 80% of their installed capacity, and that remaining generators in the system are operated at their rated capacity, in other words, 100% of their installed capacities. This condition is severer than actual generator operation condition because, in reality, some of generators will be out of service due to periodical inspection. Therefore, the total generator output can be considered smaller than that of this analysis and such overloads are expected to be solved.

Environmental and Social Consideration on Power Network System Plan

Considering the socio-environmental situation in Lao PDR, the followings are the most essential issues with regards to transmission line projects.

1) Minimizing resettlement:

With the increase of population and urbanization, the population density have risen near National Road 13 South, the main road go through southern provinces, in Vientiane Capital City, capital city of Khammouan Province, Savannakhet Province and Champasack Province. Given the tendency continue, land acquisition for the transmission line route would be more difficult near future. Accordingly, it needs to pay more due consideration for alignment of transmission line in those areas in order to minimize resettlement in the future.

2) Reducing disturbance to natural environment:

In response to the increase conservation effort of the Government, the route selection of transmission line needs more concern in the vicinity of conservation areas. A conventional monitoring method for the habitat of endangered species in transmission line route needs to be reviewed and re-designed in more practical and effective manner.

3) Lower the risk of UXO:

The survey of location and cleaning of UXO is under way by the Government. Consequently, it is considered that the number of UXO will be decreased in the future. However, the number of UXO is so enormous that the cleaning operation is expected to take time. Accordingly, the site survey and cleaning of UXO in the project are needs to be practiced continuously.

4) Remedying the disadvantage of ethnic minority people:

Considering the following two facts that 1) the number of ethnic people who understand the official language has been increasing and 2) gathering the information on land use for those people by Ministry of Agriculture and Forest are under way, the needs of special consideration for those people is expected to decrease in the future. However, taking account of the high rate of ethnic people (about

40% in total population) in this country, a special attention such as collect information on the distribution of ethnic minority and their situation, needs to be constantly paid in the project area.

S-7. Selection of Highest Prioritized Project

Criteria for Selection of Prioritized Project

Before selecting the highest prioritized project, several prioritized projects were selected in advance. Among the prioritized projects, the highest prioritized project was selected that would be given the highest priority to be studied.

Before selecting the prioritized projects, the selection criteria were set out based on the discussion with the counterparts

On the basis of the abovementioned criteria, ten projects that could bring the wide benefit through the domestic power supply in Laos were selected as the prioritized projects among all the transmission line and substation projects planed up to 2016 in PDP. The ten of the selected prioritized projects were evaluated from the viewpoints of urgency, effectiveness, costs and social/environmental considerations and the highest prioritized project was selected.

10 short-listed projects for the prioritized project were screened from the points of environmental and social consideration. Considering its importance at early stage of project design, possible negative impacts regarding transmission route selection were examined in each short-listed project. After reviewing the information gathered at the site survey in North and South Provinces as well as reliable second information resources collected during the second site study, 4 measures, resettlement and loss of agricultural lands, ethnic people, disturbance to wild life or in protected areas and accidents caused by UXO were considered to be applicable to screen the impacts. Possible negative impacts were predicted in each candidate project, however, the degree of impact is considered to be not severe and minimizing negative impact is attainable in terms of developing appropriate mitigation measures at project designing phase.

Construction of New 1 and Kengkok-Saravan transmission line are both selected as the projects where the importance should be put on. The project of construction of Kengkok-Saravan was finally selected based on the discussion with the counterpart as the highest prioritized project for this study that can carry on the wide power trade and can much reduce the power import from Thailand.

Conductor Size

Conductor sizes which satisfy both the system planning criteria and economic efficiency simultaneously were determined through the study of relationship between power flow and annual cost (sum of construction cost, O&M cost, and cost of transmission line losses) by conductor sizes. As the cost of transmission line loss, the export tariff for Thailand (hourly average) was applied since the income by power export to Thailand will decrease due to the transmission line loss. The relationship between the Least-annual-cost conductor size and power flow is described in below table.

Table S-7.1: Relationship between the Least-annual-cost Conductor Size and Power Flow

Conductor Size with Least Annual Cost	Power Flow		
	ACSR240mm^2 (Single)	ACSR410mm^2 (Single)	ACSR410mm^2 (Double)
Double Circuit Tower	～61MW	61～135MW	135MW～

Based on the calculation result, the power flow of the target transmission line is about 42MW/cct. Therefore, as of 2016, the most economical conductor type is ACSR 240 (single). After 2016, the power flow of the same section is expected to exceed 61MW/cct, the crossing point of the curves above that the type of the most economical conductor changes from ACSR 240 (Single) to ACSR 410 (Single). However, in this study, ACSR 240 (Single) was selected for the system analysis since this is the severer condition than that with ACSR 410 (Single).

Examination of the Location for the Sending End and the Receiving End of the Transmission Line

For the transmission line, either Kengkok or Pakbo can be the candidate starting point and either Saravan or Ban Jianxai can be the candidate ending point. Besides, there is a concept to place Taothan switching station (we called this “Napon” in this section of the report), 55km westward from Saravan substation. Therefore, in this section, the system analysis taking into consideration the most prioritized project selected in the former section was conducted. As a result, under normal operation condition, no overloading of transmission lines or abnormal voltage at substation buses occurs. And the maximum three-phase short circuit fault currents as of 2016 are below allowable level. The calculation results shows that the system configuration of “Pakbo – Napon – Saravan 2cct” as of 2016 has the minimum transmission line loss.

The calculations were executed under the criteria that “when the oscillations of the phase angles among rotors of synchoronous generators which constitute the system tends to converge even in case of the severest single contingency, the system is stable. ”In the dry season, for any candidate system configurations between Kengkok or Pakbo and Saravan or Ban Jianxai, the oscillation waveforms of phase angle differences were found to be converged. Therefore, it was confirmed that the four candidate systems can be stably operated even in the case of a severe fault condition. In the wet season, for the cases that have the connection between Napon and Ban Jianxai, the amplitudes of the oscillation waveforms of phase angle differences were larger than those for the cases that have the connection between Napon and Saravan although the waveforms did not diverge. From the above results, the connection pattern “Pakbo-Kengkok 1cct (existing) and Pakbo-Napon-Saravan 2cct” is considered the best connection pattern in terms of stability among the candidate connection patterns.

There are four candidate connection patterns starting from either Kengkok or Pakbo and ending at either Saravan or Ban Jianxai substations for the most prioritized project. Construction costs of the four candidate connection patterns were compared in order to confirm the least cost construction section among them. The comparison results were shown in the table below. The construction costs in the table constitute construction costs of transmission and substation facilities and costs for UXO investigation and disposal. The case 3 is the least cost connection pattern.

Table S-7.2: Construction Costs

No.	Case	Connection Pattern	Construction Cost (’000 US$)
1	PF-D1 PF-W1-80	Pakbo – Kengkok 2cct (existing + 1cct) Kengkok – Napong – Saravan 2cct	33,281
2	PF-D2 PF-W2-80	Pakbo – Kengkok 2cct (existing + 1cct) Kengkok – Napong – Ban Jianxai 2cct	34,973
3	PF-D3 PF-W3-80	Pakbo – Kengkok 1cct (existing only) Kengkok – Napong – Saravan 2cct	32,926
4	PF-D4 PF-W4-80	Pakbo – Kengkok 1cct (existing only) Kengkok – Napong – Ban Jianxai 2cct	34,619

From the viewpoints of cost, loss, and stability, therefore, we recommend that the construction section of the most prioritized project be from Pakbo to Saravan substations.

Effects of Highest Prioritized Project

The result shows that the case with the interconnection of 115 kV transmission line would bring more 4.1 billion Yen than the case without the interconnection of the 115 kV transmission line from economic aspect. Therefore, it was found out that the 115 kV Transmission project linking Central-2 region with Southern region would be superior also from economic points of view.

S-8. Simulation of Balancing Supply and Demand Up To 2030

Demand Forecast

Demand forecast for the detailed simulation of balancing supply and demand is described in the table below. Demand forecast is estimated by the information of potential customers from EDL.

Table S-8.1: Demand Forecast for the Detail Simulation (Base Case)

		Lao North + Central1	Lao Central2	Lao South	Thai Northeast	Thai Central + South
2016	Peak Demand(MW)	1,059	347	221	3,587	30,744
	Energy (GWh)	6,266	1,635	1,290	17,547	201,792
	Load Factor (%)	68	54	67	56	75
2020	Peak Demand(MW)	1,207	401	245	4,061	38,369
	Energy (GWh)	7,300	1,845	1,432	21,932	252,212
	Load Factor (%)	69	53	67	62	75
2030	Peak Demand(MW)	2,002	691	372	5,248	59,676
	Energy (GWh)	13,415	3,135	2,330	34,198	393,274
	Load Factor (%)	76	52	72	74	75

Power Development Plan

Power development plan for the basic simulation of balancing supply and demand is utilized as the detail simulation. The development plan after 2017 is not developed yet. The plan after 2017 will be developed in discussion with counterpart personnel of DOE and EDL, which is based on the results of the basic simulation.

Selection of Cases for Detail Simulation of Balancing Supply and Demand

In the detail simulation of balancing supply and demand, the additional power plants will be selected to meet the demand forecast in 2030 based on the simulation in 2016, 2020 and 2030. The basic policy for long-term development plan is that the demand in Lao systems should be satisfied by themselves. The cases has been selected considering potential of hydropower development and primary energy deposit in the Lao territory to establish the appropriate development plan.

Situation of Balancing Supply and Demand

Results of simulation in 2030 based on the latest development plan in considering potential development are illustrated in the Figure below. The supply power could short in the Lao central 2 system.

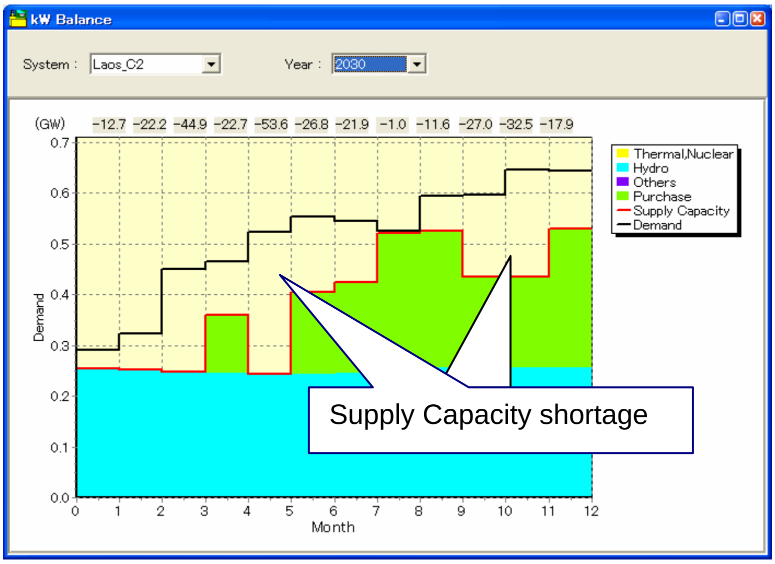

Figure S-8.1: Monthly Balance of Supply/Demand Lao Central2 system (2030)

The results of simulation demonstrates that the additional 280MW could be required to secure system reliability in dry season, May in 2030. The additional 450MW would be required in the high demand cases. It means that total 730MW could be required additional development by 2030 in the high demand case. The supply during dry season will be required in the every system. The additional supply for the Loa central2 system is necessary to secure system reliability through the year.

For the aluminum factory supply case, it required huge supply power that is as five times as present EDL system scale. This request cannot catch by the existing plan. The supply to aluminum factory causes following issues.

- Insufficient credit for fund raising and preparation duration for EDL due to too large to EDL ability,
- Impossible to recover EDL investment if the aluminum factory withdrawal development (Stranded costs),
- Necessity of alternative power for MOU with neighboring countries when IPPs for export are utilized to supply for the aluminum factory.

Potential of Primary Energy

There is coal deposit mainly in the northern part of Lao PDR. There is an anthracite deposit potential in Saravan in the Lao central2 area uncertainty. The amount of deposit could generate over 60 years in the 450MW coal fired thermal plant, where coal heat value of 6000kcal/kg, 30% of heat rate and 70% of capacity factor of the thermal power plant. The government of Lao has policy for coal mining is that the anthracite is preferred to export for earning foreign currency rather than utilize for domestic electric power generation.

Proposal of Case Selection for Detail Simulation

The results of simulation of balancing supply and demand demonstrate that the supply capacity could be insufficient in dry season except the Lao south system. The power exchange from Thai system is necessity to secure system reliability. The Lao central 2 system has insufficient supply capacity through the year. The Lao south system has sufficient surplus supply capacity. The situations demonstrate that the cases for simulation are additional supply in dry season and reinforcement of interconnection between the Lao central2 system and south system.

For mitigation of additional supply capacity in the dry season, there are the power import from neighboring countries and the thermal power development. For mitigations of additional supply to the Lao central2 system, there are the coal thermal power development in the Saravan, the reinforcement of interconnection with the Lao south system and the connection with IPPs located in the central2 area such as the Nam Theun2 and Nam Theun Hinboun. For the supply to the aluminum factory, there are the utilization of export IPPs, the thermal power plant development and the import from neighboring countries.

The blackout in Vientiane system due to fault in Thai system demonstrated that it cases ruined system reliability that the large share of supply capacity is depended on a power import. Thus, for long-term planning, the basic policy should be adopted a balance within the Lao PDR systems between supply and demand.

The proposed cases were as follows considering aforementioned points of views.

1) Saravan coal fired thermal power development (Supply in dry season, for the Lao central2 system)

2) Theun Hinbuoun hydropower connection into the Lao central2 system

3) Reinforcement of interconnection between the Lao central2 and south system

4) Selection of supply power (IPP) for the aluminum factory (including power import)

The cases for detail simulation will be selected in discussion with counterpart personnel from DOE and EDL. The least cost power development plan will be recommended with the detail simulation of balancing supply and demand.

Power Development Plan by 2030 (Including IPP)

The power development plan for the study has agreed with the DOE and EDL. The amount of agreed power development is 3,701MW at 2030. The power development for export is 17,854MW.

Detail Simulation

The detail simulations are conducted in 2020 and 2030. The necessary additional power development scenarios are selected.

1) Situation of System reliability

The reserve margin capacity of 76MW is required to secure the Lao planning criterion of system reliability; LOLE 24-hour. The results of simulation addressed that the reserve capacity of 300MW could be prepared in the whole Lao systems. The reserve capacities in the Lao central 2 system have remained 200MW shortage after power from interconnected systems. The additional measurements are necessary to secure their demand.

2) Situation of balancing Supply and Demand

Simulations have been conducted on the base demand as 7%/year GDP growth basis, which are based on the existing power development plan and latent power development in the Lao territory. In the results, there is any power shortage in 2020. In the Lao central 2 system has power shortage from 2028.

In the results of simulation on balance supply and demand, 125MW of additional supply capacity is required to develop in dry season May of the year 2030 to catch up the demand. The Lao north and central1 and central2 systems have power shortage through the year in 2030 under the high demand forecast case. 1000MW of additional power supply should be installed in the Lao north and central1 system. 900MW of additional power supply should be installed in the Lao central2 system. The 1900MW of additional power supply should be developed. Both systems should be developing a power supply to secure supply during dry season. Hydropower which is curtail one third (1/3) of installed capacity in dry season should be develop third times as necessary peak supply capacity in dry season.

3) Situation of Development on Latent Primary Energy

320 MW of them are still remained in undecided customers, so far. In addition, Houay Ho hydropower (216MW) will transfer the Lao side after its contract PPA is expired in 2024. Thus, amount of available hydropower development potential projects is 536 MW totally.
Coal reserve is located in the north area of Lao PDR. In the central 2 area, some anthracite reserve might be located. Amount of available thermal power development that is calculated roughly is equal to operate 450MW coal thermal plant.

4) Scenarios of Detail Simulation balancing Supply/Demand

Peak supply capacity of the Lao systems excluding the south system in dry season is depended on the import power from Thai system in considering with the result of balancing supply and demand simulation. The supply capacity in the Lao central 2 system is insufficient and the Loa south system has surplus supply capacity. The power development for dry season and reinforcement capacity between central 2 system and south system are recommended for one alternative of countermeasures.

5) Results of Detail Simulation balance between Supply/Demand

450 MW of coal thermal power plant is required between 2027 and 2030 in the central 2 area at base demand basis. For high demand case, additional thermal power plants will be required as 1000MW located in the north/central1 system and 900MW located in the central2 system. 150MW is the appropriate largest unit size in considering balance between supply and demand only.

The improvement of system reliability is not obtained when capacity increases from original planning capacity of 300MW in the base demand case. The balance between supply and demand will not improve if interconnection capacity increases over 30MW because surplus supply capacity in the south system decreases in dry season.

Recommendation for Power Development Plan

1) Primary Energy Master plan study

Electric power development of 500MW scale is needed in around 2030 as the power demand increase. It is necessary to develop three to five times of the necessary supply capacity in dry season from an influence of output decrease, when only hydropower plants supply the incremental demand. Thus, thermal power plants will be economical supply in the dry season. The infrastructure for import fuel has not developed. It is necessary to decided sharing costs of fuel infrastructure to secure benefits of the national economy whether only electricity tariff bears its or not, after adjusting national estate development plan and industry promotion development plan.

2) Feasibility study of Coal thermal plants

The power supply in dry season should be developed in the least cost manner. The feasibility study of thermal power plant in usage of an appropriate fuel should be conducted from effective development of primary energy in the Lao PDR and energy master plan aspects. Environmental conservation standards for thermal power plant have not established such as air and water quality conservation regulations. The capacity building should be necessary on the environmental conservation for thermal power plants.

3) Establishment of System Operation and Reinforcement Plan for introducing IPP into Lao system

Almost all power plants for export are connected to Thai system or Vietnamese system. The power plants directory connected to the Lao system are Nam Gum 1 and some small plants only. The system reinforcement plan and system operation rule should be established to operate system stable and economical when large IPPs connect into the Lao system after expiring their PPA. The capacity building of system operation should be support in order to secure a stable and economic system operation.

S-9. Power System Plan Up to 2030

The PDP up to 2016 made by EDL has been reviewed in Chapter 7. In this chapter, the power system plan up to 2030 was made based on the power generation plan up to 2030 and the power demand forecast described in the section 6.7. The targeted years were 2020 and 2030.

Preliminary Power System Plan

The main power sources are owing to hydropower in Laos and the locations of the power generations are varied among the regions. The scales of the transmission lines should be examined so as to transmit the power to the areas where the power shortage is expected to occurs in dry seasons and to utilize the hydropower for the sufficient power export in wet seasons. Thus, the regional power supply demand balances has been studied both for wet and dry seasons as the preliminary power system planning and the required power transmission abilities has been estimated for the interregional power trade. The candidates of the transmission lines further required until 2020 are the transmission lines able to transmit the power of around 900-1,000 MW from Luangprabang or Xiengkhuang to Vientiane, the reinforcement of the interconnection from Vientiane to Thailand, the reinforcement of the interconnection from the south to Thailand, the transmission line to the appearing special consumers and the 115/22 kV substations and the transmission line from the appearing power stations to the main grid. The candidates of the transmission lines further required until 2030 are the transmission lines able to transmit the power of around 200-400 MW from the thermal station appeared in Saravan to Savanhakhet and Kammoun.

Power System Analysis for the System in 2020

Power system analysis was of the future transmission system for domestic power supply in 2020 was conducted to confirm the technical adequacy of the system plans.

Power Flow and Voltage Analysis

Power flow and voltage analysis for both the peak demand period of time in dry and wet seasons were conducted for the power system as of 2020. Both normal operation and single contingency conditions were considered.

For the power stations whose dry season outputs are unknown, 70% of their installed capacities (reservoir type) and 30% (run-of-river type) were assumed. In the wet season, power outputs of the generators were set in order for the total output of all generators in Laos to become around 90% of the sum of the total generator outputs so as to maintain system stability. For some substations, shunt capacitors were installed to maintain bus voltages within allowable range. At Hongsa substation, phase shifters were assumed to be installed to 115kV bus so as to control the power flow.

1) Analysis Results (Dry Season)

a) Normal Operation Condition

No overloading of transmission lines or abnormal voltage at substation buses occurred.

b) Single Contingency Condition

No overloading of transmission lines or abnormal voltage at substation buses occurred to the power system in Laos.

2) Analysis Results (Wet Season)

a) Normal Operation Condition

No overloading of transmission lines or abnormal voltage at substation buses occurred.

b) Single Contingency Condition

Overloading occurred to the remaining circuits of Hongsa substation - new switching station, Phonetong substation - New 1 substation and Khoksaad substation - Thanaleng substation in the case of the single circuit fault of the 115kV transmission lines in question resulted from huge surplus power exported to EGAT system through the lines. Setting high overall average operation rate caused the surplus power.

In order to solve the overloading problem, such countermeasures as increase in the number of circuits and/or replacement of the conductors to the ones with larger transmission capacities should be considered. From the system operation point of view, further study on the generator operation in the wet season should be considered. Further study on the control range and method of the phase angle of the phase shifter for operation of phase shifters at Hongsa Substation is considered necessary.

Transmission Line Loss

Transmission line losses of the whole system for domestic power supply as of year 2020 for both dry and wet seasons (excluding losses of the system for export) are shown in the table below.

Table S-9.1: Transmission Line Loss for Domestic Power Supply System in Laos

Season	kW Loss [MW]	Annual Energy Loss [MWh]	Annual Energy Loss [million USD]
Dry	70	339,100	13.8
Wet	201	975,154	39.7

Fault Current Analysis

The three-phase short circuit current values of the planned system are maintained within the allowable maximum fault current level

Stability Analysis

Stability analysis for the planned system in 2020 was conducted. Fault locations were selected taking into consideration both typical heavy-loaded sections in North and Central-1 areas and the interconnecting lines between Central-2 and South areas. Generator models for the analysis were ones provided by EDL. Application of the PSS and Governor was assumed for some of the power stations with the install capacities of more than 60MW. As the PSS and Governor models, typical PSS and Governor models were applied, respectively. For the existing power stations, PSS and governor were considered in accordance with the actual condition.

It was confirmed that the planned system was stably operated under such severe conditions as single circuit fault of the primary heavy-loaded sections in North and Central-1 areas and the fault of the interconnection lines between Central-2 and South areas in both dry and wet seasons.

System Analysis of Bulk Transmission System in 2030

Rough stability analysis on the bulk transmission system that constitutes 230kV bulk transmission lines, which interconnect between areas, was conducted Fault locations were selected taking into consideration both typical heavy-loaded sections in North and Central-1 areas and the interconnecting lines between Central-2 and South areas. Generator models for the analysis were ones provided by EDL. Application of the PSS and Governor was assumed for some of the power stations with the install capacities of more than 60MW.

It was confirmed that the planned system was stably operated under such severe conditions as single circuit fault of the primary 230kV heavy-loaded sections in North and Central-1 areas and the fault of the interconnection 230kV transmission lines between Central-2 and South areas in both dry and wet seasons.

In the dry season in 2030, huge amount of power will be exported through interconnecting lines between EGAT and EDL systems in North and Central-1 areas due to lack of generating capacity. The power inflow through the 500/115kV transformer at Hongsa substation from EGAT side will substantially exceed the contracted capacity of 100MW even with control of the phase angle of the phase shifter, and interconnecting lines between Central-1 area and EGAT system will be overloaded. Similar issues are predicted as long as EDL relies heavily on power import from EGAT. Therefore, further study on power development and/or international interconnection lines may be necessary.

S-10. Evaluation for the Sub-projects

Transmission Line Sub-projects

Based on the Optimum Transmission System formulated in Chapter 9, the total length of the sub-projects from 2010 to 2030 are shown in the following table.

Table S-10.1: The total length of the sub-projects from 2010 to 2030 (km)

Construction Year	Length		
	115 kV	230 kV	Total
2010 - 2016	3888.8	376.4	4,265.2
2017- 2020	806.0	166.0	972.0
2021- 2030	295.0	345.0	640.0
Total	**4989.8**	**887.4**	**5,877.2**

Substation Sub-projects

The system reinforcement sub-projects for substations include the following.

1) Construction of new substations/switching stations

According to system planning up to 2030, construction of new substations and switching stations including the ADB and WB programs has been planned. Number of units and unit capacity of transformers required for the stations were determined in the following item 3) “Plans for Addition, Replacement and Transfer of Transformers”. The stations that would need the additional transmission line bays and/or transformer bays in future should secure the enough space for them.

2) Upgrading the substation voltage level

According to system planning up to 2030, upgrading the existing 115 kV substations to 230 kV stations has been planned.

3) Addition, Replacement and Transfer of Transformers

Programs for addition, replacement and transfer of 115 kV transformer have been planned in accordance with the following criteria.

a) The ‘N-1’ criteria should be applied to the stations in Vientiane Capital after 2011. In that case, short duration overload of transformer would be permitted to 110% of the rating. On the other hand, the overload of transformer should not be permitted in the other substations, and the transformer should be added and/or replaced to meet the demand before the year forecasted the overload.

b) The total capacity of transformers of each substation in each year up to 2030 has been estimated based on the peak MVA applying the power factor to be 0.95 for the substations in Vientiane Capital and 0.85 to the forecasted power demand of each substation in other areas.

c) Unit capacity of newly installed transformers should be selected from 10, 20 and 30 MVA ratings.

d) To utilize the existing transformers effectively, the transfer program of transformers among the substations was planned. The transfer has been programmed in examination on the parallel operation with the existing transformers, the lifetime of transformers, timing of transfer, etc. The lifetime of the existing transformers was assumed to be 40 years, and the replacement program of equipment was prepared.

Regarding the unit number and unit capacity of 230 kV transformer, 1 unit of 200 MVA transformer is planned to be installed in all 230 kV substations except 2 units of 200 MVA transformer in Luangprabang-2 Substation based on the result of system analysis.

4) Additional transmission line bays

According to the system planning and generation development plan, the additional transmission line bays to the particular substations have been planned.

5) Installation of static capacitors

Based on the system analysis in Chapter 9, 22 kV static capacitors have been planned to maintain the system voltage within the allowable range. Installation of static capacitors has been planned at the same timing of construction and/or extension of the substations mentioned above.

Tables 10.2-2 – 10.2-5 in the main report show the substation sub-projects including under construction projects from 2010 to 2030 in each power supply area.

Construction Costs for Transmission Line Sub-projects

1) Standard Unit Prices

For the estimation, the team has been prepared referring to the recent contract prices of such international competitive bidding projects as “Greater Mekong Power Network Development Project (JICA)”. Various ICB price data owned by the Team has also been referred.

2) Estimation of UXO Investigation and Clearance Costs

Since many UXO exist in the country, it is necessary to carry out the investigation and clearance prior to the construction works. Costs for the UXO investigation and clearance were added to the ordinary construction cost of transmission lines, because costs for the investigation and clearance would share a large portion of the construction cost for the transmission lines.

3) Estimate Conditions

The cost estimate conditions are as follows;

a) The costs were estimated in such a way as the unit cost per km multiplied by length of each line and adding the UXO survey and clearance costs of each line.

b) The costs were estimated in foreign currency (US$) portion (FC) and local currency (US$ conversion) portion (LC).

c) Costs for such miscellaneous work items as land compensation, erection insurance, camp expenses, etc. were added to the sum of cost for each work at an amount equivalent to 10 % of the sum.

4) Construction Costs for Substation Sub-projects

The summary of estimated construction costs for transmission line sub-projects from 2010 to 2030, excluding the costs of on-going projects, are shown in the following table.

Table S-10.2: Construction Costs for Transmission Line Projects (1,000US$)

Commissioning Year	Particulars	Construction Costs		
		FC	LC	Total
2010 to 2015	Construction	343,731.0	161,537.0	505,268.0
	UXO clearance	8,137.0	16,528.0	24,665.0
	Sub-total	**351,868.0**	**178,065.0**	**529,933.0**
2016 to 2020	Construction	81,515.0	44,237.0	125,752.0
	UXO clearance	2,506.0	5,086.0	7,592.0
	Sub-total	**84,021.0**	**49,323.0**	**133,344.0**
2021to 2025	Construction	20,207.0	9,676.0	29,883.0
	UXO clearance	166.0	338.0	504.0
	Sub-total	**20,373.0**	**10,014.0**	**30,387.0**
2026 to 2030	Construction	68,404.0	24,680.0	93,084.0
	UXO clearance	1,196.0	2,429.0	3,625.0
	Sub-total	**69,600.0**	**27,109.0**	**96,709.0**
	Total	**525,862.0**	**264,511.0**	**790,373.0**

Construction Costs for Substation Sub-projects

1) Standard Unit Prices

The standard unit prices has been prepared referring to the recent contract prices of such international competitive bidding projects as Greater Mekong Power Network Development Projects (JICA funded), Greater Mekong Subregion Power Trade Project (IDA funded), Northern Area Power Transmission Development Projects (ADB funded). Various ICB price data, especially for 230 kV equipment, owned by the Study Team has also been referred.

2) Estimate Conditions

The cost estimate conditions are as follows;

a) All substation equipment would be procured from abroad and the prices would be estimated in US dollars for CIF price.

b) The costs of civil and erection works are estimated in foreign currency (US$) portion (FC), and local currency (US$ conversion) portion (LC).

c) The costs for the improvement of busbar system and/or switchgear and costs for the installation of the static capacitors are included in the costs for such sub-projects as addition of transmission line bays and transformers.

d) The costs for investigation and clearance of UXO are included in the cost for construction of the new stations.

e) Costs for such miscellaneous work items as land compensation, erection insurance, camp expenses, etc. are added at an amount equivalent to 7 % of the total cost of main works.

3) Construction Costs for Substation Sub-projects

The summary of estimated construction costs for substation sub-projects from 2010 to 2030, excluding the costs of on-going projects, are shown in the following table.

Table S-10.3: Construction Costs for Substation Sub-projects (1,000US$)

Year	Construction Costs FC	LC	Total
2010～2015	144,674.7	31,668.2	176,342.9
2016～2020	43,997.7	8,407.5	52,405.2
2021～2025	38,962.9	6,871.9	45,834.8
2026～2030	23,704.4	4,131.6	27,836.0
Total	**251,339.7**	**51,079.2**	**302,418.9**

Total Construction Costs

As shown in the following table, the total construction cost for the development of transmission system from 2010 to 2030, excluding the costs of on-going projects, has been estimated at US$1,092.8 million.

Table S-10.4: Total Construction Costs for the Development of Transmission System (1,000US$)

Year	Particulars	Construction Costs FC	LC	Total
2010～2015	TL	351,868.0	178,065.0	529,933.0
	SS	144,674.7	31,668.2	176,342.9
	sub-total	**496,542.7**	**209,733.2**	**706,275.9**
2016～2020	TL	84,021.0	49,323.0	133,344.0
	SS	43,997.7	8,407.5	52,405.2
	sub-total	**128,018.7**	**57,730.5**	**185,749.2**
2021～2026	TL	20,373.0	10,014.0	30,387.0
	SS	38,962.9	6,871.9	45,834.8
	sub-total	**59,335.9**	**16,885.9**	**76,221.8**
2026～2030	TL	69,600.0	27,109.0	96,709.0
	SS	23,704.4	4,131.6	27,836.0
	sub-total	**93,304.4**	**31,240.6**	**124,545.0**
	Total	**777,201.7**	**315,590.2**	**1,092,791.9**

Implementation Schedule and Cost Disbursement Schedule

1) Implementation schedule for transmission line sub-projects

Construction periods required for the planned transmission sub-projects are slightly different among sub-projects due to various line lengths and terrain of the routes. It is assumed from experience of the past similar projects in the country that the construction period for the sub-projects would take 24 months over 3 calendar years, commencing during April of the first year and completing in March of the third year, taking into account the efficient field works in dry season.

While, the construction period for the sub-projects of conductor addition would take 12 months over 1 calendar years, commencing on the conclusion of contract.

2) Implementation Schedule for Substation Projects

Although construction periods for each substation projects are slightly different, it is assumed taking into consideration of experience from the past similar projects that the construction period for new construction of substation would take 24 months over 3 calendar years, commencing on April of the first year and completing on March of the third year, taking into account the efficient field works in dry season.

3) Disbursement schedule of transmission line and substation sub-projects

Basically, it is assumed that 10%, 80% and 10% of total construction costs of new transmission and substation construction project are to be disbursed over three years.

4) Disbursement Schedule of Investment up to 2030

The yearly investment schedule for the development of transmission and substation system excluding the costs of on-going projects from 2010 to 2030 is estimated in the following table.

Table S-10.5: Disbursement Schedule for Development of TL & SS System (1,000US$)

	Transmission Line Sub-projects			Substation Sub-projects			Total		
year	FC	LC	Total	FC	LC	total	FC	LC	Total
2010	73,735.0	38,915.0	112,650.0	21,478.3	4,474.3	25,952.6	95,213.3	43,389.3	138,602.6
2011	120,497.0	50,806.0	171,303.0	52,036.5	11,371.5	63,408.0	172,533.5	62,177.5	234,711
2012	40,912.0	28,821.0	69,733.0	32,692.4	6,438.6	39,131.0	73,604.4	35,259.6	108,864
2013	44,589.0	18,064.0	62,653.0	19,548.5	4,790.4	24,338.9	64,137.5	22,854.4	86,991.9
2014	33,004.0	20,602.0	53,606.0	11,166.6	2,975.9	14,142.5	44,170.6	23,577.9	67,748.5
2015	39,131.0	20,857.0	59,988.0	7,752.3	1,617.6	9,369.9	46,883.3	22,474.6	69,357.9
2016	44,943.0	22,090.0	67,033.0	7,396.4	1,202.6	8,599.0	52,339.4	23,292.6	75,632
2017	15,902.0	11,061.0	26,963.0	6,434.7	1,333.9	7,768.6	22,336.7	12,394.9	34,731.6
2018	5,608.0	5,508.0	11,116.0	7,948.6	1,539.1	9,487.7	13,556.6	7,047.1	20,603.7
2019	12,595.0	5,518.0	18,113.0	12,114.3	2,506.6	14,620.9	24,709.3	8,024.6	32,733.9
2020	4,973.0	5,146.0	10,119.0	10,103.6	1,825.4	11,929.0	15,076.6	6,971.4	22,048
2021	8,825.0	3,497.0	12,322.0	10,181.9	1,782.1	11,964.0	19,006.9	5,279.1	24,286
2022	1,924.0	1,946.0	3,870.0	10,696.9	1,881.5	12,578.4	12,620.9	3,827.5	16,448.4
2023	978.0	610.0	1,588.0	11,777.3	2,334.0	14,111.3	12,755.3	2,944.0	15,699.3
2024	4,847.0	1,845.0	6,692.0	3,653.8	538.8	4,192.6	8,500.8	2,383.8	10,884.6
2025	3,799.0	2,116.0	5,915.0	2,653.0	335.5	2,988.5	6,452.0	2,451.5	8,903.5
2026	8,597.0	5,302.0	13,899.0	3,442.0	560.4	4,002.4	12,039.0	5,862.4	17,901.4
2027	48,233.0	12,852.0	61,085.0	13,120.4	2,545.3	15,665.7	61,353.4	15,397.3	76,750.7
2028	9,608.0	7,306.0	16,914.0	3,760.1	577.8	4,337.9	13,368.0	7,883.8	21,251.8
2029	2,655.0	1,071.0	3,726.0	1,937.0	251.5	2,188.5	4,592.0	1,322.5	5,914.5
2030	507.0	578.0	1,085.0	1,444.9	196.6	1,641.5	1,951.9	774.6	2,726.5
total	**525,862.0**	**264,511.0**	**790,373.0**	**251,339.5**	**51,079.4**	**302,418.9**	**777,201.4**	**315,590.4**	**1,092,791.8**

Environmental and Social Consideration on the Sub-Projects

Based on the environmental and social issues described in Chapter 7 5.3, the sub-projects were screened by the environmental and social measures such as resettlement, protected areas (including conservation areas) and distribution of minority people. The sub-projects needs to be applied environmental and social consideration were selected and categorized into 4 regions, namely the North, the Central 1, the Central 2 and the South.

The screening uses the same method referring same sources and evaluation criteria employed in Chapter 8.4.(3) "screening for short-listed projects from the points of environmental and social considerations". The screening of UXO risk, which is also used as the screening measure in Chapter 8.4.(3) is addressed in the previous section of this chapter. Only the locations of protected areas in national level are examined at this time. Therefore, the further survey on protected areas in province and district level is necessary. With increase of population in near future, the necessity for minimizing resettlement of the sub-projects near national road is expected to be augment.

Considering the protected areas, there are 14 sub-projects that are adjacent to protected areas in the North region. Accordingly, at the time of designing transmission line route or substation site, special effort should be made for those subprojects in order to avoid protected areas. In addition, considering the high rate of ethnic minority distribution in the North and South region, special attention needs to be paid for their socio-economic condition and mitigation measures need to be taken as appropriate.

Economic Analysis of the Optimum Transmission System

This section undertakes economic analysis of the optimum transmission system plan, or the Optimum Plan hereafter, which is comprised of the transmission and the substation sub-projects listed in 10.1 and 10.2. The optimum transmission system plan is presumed to reflect the concept of "economic efficiency" in terms of resource allocation. The "efficiency" of the Optimum Plan would be proved by comparison of the economic internal rate of return (EIRR) of the system with the opportunity cost of capital (OCC), set as 12 % in this study. The EIRR would be calculated by identifying the Optimum Plan's costs and benefits.

Premises

The evaluation period is set as 30 years from the fiscal year of 2010 to that of 2040. Economic benefits would be obtained by multiplying incremental electricity demand (Figure S-10.1) which can be supplied by the implementation of the Optimum Plan, with the transmission and substation portion of Willingness to Pay (WTP) per electricity consumption (kWh). The latest ADB's study[1] derived WTP by consumer category based on the willigness-to-pay method. Its weighted average of WTP is estimated to be 2,434 Kip/ kWh (US$ 0.29 per kWh, with exchange rate of 8,515 Kip/ USD as of August 27, 2009 by Yahoo Finance.).

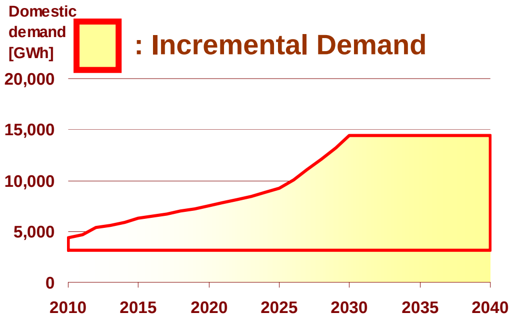

Figure S-10.1: Demand Forecast of Lao PDR between 2010 and 2040

As mentioned before, because the Optimum Plan targets only transmission line and substation related facilities, the analysis employs the corresponding portion of the weighted average of WTP. According to the latest World Bank's recent tariff study[2], the LRMC of transmission and substation

[1] Preparing the Greater Mekong Subregion Northern Power Transmission Project, ADB, Oct. 2008
[2] Tariff Study Update Project Final Report, International Development Association, June 2009

portion is led as 14 % of the total. Finally, the WTP to be used for this analysis is obtained by multiplying the aforementioned weighted average WTP with this share, resulting in US$ 0.04/ kWh.

The expense consists of construction costs and the relevant operation and maintenance (O&M) costs. The costs for the Optimum Plan in Table 10.4-4 in the main report are in financial value, and therefore, they are to be converted into disbursement flow valued at economic price with the standard conversion factor (SCF), set as 0.9.

Table S-10.6: EIRR Calculation for TL/SS Development Project

(Base Case) Unit: Thousand US$

FY	Economic Costs									Gross Benefits		Net
	TL		SS		Total Capital		O&M:TL	O&M:SS	Total	Incre. Energy	Total	
	FC	LC	FC	LC	FC	LC	FC+LC	FC+LC	Cost	(GWh)	Benefit	
FY2010	93,203	43,196	29,114	5,401	122,317	48,598	0	0	170,915	0	0	−170,915
FY2011	129,737	50,840	53,838	10,559	183,575	61,399	1,364	518	246,856	1,484	59,384	−187,472
FY2012	40,912	25,939	32,692	5,795	73,604	31,734	3,170	1,484	109,991	2,263	90,575	−19,417
FY2013	44,589	16,258	19,549	4,311	64,138	20,569	3,838	2,061	90,606	2,416	96,676	6,071
FY2014	33,004	18,542	11,167	2,678	44,171	21,220	4,447	2,419	72,256	2,707	108,335	36,078
FY2015	39,131	18,771	7,752	1,456	46,883	20,227	4,962	2,627	74,699	3,096	123,905	49,206
FY2016	44,943	19,881	7,396	1,082	52,339	20,963	5,541	2,765	81,609	3,336	133,504	51,895
FY2017	15,902	9,955	6,435	1,200	22,337	11,155	6,189	2,892	42,573	3,546	141,894	99,320
FY2018	5,608	4,957	7,949	1,385	13,557	6,342	6,448	3,006	29,353	3,815	152,660	123,306
FY2019	12,595	4,966	12,114	2,256	24,709	7,222	6,554	3,146	41,632	4,061	162,501	120,869
FY2020	4,973	4,631	10,104	1,643	15,077	6,274	6,729	3,362	31,442	4,327	173,171	141,729
FY2021	8,825	3,147	10,182	1,604	19,007	4,751	6,825	3,538	34,122	4,616	184,732	150,610
FY2022	1,924	1,751	10,697	1,693	12,621	3,445	6,945	3,715	26,726	4,934	197,435	170,709
FY2023	978	549	11,777	2,101	12,755	2,650	6,982	3,901	26,288	5,283	211,409	185,122
FY2024	4,847	1,661	3,654	485	8,501	2,145	6,997	4,109	21,752	5,668	226,796	205,044
FY2025	3,799	1,904	2,653	302	6,452	2,206	7,062	4,171	19,892	6,091	243,758	223,866
FY2026	8,597	4,772	3,442	504	12,039	5,276	7,119	4,215	28,650	6,934	277,473	248,823
FY2027	48,233	11,567	13,120	2,291	61,353	13,858	7,253	4,275	86,738	7,882	315,421	228,682
FY2028	9,608	6,575	3,760	520	13,368	7,095	7,851	4,506	32,820	8,917	356,846	324,025
FY2029	2,655	964	1,937	226	4,592	1,190	8,013	4,570	18,365	10,047	402,058	383,694
FY2030	507	520	1,445	177	1,952	697	8,049	4,602	15,300	11,280	451,397	436,097
FY2031	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2032	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2033	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2034	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2035	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2036	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2037	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2038	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2039	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
FY2040	0	0	0	0	0	0	8,059	4,627	12,686	11,280	451,397	438,711
Total	554,570	251,348	260,778	47,670	815,348	299,018	202,930	112,148	1,429,444	215,508	8,623,901	7,194,457

Economic Internal Rate of Return for the Project	20.4%
Net Present Value (at 12%)	523,915

OER 250 Kip/THB (Aug.27, 2009 by Yahoo)
OER 8,515 Kip/USD (Aug.27, 2009 by Yahoo)
Applied currency and unit: US$ thousand
Base year: Year 2009

Cost side
SCF for Local Currency Portion 0.9
O&M cost: 1% for transmission, 1.5% for substation of capital cost.

Benefit side
WTP on average 0.29 USD/kWh 2,434 Kip/ kWh
TL&SS portion of WTP (14%) Year 2009 14% (Source: WB Tariff update study, Aug.20,2009)
Benefit corresponding to this project 0.04 USD/kWh

Analysis Result

The cash flow was prepared to estimate the EIRR of the Optimum Plan (Table S-10.6). Because the EIRR was calculated to be 20.4 %, which turns out to be higher than the benchmark OCC (12 %), the JICA Study Team concludes that the Optimum Plan is considered economically viable.

The Study Team conducted sensitivity analysis, developing four future scenarios, in order to confirm the robustness of the result against future uncertainty like the recent rise of construction material cost triggered by high oil price. The result is summarized in Table S-10.7.

Table S-10.7: Results of Economic Analysis and its Sensitivity Analysis

Scenario	EIRR [%]	NPV 2009 [Million USD]	Elasticity	Boundary value
Base case	20.4	523.9	-	-
1. Capital Cost Increase +15%	17.9	417.7	- 0.82	+80%
2. Benefit Decrease –10%	18.5	400.7	0.94	-45%
3. Half Value of WTP	10.4	-92.0	0.99	-45%
4. Demand Slow Down –30%	14.6	154.4	0.95	-45%
5. O&M Cost Increase +50%	19.9	494.9	- 0.05	n.a. (17.5 % of EIRR with +300%

Note: NPV: Net Present Value (calculated at 12 % of discount rate).
Boundary value: the value of key parameter beyond which the EIRR value can be less than 12 % of OCC.

As shown in the table, the value of EIRR exceeds the benchmark of 12% for all scenarios except Half Value of WTP scenario, which is an extreme case, the Team concludes that the economic viability of the Optimum Plan is considered robust. For Half Value of WTP scenario, the Optimum Plan might no longer be economically viabil. Such scenario, however, seems less realistic because the scenario requires the condition where cost of fuel like disel decreases to less than 23 to 25 USCent/l. The result of elasticity analysis tells that electricity tariff and sales volume are the key factors to keep the Optimum Plan economically viable because their impact is estimated larger than the other factors.

Financial Analysis of the Optimum Plan

Although the revenue related to the transmission lines and substations is difficult to be identified because EDL is a power corporation that owns every facility from generation through transmission to distribution networks, the JICA Study Team undertook financial analysis of the Optimum Plan for reference. The financial cost includes construction costs and O&M costs. Financial benefit is obtained by multiplying the transmission and substation portion of existing tariff (average retail tariff) with incremental electricity demand. The result shows that the financial internal rate of return (FIRR) for the Optimum Plan is calculated as 8.3 %. Considering the weighted average cost of capital (WACC) of similar power projects of Lao PDR varies around 2 to 8 %, the Team concludes that the Optimum Plan is considered financially viable. Following table summarizes the result of financial analysis and its sensitivity analysis.

Table S-10.8: Results of Financial Analysis and its Sensitivity Analysis

Scenario	FIRR [%]	NPV 2009 [Million USD]
Base case	8.3	1,168
Adoption of proposed tariff system	10.0	1,420
Adooption of alternative new tariff system	5.1	365

(Note: NPV: Net Present Value (calculated at 2.7 % of discount rate).)

S-11. Selection of Facilities

The power system plan up to the year 2030 was formulated in Chapter 9. Among the projects in the power system plan, the transmission line for the section Pakbo - Taothan - Saravan was selected as the most prioritized project. The purpose of the project is to extend the transmission network from Central 2 region to South region.

The scope of the project is construction of the interconnecting transmission line between Central 2 and South regions and substations in the section Pakbo - Taothan - Saravan. The project is outlined as follows:

a) Construction of 115kV transmission line facility in 2014 with double-circuit TACSR 240mm^2 conductor in the section between existing Pakbo substation and Saravan substation, which is to be constructed by 2011 under the IDA fund.

b) Extension of existing 115/22 kV Pakbo substation

c) Extension of newly planned 115/22 kV Saravan substation

d) Construction of new 115/22 kV Taothan substation

115/22 kV Taothan substation has been planed because the installation of 115/22 kV Taothan substation can contribute the distribution loss reduction, the improvement of the system reliability and the promotion of the rural electrification by curtailing the length of the distribution feeders and can also improve the power system stability for the 115 kV transmission system. 115 kV has been selected because 230 kV would be less required from the viewpoints of its cost because the effects on the reduction of power reserve margin is saturated around 100-200 MW in accordance with the existing power generation plan up to 2030 as shown by the detailed power supply demand balancing simulations and the 115 kV-designed transmission line will have an enough capacity to transmit to around 2030. TACSR 240 mm2 has been considered adopted because it can be considered effective to give a flexibility of the capacity of the transmission line of this project at a certain degree in preparation for the future uncertain increase in power flow although ACSR 240 mm2 will provide the system with an enough capacity up to 2020. The commissioning year of this highest prioritized project should match the start of the operation of the Houaylamphan hydropower station that will be the first large power station in the south region after 2014.

S-12. Transmission Line

Transmission Line Route

- Pakbo S/S –Taothan S/S； 152.2 km

- Taothan S/S- Saravan S/S； 66.3 km

- Total length; 218.5 km

As results of the investigation and discussion, the team selected the transmission line route for the section to be along with existing 115 kV transmission line, Route No. 13 and Route No. 15 for reasons of less inhabited areas, easy construction and convenience for maintenance work. The selected line route is shown on Figure 12.1-1. The route is aligned behind villages where habitats exist. Terrain surrounding the route is mostly flat or very gently waved and covered by bushes, paddy field, cropland or thin forest.

Geology

Simplified boring survey was conducted at 42 points along the line route. For most of the line route from Pakbo SS to Saravan SS, no water was found in the soil and very firm sandstones, siltstones and clays whose soil bearing capacity was 400～1,200 kN/m^2 were confirmed.

Basic Design

The basic design was conducted in accordance with LEPTS and international standards.

1) Conductor and ground wire

TACSR 240 mm^2 (ASTM: T-Hawk), AS 70 mm^2 (ASTM: A220) and OPGW 70 mm^2 (ASTM: Type A) are applied for the whole line section.

2) Insulator

a) Type:

The standard disc type porcelain insulator with ball and socket complying with IEC 60305 is applied to the transmission lines for the Project.

b) Number of insulator units per string: 10 units

c) Insulator assembly

A single string of 120 kN insulator is applied to both suspension and tension insulator assembly for the Project. Insulator fittings also have to keep the same strength of insulators.

However, in case transmission line for the Project crosses over important roads or wide rivers, 120 kN double insulator assemblies are applied to both towers in the crossing section (either suspension or tension tower) for safety reason.

3) Tower Configurations

After clearance design was carried out by the above-mentioned conductor and insulator assemblies, the following 7 types of tower configurations were determined.

Table S-12.1: Tower Configurations

Tower	Suspension Tower		Tension Tower				
Line Horizontal Angle	0～3°		0～15°	0～15°	0～30°	0～60°	0～40° (Dead End)
Type	A1	A2	B1	B3	C1	D1	DE
Height [m]	34.5	37.5	33.9	39.9	33.9	33.9	33.9
Arm Length [m]	6.2	6.2	6.2	6.2	6.8	6.2	6.2
Width of tower [m]	7.2	7.5	7.8	9.5	7.8	7.8	7.8
Body Extension [m]	24.5	27.5	24.0	30.0	24.0	24.0	24.0

4) Tower Design

Towers for the Project were provisionally designed for estimation of tower weights and foundation loads.

Table S-12.2: Tower Weights and Foundation Loads Transferred from Towers

Tower	Suspension		Tension				
Line Horizontal Angle	0～3°		0～15°		0～30°	0～60°	0～45° (Dead end)
Type	A1	A2	B1	B3	C1	D1	DE
Weight [ton]	6.0	7.0	8.5	11.1	10.4	11.6	13.8
Foundation Compression Load [kN/Leg]: Normal	376	380	648	657	713	882	1,102
Foundation Tensile Load [kN/Leg]: Normal	312	313	565	566	627	772	964

5) Foundation Design

Simplified boring survey was conducted and the firm soil conditions were confirmed for the whole line, it can be assumed that normal pad and chimney type foundations are applicable to all towers in the Project.

Dimensions, concrete volume, reinforcement volume, excavation volume and back-filling volume of pad and chimney type foundations were worked out on the basis of the loads transferred from towers.

Quantities of Line Materials

Quantities of line materials are estimated from results of the above design for the Project.

1) Number of towers and total weight of towers

Table S-12.3: Number of Towers and the Total Weight of Towers

Type	Weight [ton]	Pakbo – Taothan		Taothan - Saravan		Total	
		Towers [Unit]	Total Weight [ton]	Towers [Unit]	Total Weight [ton]	Towers [Unit]	Weight [ton]
A1	6.0	324	1,944.0	142	852.0	466	2,796.0
A2	7.0	14	98.0	4	28.0	18	126.0
B1	8.5	36	306.0	16	136.0	52	442.0
B3	11.1	1	11.1	0	0	1	11.1
C1	10.4	4	41.6	2	20.8	6	62.4
D1	11.5	4	46.0	1	11.5	5	57.5
DE	13.8	2	27.6	2	27.6	4	55.2
	Total	385	2,474.3	167	1,075.9	552	3,550.2

2) Quantities of conductor and ground-wire

Quantities of conductors and ground-wires (GW) for the Project were computed by“Number of conductor or GW*Route Length [km]*1.05 (allowance for sag and margin for stringing works).

Table S-12.4: Quantities of Conductor and Ground-wire

Type	Number [Unit]	Pakbo - Taothan		Taothan - Saravan		Total
		Route Length [km]	Quantity [km]	Route Length [km]	Quantity [km]	Quantity [km]
TACSR 240 mm^2	6	152.2	958.9	66.3	417.7	1,376.6
AC 70 mm^2	1	152.2	159.8	66.3	69.6	229.4
OPGW 70mm^2	1	152.2	159.8	66.3	69.6	229.4

3) Quantities of insulators and insulator assemblies.

Table S-12.5: Quantities of Insulators and Insulator Assemblies

Tower	Item	Quantity [Unit]	Pakbo - Taothan Tower [Unit]	Pakbo - Taothan Subtotal Quantity [Unit]	Taothan - Saravan Tower [Unit]	Taothan - Saravan Subtotal Quantity [Unit]	Total Quantity [Unit]
Suspension	Insulator	60	320	19,200	139	8,340	27,540
	Single String Set	6		1,920		834	2,754
	Insulator	120	18	2,160	8	960	3,120
	Double String Set	6		108		48	156
Tension	Insulator	120	42	5,040	18	2,160	7,200
	Single String Set	12		504		216	720
	Insulator	240	5	1,200	2	480	1,680
	Double String Set	12		60		24	84
Total	Insulators			27,600		11,940	39,540
	Insulator Sets			2,592		1,122	3,714

4) Quantities of fittings of conductor and ground-wire

Table S-12.6: Quantities of Fittings of Conductor and Ground-wire [Units]

Fittings	Pakbo - Taothan	Taothan - Saravan	Total
Conductor Dampers	4,608	1,992	6,600
GW Dampers	768	332	1100
OPGW Dampers	768	332	1100
Conductor Sleeves	480	209	689
GW Sleeves	80	35	115
OPGW Joint Boxes	29	13	42
Suspension GW Fittings	338	147	485
Tension GW Fittings	47	20	67
Suspension OPGW Fittings	338	147	485
Tension OPGW Fittings	47	20	67

5) Quantities of tower foundations

Quantities of 7 types of steel-reinforced concrete foundations are summarized to classify into three type of soil condition in Table S-11.7 below.

Table S-12.7: Quantities of Tower Foundations [Units]

Soil*	Foundation	Concrete Volume / Tower	Pakbo - Taothan		Taothan - Saravan		Total
I	A-I	7.0 [m^3]	336	2,352.0 [m^3]	144	1,008.0 [m^3]	3,360.0 [m^3]
	B-I	12.4 [m^3]	34	421.6 [m^3]	16	198.4 [m^3]	620.0 [m^3]
	C-I	16.2 [m^3]	6	97.2 [m^3]	2	32.4 [m^3]	129.6 [m^3]
	D-I	21.8 [m^3]	4	87.2 [m^3]	1	21.8 [m^3]	109.0 [m^3]
	DE-I	31.3 [m^3]	2	62.6 [m^3]	2	62.6 [m^3]	125.2 [m^3]
II	A-II	9.9 [m^3]	2	19.8 [m^3]	2	19.8 [m^3]	39.6 [m^3]
III	B-III	22.8 [m^3]	1	22.8 [m^3]	0	0 [m^3]	22.8 [m^3]
		Total	385	3,063.2 [m^3]	167	1,343.0 [m^3]	4,406.2 [m^3]

(*Soil-1: 600 kN/m^2 ～, Soil-II: 400 - 599 kN/m^2, Soil-III: 200 - 399 kN/m^2)

S-13. Substation Facilities of the Project

Scope of Works

1) Pakbo Substation

The scope of works for Pakbo SS under the Project is as follows;

a) Extension of gantries and busbars

b) Replacement of 115 kV TL bays for Thakhek SS

c) Installation of two TL bays for Taothan SS

d) Civil and erection works

e) Procurement of accessories including conductors, cables, insulators, etc., and special tools and measuring instruments for operation and maintenance

f) Procurement of spare parts

2) Taothan Substation

The scope of works for Taothan SS under the Project is as follows;

a) Cleaning of trees and other vegetation from the complete substation area and cutting, filling, leveling and compacting of the substation area

b) Installation of one unit of 115/22 kV 20 MVA main transformers and one unit of 22/0.4 kV 100 kVA station service transformer

c) Construction of 115 kV outdoor switchyard

d) Construction of 22 kV outdoor switchyard

e) Installation of communications equipment

f) Construction of Station Control Building

g) Civil and erection works

h) Procurement of accessories including conductors, cables, insulators, etc., and special tools and measuring instruments for operation and maintenance

i) Procurement of spare parts

3) Saravan Substation

The scope of works for Saravan SS under the Project is as follows;

a) Extension of gantries and busbars

b) Installation of two TL bays for Taothan SS

c) Civil and erection works

d) Procurement of accessories including conductors, cables, insulators, etc., and special tools and measuring instruments for operation and maintenance

e) Procurement of spare parts

Specification and Quantity of the Major Equipment

1) Specifications of main power transformers

a) Rated power (continuous) 16,000/20,000 kVA (ONAN/ONAF)

b) Number of phase 3 phase

c) Rated frequency 50 Hz

d) Rated voltage ratio (High/Medium/Tertiary voltages) 115/22/15 kV

e) Connection Star - Star - Delta

f) Vector group notationYNyn0+d1

g) Short-circuit impedance 10 % (10 MVA base at 75°C, rated tap)

h) Cooling ONAN/ONAF

i) Insulation levels
   i) HV line terminal and neutral LI / AC* 550 / 230 kV
   ii) LV line terminal and neutral LI / AC* 125 / 50 kV
   * LI: Lightning impulse withstand voltage, AC: Short duration AC withstand voltage

2) Specifications of switchgear

All main facilities installed under the Project should be of outdoor type. Major specifications of the equipment are as follows.

		115 kV equipment	22 kV equipment
a)	Circuit Breakers (3 -phase)	SF6 gas type Rated voltage: 123 kV Rated normal current: 1,250 A Short-circuit breaking current: 40 kA Operation sequence: O - 0.3s - CO - 3min - CO Rated insulation level (IEC 60694) - Rated short-duration power-frequency withstand voltage (rms): 230 kV - Rated lightning impulse withstand voltage (peak): 550 kV	SF6 gas type （3-pole） Rated voltage: 24 kV Rated normal currents: 630 A, 1,250 A Short-circuit breaking current: 25 kA Operation sequence: O - 0.3s - CO - 3min - CO Rated insulation level (IEC 60694) - Rated short-duration power-frequency withstand voltage (rms): 50 kV - Rated lightning impulse withstand voltage (peak): 125 kV
b)	Disconnecting Switches (DS) (3 phase)	Two-column rotary type with horizontal operation Rated voltage: 123 kV Rated continuous current: 1,250 A Rated short-duration withstand current: 40 kA Rated insulation level (IEC 60694) - Rated short-duration power-frequency withstand voltage (rms): 230 kV - Rated lightning impulse withstand voltage (peak): 550 kV 110 V DC motorized and manual operation	Two-column rotary type with horizontal operation Rated voltage: 24 kV Rated continuous currents: 630 A, 1,250 A Rated short-duration withstand current: 25 kA Rated insulation level (IEC 60694) - Rated short-duration power-frequency withstand voltage (rms): 50 kV - Rated lightning impulse withstand voltage (peak): 125 kV 110 V DC motorized and manual operation
c)	DS with Earthing Switch (3 phase)	same as item b)	same as item b)
d)	Current Transformer	Rated voltage: 123 kV TL bay: 800-400/1/1/1/1 A, 5P20 & cl. 0.5, 25VA TR bay: 200-100/1/1/1/1 A, 5P20 & cl. 0.5, 25VA	Rated voltage: 24 kV TR bay: 600-300/1/1/1 A, 5P20&cl. 0.5, 25VA DL bay: 200-100/1/1 A, 5P20&cl. 0.5, 25VA Bus-tie: 600-300/1/1 A, 5P20&cl. 0.5, 25VA
e)	Voltage Transformers	Capacitive Type Voltage ratio: 115 /√3 kV, 110 /√3 V, 110 /√3 V Accuracy and burden; -secondary (measurement): 0.5, 100 VA -tertiary (protection): 3P, 100 VA Coupling capacitance: 8,800 pF	Inductive Type Voltage ratio: 22 /√3 kV, 110 /√3 V, 110 /√3 V Accuracy and burden; -secondary (measurement): 0.5, 100 VA -tertiary (protection): 3P, 100 VA
f)	Surge Arresters	ZnO type with surge counter Rated voltage: 123 kV Rated voltage (rms): 96 kV Rated discharge current: 10 kA	ZnO type with surge counter Rated voltage: 24 kV Rated voltage (rms): 21 kV Rated discharge current: 10 kA
g)	Capacitor Banks	-	Rated voltage: 24 kV Rated short-duration power-frequency withstand voltage (rms): 50 kV Rated lightning impulse withstand voltage (peak): 125 kV Rated capacity: 2.5 & 5 MVar

3) Quantity of Major Equipment

With reference to the single-line diagrams and layout drawings of each substation, quantity of the main facilities of each substation required for the Project is shown in the following table.

Table S-13.1: Quantity of Major Equipment

	major equipment	Pakbo SS	Taothan SS	Saravan SS
1)	Transformers			
a)	115/22 kV main TR	-	1 unit	-
b)	Auxiliary TR	-	1 unit	-
2)	115 kV switchgear			
a)	Circuit breakers (3 phase)	2 units	6 units	2 units
b)	Disconnecting switches (3 phase)	4 units	12 units	4 units
c)	DS with earthen switch (3 phase)	2 units	5 units	2 units
d)	Current transformers	2 sets	5 sets	2 sets
e)	Voltage transformers	2 sets	5 sets	2 sets
f)	Surge arresters	2 sets	5 sets	2 sets
3)	22 kV switchgear			
a)	Circuit breakers (3 phase)	-	7 units	-
b)	Disconnecting switches (3 phase)	-	7 units	-
c)	DS with earthing switch (3 phase)	-	5 units	-
d)	Current transformers	-	5 sets	-
e)	Voltage transformers	-	2 sets	-
f)	Surge arresters	-	5 sets	-
g)	Capacitor banks	-	1 set	-

S-14. Implementation and Operation Plan

Implementation Policy

Preparatory works to accelerate the Project, such as acquisition of the environment certificate for the Project from WREA, arrangement of fund for the Project, employment of a project consultants, etc. are to be required as the next step for the Project.

1) Mode of Procurement

Although the Project comprises of two components: transmission line and substation, the Project will be in principle executed under one contract of transmission line and substation, and the contractors will be selected through ICB (International Competitive Bidding) mode for full-turn-key basis.

2) Origin for Procurement

Origin of the facilities/equipment for the Project will not be limited in principle, because of ICB-base procurement. However, the contractors for each contract lot should be carefully selected taking into account their qualifications for quality control of goods, production capacities, experience in similar projects, remedial claims of their previous contracts, financial status of the contractor and their major subcontractors, and others. Bidding documents prepared by the consultants will specify bidder's qualification and its evaluation criteria.

Equipment/materials for the Project and construction works at site will be procured in the ICB full turn-key base. EDL will be responsible for special particulars required for the project execution. Following table shows major works allotted for the contractors and EDL. EDL should arrange its staffs and budget to execute the allotted works.

Table S-14.1: Scope of Works

	Contractors	EDL
Procurement of Goods	- Design and manufacture of goods - Factory tests of goods - Packing for export & transportation - Storage of goods at site	- Examination on drawings & documents from contractors - Pre-arrangement for customs clearance of imported goods - Issue of payment certificates
Construction	- Civil & building works for the Project - UXO survey/remove - Overall construction of line facilities - Overall construction of substations - Commissioning test	- Securing of land for the Project - Acquisition of right for tree clearing - De-energizing schedule - Dispatch of inspectors - Issue of payment certificate - Acceptance of completion

Procurement, management and supervision of the Project after the contracts between EDL and the contractors would have been concluded will be performed by the consultants as follows.

a) Detailed Design and Preparation of Bidding Documents

b) Public Bid and Contract

c) Procurement Management

d) Supervision of Contractors' Field Works

e) Commissioning Test and Inspection for Defect Liability Period

Implementation Schedule

The period from appointment of the project consultants to the conclusion of the turn-key contracts for both transmission line and substations is assumed to be 12 months. The period from the conclusion of the contracts to the taking-over of the facilities is assumed to be 24 months making total implementation period to be 36 months after appointment of the project consultants.

Operation and Maintenance

Four (4) power regions of Lao PDR are to be interconnected when the Project would have been completed. The interconnected system should be more systematically, stably, and economically operated and maintained. For stable and economical operation of the national power system including power stations, transmission lines, substations, and distribution networks, as well as power export and import, Load Dispatching Center (LDC) is indispensable in the near future. EDL is now planned to construct the LDC with the financial assistance by IDA and is selecting the design consultant as of October 2009.

The high voltage power systems including 115 kV and 230 kV system and MV/LV networks in the country will be broadly extended before the commissioning of the Project. Considering the circumstances, following measures will be required for stable and sustainable operation of the facilities to be completed for the Project.

a) Education to O&M Persons of Transmission Lines and Substations

b) OJT of EDL's Staffs during Project Implementation

c) Procurement of Measuring Instrument, Spare Parts and Tools

d) Standardization of Recording Format of Operation Data

e) Development of Communications among Power Systems

f) Aggressive Utilization of EDL's Training Center

EDL provides the standard O&M manuals (Lao version) for 115 kV transmission lines and substations. The manuals have been revised as needed referring to experience in faults occurred and measures taken for restoration of the faults. The revised manuals are explained in detail to staffs of each substation, transmission line group, and branch office. The present O&M manuals are prepared on the bases of the manuals submitted by the related consultants and suppliers to the projects. The contracts of the contractors for the Project should also include a term for duty of submission of the O&M manuals.

The present EDL's standard manuals seem adequate. However, in implementing the Project, review of the standard manuals is recommended taking into account the O&M organization and particular circumstances around the Project, referring to the following draft contents of the manuals.

S-15. Initial Environmental Examination of Highest Prioritized Project

In Lao PDR, it is stipulated in legislations that all development projects are obliged to obtain ECC issued by WREA before starting construction activities. In order to obtain ECC, a project owner needs to conduct IEE at F/S phase and then submit IEE reports to be reviewed by DOE and WREA. Upon acceptance of IEE, ECC is issued. Followed by this provision, IEE was conducted for the highest prioritized project.

Through IEE, information on natural environment and socio-economic situation within project area was collected. Based on the information, anticipated negative impacts were accessed and the result was integrated into IEE report, with Environmental Management Plan (EMP) and Resettlement Action Plan (RAP).

The IEE of the project was conducted by local consulting firm from June to August 2009. The summary of the IEE as well as process and procedures for implementing environmental and social consideration for the project are addressed in this section.

Natural and Social Environment within the Project Area

Land Use: Vegetation along the proposed transmission line route is generally fragmented and degraded with the majority of the vegetation along the route having been cleared for agricultural land such as rice paddies. About 544.3ha is estimated to be impacted resulting from securing ROW.[3]

[3] In Lao PDR, 115kv Transmission Line Right-Of-Way (ROW) is 25m (12.5 meters from the centre line). Fixed assets,

544.3ha of impacted area consist of 9% of Mixed Deciduous Forest, 40% of Unstocked Forest, 50% of Rice paddy and 1% of Tree plantation land. The area directly impacted from tree clearance of ROW is estimated about 50ha based on the site survey through IEE, land use map (Ministry of Agriculture and Forest 2002) and satellite image.

Agricultural pattern in the project area is dominated by traditional Lao Loum lowland sedentary agriculture practices. A small amount of upland rotating agriculture is practiced.

All villages have been issued Land Certificate for Agricultural Land and those lands are imposed on Land Certificate Tax.[4]

Protected Areas: There is no NBCA, protected area nor conservation area at provincial and district level in the project area. The transmission line route passes in between the boundary of 2 NBCAs (Phou Xieng Thong and Xe Bang Nuan). Direct impact to the biodiversity of the NBCA is not predicted, however, cumulative impacts to the area need to be constantly monitored and develop mitigation plan as appropriate.

Scenic Spot, Historic and Cultural Heritage: There is no scenic spot or historic and cultural heritage identified in the project area.

Ethnic Minority People: About 92% belongs to Lao-Tai linguistic family (majority in Lao PDR) and 8% consisting of Ethnic Minority groups such as Katan, Ta-Oy, Xuay and Suiy which all are belong to Mon-Khmer linguistic family. Village level surveying found all ethnic groups to have a long association with the local area and the minority groups have generally been absorbed into the mainstream Lao-speaking society and are treated without discrimination as Lao citizens within the administration and civic society.

Local Economy: More than 80% of workforce in the project area practiced agriculture based activities. About 20% of workforce belongs to service industry and manufacture sector.

Vulnerable Groups: About 12.5% of households in the project area belong to vulnerable groups. It consists of Single Female Head Households 6.4%, Landless Households 3.5%, No Labor Households 1.4% and Elderly Households 0.9%.

Health: Because most of the villages in the project area are located along national road, accessibility to a district health centre and provincial hospital is satisfying. Reported health issues in the past twelve-month include malaria, dengue, diarrhea and some cases of HIV/AIDS.

UXO: More than half of the surveyed villages reported that no land within the village boundaries was affected by UXO. Those villages that did report UXOs were mainly in Saravan and Vapi district of Saravan Province. These villages also reported that land mine clearance teams had completed work in their villages and that over the last five years, few UXO incidents had occurred.

more than 3 meter tall is not allowed within ROW and tall trees within 12.5m are on both sides needs to be trimmed and pruned at or below 3 meters. Trees and other agricultural assets less than three meter tall such as rice paddy are allowed in ROW. On government land, any trees that have the potential to grow above 3m needs to be cleared. On private land, trees that can survive at less than 3m need to be pruned and maintained below this height. There is no legislation stipulated for these conditions, however, these clearance policies have been practiced in EDL. Accordingly, this project will follow the EDL's clearance practice.

[4] The Land Use Certificate is one of the legal proofs on ownership of a land and the written information on the Certificate is a basis for calculating compensation.

Compensation on Land Acquisition and Resettlement

A compensation principles and procedures are stipulated in "Decree on the Compensation and Resettlement of the Development Project (Oct 2005)". It is addressed that "Project owners must compensate project's affected peoples for their lost rights to use land and for their lost assets (structures, crops, trees and other fixed assets) in full or in part, at replacement cost".

Although the Decree on the compensation and resettlement of the development project and other legislations provides general provision on land acquisition and resettlement, there is no legal framework addressing compensation standard for transmission line project. To present, the compensation for the transmission line project has been estimated referring to relevant legislations such as above and international standards. Based on the standard, the means of compensation is finalized with an agreement between affected person and provincial line ministries at the province where project is located.[5]

Stakeholders Meetings

Through conducting IEE, three types of stakeholders meetings were held. Meetings with officials for the project at the central, provincial and district level and meetings with Villagers in the project area during filed survey purposed to provide a brief description of the project and the IEE process. Participants were given an opportunity to provide comments, advice and information relevant to the project. Besides, two open stakeholders meetings (workshops) were held in Savannakhet and Saravan Provinces. The aim of these consultations was to report the findings of the IEE, outline the next steps in the environmental approvals process and to get feedback from stakeholders.

Result of IEE

The result of the assessment indicates that the environmental impacts are predicted to be minor. Thus further conduction of EIA is not necessary. The transmission line route has been selected to minimize impact on environmental and social resources.

The total area of the ROW for the length of the proposed transmission line is 5.5km m^2. The ROW travels through the land of 903 households within 81 villages. At the time of IEE, 33 fixed assets were confirmed on the transmission line route. The route, however, was re-aligned in order to avoid these assets. Consequently there is no necessity of resettlement for the project.

The key socio-economic impacts of the transmission line will be the loss of productive land (forests and agricultural land) within the footprint of the substation and the towers and the loss of forests and commercial trees within the ROW.
Other impacts resulting from the Project are likely to include temporary nuisance impacts related to construction activities. The impacts, however, are anticipated to be minor.

With adequate compensation and implementation of management and mitigation measures the residual environmental and social impacts are likely to be minor.

Findings and Recommendations on Environmental and Social Consideration for the prioritized project

The issues such as prevention and mitigation measures, monitoring methods, capability of implementing environmental and social consideration had been discussed with counterpart institution

[5] After finalizing TL route in D/D, Detailed Measurement Survey is to be implemented in order to define APs and their lost assets. The information collected at DMS is to be a basis of compensation estimation.

through the Study period. The results of discussion were integrated into the IEE reports. In working with the counterpart, it was concluded that the following issues are deemed to be the most vital regarding environmental and social consideration for the project.

Budgetary Planning Situation: Regardless of project's financier, the cost concerning environmental and social monitoring has been paid by EDL[6]. Accordingly external monitoring on allocation of the monitoring budget in EDL has been difficult to carry out. Besides, a budgetary plan itself has been not always formed reflecting a tight financial situation of EDL. Thus appropriate budget allocation for the monitoring of EMP and RAP has been realized infrequently.

Recommendation: A budgetary plan needs to be reflected the availability of EDL fund. In other words, the monitoring plan needs to be developed based on what is available and formed duly excusable by EDL.

Law Enforcement Situation: There is no specific legislation or guideline developed on monitoring. Without proper law enforcement such as emission standards, regulation on detailed procedures on monitoring etc., and instruction of monitoring procedure, it has been made situation requiring great effort for allocating staff and budget nor setting technical standards for monitoring. Consequently, lack of domestic legislation forces to follow international standard that are not always suitable for the situation of Lao PDR.

Recommendation: There is a situation that setting up of monitoring procedure guideline has been under way. Until enacting the guideline, a monitoring plan needs to be formed taking account of situations addressed here and developed functionally.

Environment Unit (EU) Capacity of Implementing Monitoring Situation: Monitoring activities in a project area have been carried out by one official as EU assigned in each EDL branch. Considering a scale of electricity project in general, the number is not sufficient to achieve appropriate implementation of EMP and RAP. Yet unlike all EO officials who have a background in environmental field, EU officials do not always have an expertise in this field. As a result, it has been a bar from smooth implementation of EMP and RAP, especially in operation phase of the project which, full responsibility is taken from EO to EU. Thus strengthening the capability of EU on monitoring considered to be an urgent matter.

Recommendation: Program such as exchanging officials between branch offices and EO deems to be useful in order the EU officials to share knowledge with EU.

S-16. Estimate of the Project Costs

The total costs for the Project has been estimated on the basis of the ICB prices as 2009.

Cost for Social and Environmental Consideration

The compensation cost includes Detailed Measurement Survey (DMS), cost for the compensation incurred by the permanent land acquisition for constructing transmission tower base, cost for the compensation of the rice paddy and non-paddy land losses, compensation cost for losses of trees, cost for the compensation incurred by the temporary occupation for constructing activities, rental land, loss of agricultural products and rehabilitation cost. The total of the compensation costs has been estimated around US$166,844.51. The total of the monitoring and evaluation cost has been estimated around US$43,136.5. UXO scarcely remains on the some areas in Saravan of the selected transmission line

6 In WB current funded project, external monitoring has been eligible for financing out of WB loan. (Technical Guidelines on Compensation and Resettlement of the Development Project 2005 WREA)

route for the Project Costs for UXO Investigation and Clearance has been estimated around US$726,200.

Construction Cost

The construction cost of the Project attributed to the transmission line is shown in Table S-16.1. The cost has been estimated base on the results of the site surveys from January to August 2009 and the design of the towers and the volume of the bases discussed in Chapter 12.

Table S-16.1: Construction Cost for Transmission Line (1,000 US$)

Intervals	Contents	FC	LC	Total
Pakxan SS～Thakhek SS (194.6 km)	Materials	11,979.4	0	11,979.4
	Construction	999.0	4,245.8	5,244.8
	Total	12,978.4	4,245.8	17,224.2
Thakhek SS ～ Pakbo SS (105.2 km)	Materials	4,839.5	0	4,839.5
	Construction	417.4	1,765.9	2,183.3
	Total	5,256.9	1,765.9	7,022.8
Total (299.8 km)	Materials	16,818.9	0	16,818.9
	Construction	1,416.4	6,011.7	7,428.1
	Total	18,235.3	6,011.7	24,247.0

The unit cost of the transmission lines per km has become reduced by around 40% from the averaged cost evaluated for the optimum transmission and substation system covering the whole of the nation.

The cost of the substation has been estimated base on the facility configuration determined in Chapter 13 “Substation Facilities of the Project”. The construction of the substation facilities of the Project requires the land acquisitions for Pakbo and Taothan substations, however, because the land of Pakbo substation is owned by EDL and the candidate of the land for the Taothan substation is owned by the provincial government, the cost for the land acquisition will not be required.

Table S-16.2: Construction Cost of Substation Facilities (1,000 US$)

stations		FC	LC	Total
Pakbo Substation	Plant & Equipment	681.0	65.8	746.8
	Civil & Erection	32.0	315.7	347.7
	subtotal	713.0	381.5	1,094.5
Taothan Substation	Plant & Equipment	4,069.9	427.5	4,497.4
	Civil & Erection	95.0	1,479.9	1,574.9
	subtotal	4,164.9	1,907.4	6,072.3
Saravan Substation	Plant & Equipment	688.6	62.9	751.5
	Civil & Erection	14.0	82.0	96.0
	subtotal	702.6	144.9	847.5
	Total	**5,579.6**	**2,433.8**	**8,013.4**

The total project cost is show in the following table. The Project will be implemented in 36 months.

Table S-16.3: Total Project Costs (1,000 US$)

Items	FC	LC	Total
Transmission Lines	18,235.3	6,011.7	24,247.0
Substation Facilities	5,580.5	2,433.8	8,014.3
Sub-total	23,815.8	8,445.5	32,261.3
Compensation		166.8	166.8
Environment monitoring	-	43.1	43.1
UXO survey & clear	-	271.2	271.2
Consultant fee	2,258.3	192.0	2,450.3
Physical contingency	1,190.8	422.3	1,613.1
Price contingency	714.5	253.4	967.9
Total	27,979.4	9,794.3	37,773.7

S-17. Project Evaluation

Evaluation Criteria

This chapter conducts both economic analysis from national point of view and financial analysis from project-operating entity's point of view toward the prioritized transmission project (form now on, the Project). The analyses aim to examine the viability of the project.

The economic efficiency of the Project would be proved by comparison of the Economic Internal Rate of Return (EIRR) of the Project with the Opportunity Cost of Capital (OCC) for Lao PDR set as 12 %. The EIRR is derived by calculating net cash flow of economic costs and benefits. The economic costs include the construction costs and the related O&M costs of the Project. Its local currency portion is adjusted to economic price using the standard conversion factor of 0.9. The economic benefits from this Project are obtained by multiplying the saved electricity import and the increased electricity export against Thailand with respective import/export tariff.

The financial evaluation assesses the financial viability of the Project by comparing the financial internal rate of return (FIRR) of the Project with the weighted average cost of capital (WACC), or the fee to finance the Project's cost. For this purpose, the WACC is set as 2.7 %. The FIRR is derived by calculating net cash flow of financial costs and benefits. The financial costs include the capital cost and its relevant O&M cost, while the financial benefit is obtained by multiplying the transmission and substation portion of domestic retail tariff with electricity transmitted over the Project's transmission line. The evaluation period is from the fiscal year (FY) of 2011 to FY 2043 including detailed designing and construction of FY 2011 to FY 2013.

Results of Evaluation and Sensitivity Analysis

EIRR and FIRR of the Project were computed under the criteria set in the above section. The results are following:

EIRR: 27.9 %, NPV: 41.9 Million USD (at 12 % of discount rate)

FIRR: 17.1 %, NPV: 128.0 Million USD (at 2.7 % of discount rate)

Because both indices exceed their corresponding benchmarks, OCC (12%) and WACC (2.7%), the JICA Study Team concludes that the Project is economically as well as financially viable. The Team also conducted sensitivity test to see the results' robustness under anticipated future circumstance.

Table S-17.1 and Table S-17.2 summarize the results for economic analysis and financial analysis respectively.

Table S-17.1: Results of Economic Analysis

Scenario	EIRR [%]	NPV2009 [Million USD]	Elasticity	Boundary value
Base Case	27.9	41.9	-	-
1) Capital Cost Increase +15%	25.2	38.5	- 0.63	+190%
2) O&M Cost Increase +50%	27.5	41.0	- 0.02	n.a. (EIRR of 21.1 % with 1,000%)
3) Power Trading Slow Down –30%	20.8	21.6	0.85	-60%

Note: NPV stands for Net Present Value, calculated at 12 % of discount rate.
Boundary value: the value of key parameter which derives the EIRR value less than 12 %, OCC.

Table S-17.2: Results of Financial Analysis

Scenario	FIRR (%)	NPV2009 [Million USD]	Elasticity	Boundary value
Base Case	17.1	128.0	-	-
1) Capital Cost Increase +15%	15.4	122.4	- 0.67	n.a. (3.5 % of FIRR with +300 % rise)
2) Benefit Unit Value Decrease –10%	15.6	111.0	0.87	-80%
3) O&M Cost Increase +50%	16.7	124.1	0.05	n.a. (14.6 % of FIRR with +300 % rise)
4) Demand Slow Down –30%	12.4	76.9	0.91	-80%
5) Adoption of Proposed New Tariff System	24.1	158.9	-	-
6) Adoption of Alternative New Tariff System	14.7	76.9	-	-

Note: NPV stands for Net Present Value at 2.7 % of discount rate
Boundary value: the value of key parameter which derives the FIRR value less than 2.7 % of WACC.

As shown in the tables, the value of EIRR exceeds the benchmark of 12% for all scenarios, while the value of FIRR exceeds the benchmark of 2.7 % for all scenarios. The Team concludes that the economic and financial viability of the Project is considered robust.

It also turned out that the FIRR in the scenario e) would be the largest among all. This confirms that the adoption of the propose tariff system would be one of the factors to enhance the EDL's financial robustness.

Financing Plan

The JICA Study Team concludes that the appropriate financing scheme for the Project is loan from overseas development agencies, specifically Japanese Yen loan as appreciated by EDL. The financial analysis result undertaken in 17.2 shows that the FIRR of the Project exceeds its benchmark of WACC, 2.7%. The analysis result of EDL's financial status in 3.9 also confirmed that EDL is qualified with further loan as it satisfies the condition set in its loan policy, e.g. equity ratio keeps around 60% past five years. For those reasons, the Study Team concludes that the proposed financing plan is viable.

S-18. Conclusion and Recommendation

We hope that the results of this study will be taken into consideration for formulating the power sector policy and the power development program in Lao PDR.

The transmission line from Pakbo substation to Saravan substation has been selected as the most prioritized project. It is recommended that EDL proceed to the works for obtaining the Environment Certificate by WREA and start urgently preparing the financial arrangement of the project.

The total amount of the budget reaches around US $37.4 million. It can be concluded from the results of the economic and financial evaluation of the project that the implementation of the project will be economically and financially feasible

It is recommended that EDL conduct, with the technical skills obtained through this plan, the power system analysis for confirming yearly situations, make an effort to update the basic power system plan based on this plan and utilize the plan for the study of the implementation plan at the feasibility study stage of the individual projects of power generation and transmission lines and substations reflecting the latest information about the updated power demand forecast due to the change in the actual power demand, the change in the economic trends and the revision of the power generation development program.

EDL will need to study the functions of the Central Load Dispatching Center and the organization for the power system operation. The training of the staff and the arrangement of the manuals of the operation and maintenance should be further strengthened.

The common rule (Grid Code) applied to all the power system users is urgently required to be established that determines the technical requirements of connecting the EDL power system and the types of the information provided with the power system operator.

The additional power generation with several hundreds MW will be required in around 2030. The development of the thermal power plants in Laos should be considered because the hydropower potential is expected to become short of its provisions in that time and a certain amount of coal is estimated buried in the north and the south.

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