No.

MINISTRY OF INDUSTRY AND HANDICRAFTS
ELECTRICITE DU LAOS

THE STUDY ON MASTER PLAN OF TRANSMISSION LINE AND SUBSTATION SYSTEM IN LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT

(MAIN REPORT)

SEPTEMBER 2002

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
TOKYO ELECTRIC POWER COMPANY

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PREFACE

In response to a request from the Government of Lao People's Democratic Republic, the Government of Japan decided to conduct the Study on Master Plan of Transmission and Substation System in Lao P.D.R. and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent a study team headed by Mr. Ko NAKAJIMA of Nippon Koei Co., Ltd. organized by Nippon Koei Co., Ltd. and Tokyo Electric Power Company to Lao P.D.R. six times from March 2001 to September 2002.

The team held discussions with the officials concerned of the Government of Lao P.D.R., and conducted related field surveys. After returning to Japan, the team conducted further studies and compiled the final results in this report.

I hope this report will contribute to the improvement of the situation of electricity supply in Lao P.D.R. and to enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Lao P.D.R. for their close cooperation throughout the study.

September 2002

Takao KAWAKAMI
President
Japan International Cooperation Agency

September 2002

Mr. Takaaki Kawakami
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Kawakami,

Letter of Transmittal

We are pleased to submit you the final report on the Study on Master Plan of Transmission and Substation System in Lao People's Democratic Republic.

This study was conducted by the joint venture of Nippon Koei Co., Ltd. and Tokyo Electric Power Company under a contract to JICA, during the period from March 2001 to September 2002. In conducting the study, we have formulated the Master Plan for the optimum transmission and substation system in Lao P.D.R. up to 2020.

We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs and the Ministry of Economy, Trade and Industry. We would also like to express our gratitude to the officials concerned of the Ministry of Industry and Handicrafts, the Electricite du Laos and Embassy of Japan in Lao P.D.R. for their cooperation and assistance throughout our field survey.

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

Very truly yours,

K. Nakajima

Ko NAKAJIMA
Team Leader

The Study on Master Plan of Transmission and
Substation System in Lao P.D.R

Nippon Koei Co., Ltd.

THE STUDY ON MASTER PLAN
OF
TRANSMISSION LINE AND SUBSTATION SYSTEM
IN
LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT

(Main Report)

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ABBREVIATIONS

ACSR	:	Aluminum Conductor Steel Reinforced
ADB	:	Asian Development Bank
AFTA	:	Association of Southeast Asian Nations Free Trade Area
ASEAN	:	Association of Southeast Asian Nations
BOT	:	Build, Operate, and Transfer
BOOT	:	Build, Own, Operate, and Transfer
CA	:	Concession Agreement
CB	:	Circuit Breaker
CIF	:	Cost, Insurance, and Freight
CPC	:	Committee for Planning and Cooperation
CPI	:	Consumer Price Index
CT	:	Current Transformer
DIP	:	Department of Investment Promotion
DL	:	Distribution Line
DOE	:	Department of Electricity in MIH
DS	:	Disconnecting Switch
EDS	:	Every Day Stress
EDL	:	Electricite du Laos
EGAT	:	Electricity Generating Authority of Thailand
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
EU	:	European Union
FIRR	:	Financial Internal Rate of Return
FOB	:	Free on Board
GEF	:	Global Environment Facility
GDP	:	Gross Domestic Product
GMS	:	Greater Mekong Sub-region
HDI	:	Human Development Index
HDSS	:	Hydropower Development Strategy Study
HV	:	High Voltage (230 kV and 115 kV in Laos)
ICB	:	International Competitive Bidding
IEC	:	International Electro-technical Committee
IDA	:	International Development Association
IKL	:	Isokeraunic Level
IMF	:	International Monetary Fund
IPP	:	Independent Power Producer
IRR	:	Internal Rate of Return
ISO	:	International Standards Organization
JBIC	:	Japan Bank for International Cooperation
JICA	:	Japan International Cooperation Agency
JIS	:	Japanese Industrial Standard
LAO P.D.R.	:	Lao People's Democratic Republic
LDC	:	Load Dispatching Center

LF : Load Factor
LNGC : Lao National Grid Company
LOLP : Loss of Load Probability
LRMC : Long Run Marginal Cost
LV : Low Voltage (380/220 V in Laos)

MIH : Ministry of Industry and Handicrafts
MOSES : Multi-Objective Scenario Evaluation System
MOU : Memorandum of Understanding
MV : Medium Voltage (34.5 kV and 22 kV in Laos)

NBCA : National Bio-diversity and Conservation Area
NEAP : National Environmental Action Plan
NETG : National Electricity Transmission Grid
NPV : Net Present Value
NTL : Non-Technical (Energy) Loss

OCC : Opportunity Cost of Capital
OH : Overhead (line)
OPGW : Optical fiber Ground-wire
O&M : Operation and Maintenance

PEA : Provincial Electricity Authority (in Thailand)
PIP : Public Investment Program
PLC : Power Line Carrier (communications)
PPA : Power Purchase Agreement
PS : Power Station
PSS/E : Power System Simulator for Engineering
PSSS : Power Sector Strategy Study (by ADB)
PT : Potential Transformer

RUS : Rated Ultimate Strength

SS : Substation
STEA : Science, Technology, and Environmental Agency
STEP : JICA Study Team for Electric Power Standard Establishment
SCF : Standard Conversion Factor
SHS : Solar Home System
SwS : Switching Station

TA : Technical Assistance
TL : Transmission Line
TOR : Terms of Reference
TR : Transformer

UNDP : United Nations Development Program
UNHCR : United Nations High Commissioner for Refugees
UXO : Unexploded Ordnance

WB : World Bank
WTO : World Trade Organization
WTP : Willingness to Pay

UNITS

LENGTH

mm	:	Millimeters
cm	:	Centimeters (10.0 mm)
m	:	Meters (100.0 cm)
km	:	Kilometers (1,000.0 m)

EXTENT

cm^2	:	Square-centimeters (1.0 cm x 1.0 cm)
m^2	:	Square-meters (1.0 m x 1.0 m)
km^2	:	Square-kilometers (1.0 km x 1.0 km)
ha	:	Hectares (10,000 m^2)

VOLUME

cm^3	:	Cubic-centimeters (1.0 cm x 1.0 cm x 1.0 cm)
m^3	:	Cubic-meters (1.0 m x 1.0 m x 1.0 m)

WEIGHT

g	:	grams
kg	:	kilograms (1,000 g)
ton	:	Metric ton (1,000 kg)

TIME

sec.	:	Seconds
min.	:	Minutes (60 sec.)
hr.	:	Hours (60 min.)

CURRENCY

KIP	:	Lao Kip
US$	:	United State Dollars
J¥	:	Japanese Yen
ECU	:	Euro Currency Unit

ELECTRIC

V	:	Volts (Joule/coulomb)
kV	:	Kilo volts (1,000 V)
A	:	Amperes (Coulomb/second)
kA	:	Kilo amperes (1,000 A)
W	:	Watts (active power) (J/s: Joule/second)
kW	:	Kilo watts (10^3 W)
MW	:	Mega watts (10^6 W)
GW	:	Giga watts (10^9 W)
Wh	:	Watt-hours (watt x hour)
kWh	:	Kilo watt-hours (10^3 Wh)
MWh	:	Mega watt-hours (10^6 Wh)
GWh	:	Giga watt-hours (10^9 Wh)
VA	:	Volt-amperes (apparent power)
kVA	:	Kilo volt-amperes (10^3 VA)
MVA	:	Mega volt-amperes (10^6 Wh)
var	:	Volt-ampere reactive (reactive power)
kvar	:	Kilo volt-ampere reactive (10^3 var)
Mvar	:	Mega volt-ampere reactive (10^6 var)

EXECUTIVE SUMMARY

Executive Summary

(1) Background of the Study

Lao PDR has an estimated hydropower generation potential of more than 18,000 MW in its territory. The Government of Lao PDR (GoL) has a basic policy for the power sector that aims to acquire foreign currencies by exporting electric energy to its neighboring countries and to raise electrification ratio of the country.

Export of electricity has greatly contributed to the country's revenue since commissioning of the Nam Ngum power station in 1971. Contribution of the energy export from Nam Ngum - Nam Leuk and Xeset systems to Thailand was US$ 22 million (796 GWh) in 2001. This was 8 % of total foreign currency earnings of the country in the year. On the other hand, due to lack of the domestic transmission facilities, some areas of the country should import electricity at higher rate than that for export. Total amount of imported energy was US$ 6.5 million (183 GWh) in 2001.

Recently, the World Bank (WB) and the Asian Development Bank (ADB) are assisting in development of transmission systems in combination with distribution networks in the northern area and the southern area. However, a master plan for the development of a comprehensive transmission system to cover the whole country has not been established.

Under the situation, GoL proposed in May 2000 to the Government of Japan a request for the Study on Master Plan of Transmission Line and Substation System in the country for the domestic power supply purpose. The Government of Japan entrusted to the Japan International Cooperation Agency (JICA) to examine the request. JICA discussed details of the request with officials of Ministry of Industry and Handicraft (MIH) and Electricite du Laos (EDL) during November 2000 and decided to conduct the Study.

(2) Objective of the Study

Specific objectives of the study were to formulate an optimum development plan up to the year 2020 of the transmission lines and substations for domestic power supply over the country, to select the highest priority project from the optimum plan, and to design of the facilities for the highest priority project, taking into account the development program of EDL's power plants and efficient utilization of energy from IPPs' power plants.

The Study was carried out during a period of February 2001 to September 2002 in cooperation with the counterparts from EDL and accomplished in three (3) study stages; the investigation stage, system study stage, and the master plan formulation stage.

(3) Results of Study

(3-1) Review on Existing Transmission Systems and Current Generation Development Plan

At present there are only 4 independently operated power systems in the country including importing systems as seen in Figure 6.4-1 of Part I.

EDL establishes its own generation development program for the domestic supply and IPP projects by the year 2020 in consultation with MIH as shown on Tables 4.2-1 and 4.2-2 of Part I, which was the base of the master plan study of the study team. Total 15 new power stations are programmed for domestic supply use with total installed capacity of 852 MW for annual average production of 3,936 GWh. The capacity to be developed is equivalent to 300 % of the current capacity, and the total production is 360 % of the current generation. Total installed capacity and average annual production of IPP plants in the year 2020 are planned to be 7,013 MW and 33,243 GWh, respectively.

(3-2) Electricity Demand Forecast

Electricity demand forecast was examined by year and by district until 2020. Both annual energy consumption in GWh and peak demand in MW were forecasted. Energy demand in each district was forecasted for four categories, residential, industrial, commercial & service and agricultural sectors.

The general electrification policy of the country in the Socio-Economic Development Strategy published by the GoL in March 2001 stipulates a rate of electrification of all households by the year 2020 to be 90%. Residential energy demand was forecasted based on this electrification policy for household. Energy demands of industrial sector and commercial & service sector were forecasted on the base of elasticity between growths of GDP and energy consumption in the respective sector. Energy demand for agricultural sector was separately forecasted. Following table summarizes results of the electricity demand forecast of the Team by the year 2020.

Descriptions	Unit	Scenari	2005	2010	2015	2020
Energy Demand	(GWh)	High	1,374	2,196	3,350	4,715
	(GWh)	Base	1,337	2,093	3,138	4,320
	(GWh)	Low	1,302	1,997	2,945	3,975
Losses	(GWh)	High	343	493	670	832
	(GWh)	Base	334	470	628	762
	(GWh)	Low	326	448	589	701
Total Energy Demand	(GWh)	High	1,672	2,688	4,020	5,547
	(GWh)	Base	1,672	2,563	3,765	5,082
	(GWh)	Low	1,628	2,445	3,534	4,676
Peak Demand	(MW)	High	340	512	765	1,055
	(MW)	Base	331	488	716	967
	(MW)	Low	322	465	672	890

(3-3) Supply and Demand Balance

Balance of the total supply capability in the development plan of MIH/EDL and base-case electricity demand forecasted by the study team indicates the following:

- In the year 2005 when Central 1 and Central 2 will be interconnected, total installed capacity of interconnected transmission network is exactly the same as the assumed peak load of the network in 2005.
- In the year 2006, the completion of Nam Ngum 2 and Nam Beng 3 power stations will realize remarkable increase in the supply capacity of the interconnected network to meet the demand with sufficient reserved margin.
- After the year 2008 when the most demanding areas will be interconnected to form a unified national grid, supply capacities in both peak load and energy demand of the grid will continue to increase with the completion of various power plants in the generation development program of MIH/EDL, which are quite sufficient to meet the growing demand till the year 2020 as seen in Figure 5.6-3 of Part I.

(3-4) Formulation of Optimum Transmission System

Power plants for domestic supply are basically EDL's own plants only excluding IPP plants. While, agreements of IPPs with the GoL have and will have such a particular term that approximately 5 % of total energy and power produced at its plant should be delivered for the domestic consumption. The team planned that only such IPP plants providing with generator(s) for solely supplying to the domestic demand and being separated from export-use facilities would be connected with the EDL's domestic transmission grid, for reasons of stable operation of the grid and a reliable supply. Other IPP plants having no solely generator(s) will not be connected to the national grid, but agreed energy for domestic supply will be delivered to their surrounding areas through 22 kV feeders from the plants for contributing to rural electrification.

The expansion plan of transmission systems was chronologically formulated taking into account the following elements.

(a) Demands of power and energy forecasted in Chapter 5,
(b) Policy of the GoL on electrification rate of the country to be 90% by 2020,
(c) Linkage with availability of power and energy at the time, i.e., development program of power plants,
(d) Effective utilization and reinforcement of the existing transmission facilities, and programmed development of transmission systems in the country under international organizations,
(e) Satisfaction of criteria for systems and reliability,

(f) Impact to social and environment, and

(g) Facilities to be on the least cost basis

Results of the examinations on electricity demand, transmission distance and power flow concluded that 115 kV is the most economical system voltage for domestic supply by 2020. The plans of interconnections among power plants, substations and demand points were determined in comparisons of various alternatives for each section. Figure 6.8-1 of Part I shows the connections of points thus formulated till the year 2020.

The study team indicated the areas where EDL grids will not cover and recommended such alternative electricity sources as solar, mini/micro hydro, or diesel generator adequate for those areas.

(3-5) Analysis of Optimum Transmission System

For verifying adequacy of the formulated system for the system planning criteria, the optimum system was analyzed by PSS/E computer software. The analyses were conducted for power flow, stability, fault current, line loss, etc. on various cases in every 5-year system. Results of the analyses concluded that the formulated optimum systems in each year were quite appropriate satisfying all the system planning criteria. Further, the study team recommends several operation plans of the future systems as one of the results of analyses.

(3-6) Conceptual Facility Design and Cost Estimate of the Optimum System

The study team conducted the conceptual design of facilities for transmission lines and substations for the formulated optimum system applying the design criteria agreed between EDL and the team and also referring to the technical standards established by JICA STEP team. On the basis of the design, the study team estimated the total project cost of the optimum transmission and substation system over the whole country. Estimated total project cost on the ICB base was US$ 480 million including the currently progressing and planned projects under assistance of IDA, ADB and other organizations.

(3-7) Evaluation of Optimum Transmission Lines and Substation System

With the reasons that most of trunk transmission systems will be completed by the year 2008 and there might be some uncertainties in the EDL's development program of power stations after 2010, evaluation of the optimum system in the year 2010 was conducted. Cost included those for transmission lines and substations and MV & LV distribution networks (estimated by the study team) required for 2010 systems. Benefit was assumed to be incremental sales of energy to the areas through the formulated system, applying energy tariff that was estimated from the weighted willingness to pay of the existing and new customers deducted by generation cost. The generation cost was estimated from the ADB TA report. EIRR (Economic Internal Rate of Return) of the optimum system thus computed was 23 % which turns out to be higher than the said OCC (Opportunity Cost of Capital) 11 % of Lao PDR and was judged as viable in economic terms.

EDL, an implementing agency of the project, is a power corporation that owns every facility from generation through transmission to distribution networks, and is responsible for the entire flow from power production to retail sale to energy users. This indicates uncertainty of hand-over or wholesale price between generation outlet and transmission inlet. Furthermore, this Project is to develop the transmission and sub-station facilities over the country, the project covers many remote and scattered demanding points, and the present power tariff includes subsidy. Under those conditions, revenue related to the transmission lines and substations is difficult to be identified. Assuming that 40 % of the current tariff regulated toward the year 2005 would be allocated for the portion of transmission lines, substations and distribution network, trial calculation of FIRR for the Project was carried out. Result of the calculation was however negative.

(3-8) Selection of Highest Priority Project

The highest priority project was selected from candidates systems in the formulated optimum system to be developed by 2005, but the progressing project and the certain projects to be implemented under the international funds were excluded from candidates. The evaluation items for the candidate projects were determined through discussions with EDL as below:

(a) Urgency of the subproject in the respect of the governmental development program,

(b) Impact for environmental and UXO circumstances,

(c) Saving of imported energy by a subproject,

(d) Number of beneficiaries from a subproject, and

(e) Efficiency of investment (e-1) : Energy sales per investment
(e-2) : Beneficiaries per investment

The evaluation concluded that the section of Pakxan-Thakhek-Pakbo system was the highest priority project.

(3-9) Facility Design of the Highest Priority Project

The study team achieved the preliminary design of the 115 kV double circuit of ACSR 240 mm^2 transmission line of Pakxan - Thakhek - Pakbo and the 115 kV substations at Pakxan, Thakhek, and Pakbo of the highest priority project.

The transmission line route was aligned over 300 km almost along the national road No.13 as seen in Figures 2.1-1 to 2.1-4 of Part II. The route was selected in details taking into account results of the examinations on environment, regional restriction of land use, security of the facilities, easiness of construction and maintenance, and also referring to the advice of EDL. Most of the route passes in flat area, and soil conditions for towers deem to be quite solid so that no special foundations will be required for the line. Final route and soil condition will be confirmed by the field survey to be carried out in the detailed design stage of the project.

Each substation for the project is to be provided in the premises of the existing EDL substations or premises of the substation newly to be completed during 2004. No issues for land and environment are anticipated for the substations, accordingly.

Design of the facilities was done so as to meet various articles ruled in the Laotian Electric Power Technical Standard of the JICA STEP team and also to satisfy the design criteria agreed between EDL and the study team.

In accordance with results of the design, the team prepared the implementation schedule and estimated the project cost with its disbursement schedule. Estimated project cost for both transmission lines and substations was approximately US$ 27.7 million. The Project needs 36 months to be completed from assignment of the consultants to the commissioning of all the facilities including 13 months for preparatory works and 23 months for manufacturing, construction, and tests.

The highest priority project was economically and financially evaluated in IRR analysis. EIRR for the project was worked out to be 23.9 % on the basis of save of import energy. FIRR of the Project was calculated to be 14.9 % on the basis of incremental energy sales. Both EIRR and FIRR are higher than OCC of 11 % assumed for the country, and the Project was judged to be viable.

Besides, following Project effects are assured by its implementation.

(a) Reduction of import energy estimated at approximately 6,290 GWh or US$ 32 million for a period of 15 years from 2006 to 2020.
(b) Electrification of 980,000 persons in the area,
(c) Contribution to development of regional industrial, agricultural, and commercial sectors,
(d) Contribution to improvement of Basic Human Needs, and
(e) Start-up of the comprehensive national transmission network.

Thus, the Project is recommended to be implemented at the earliest time.

In addition, the study team made various recommendations for the efficient and proper operation of the power system in the country in Chapter 8 of Part II.