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

# Lao People's Democratic Republic Data Collection Survey on Power System Development in Southern Region in Lao PDR

# Final Report

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Japan International Cooperation Agency

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## Abbreviations

| | |
|---|---|
| A | Ampere |
| ACSR | Aluminum Conductor Steel Reinforced |
| ADB | Asian Development Bank |
| CA | Concession Agreement |
| cct | Circuit |
| CIF | Cost, Insurance and Freight |
| COD | Commercial Operation Date |
| CSG | China Southern Power Grid Co. |
| DC | Direct Current |
| DOE | Department of Electricity in MEM |
| EDL | Electricité du Laos |
| EGAT | Electricity Generating Authority of Thailand |
| EIRR | Economic Internal Rate of Return |
| EPZ | Economic Private Zone |
| FS | Feasibility Study |
| FC | Foreign Currency |
| FIRR | Financial Internal Rate of Return |
| FY | Fiscal Year |
| GDP | Gross Domestic Product |
| GMS | Greater Mekong Sub-Region |
| GW | Giga Watt |
| GWh | Giga Watt hour |
| HVDC | High Voltage Direct Current |
| Hz | Hertz |
| IEC | International Electrotechnical Commission |
| IPP | Independent Power Producer |
| IRR | Internal Rate of Return |
| JICA | Japan International Cooperation Agency |
| JPY | Japanese Yen |
| kA | Kilo- Ampere |
| kV | Kilo-Volt |
| Lao PDR | Lao People's Democratic Republic |
| LC | Local Currency |
| LDC | Load Dispatching Center |

| | |
|---|---|
| LDC | Least Developed Country |
| LEPTS | Lao Electric Power Technical Standards |
| MEM | Ministry of Energy and Mines (Lao PDR) |
| MOM | Minutes of Meeting |
| MOU | Minutes of Understanding |
| MV | Medium Voltage |
| MW | Mega Watt |
| MWh | Mega Watt hour |
| NPV | Net Present Value |
| O&M | Operation & Maintenance |
| ODAF | Oil Directed Air Forced |
| ONAF | Oil Natural Air Forced |
| OPGW | Optical fiber Ground-wire |
| PDA | Project Development Agreement |
| PDEM | Provincial Department of Energy and Mines |
| PDP | Power Development Plan |
| pF | Pico Farad |
| PLC | Power Line Carrier |
| PPA | Power Purchase Agreement |
| PSS | Power System Stabilizer |
| PSS/E | Power System Simulation/Engineering |
| ROW | Right Of Way |
| S/W | Scope of Work |
| SLACO | Sino Lao Aluminum Company |
| SEZ | Special Economic Zone |
| S/S | Substation |
| TL | Transmission Line |
| TR | Transformer |
| UHV | Ultra High Voltage |
| UNOSAP | United Nations Operational Satellite Applications Programme |
| USD | United States Dollar |
| UXO | Unexploded Ordnance |
| WB | World Bank |

# Chapter 1 Policy of the Study

## 1.1 Objectives and Targets of the Study

### (1) Objectives of the Study

The objectives of the study is to prepare a report for the formation of a future yen loan-financed project by reviewing the latest PDP2010-2020(draft) of Lao PDR, developing some power development scenarios through discussions with the Laos side and analyzing the electric power system in Lao PDR. Specifically, the Study Team will conduct the following activities.

- ❖ To conduct a power system analysis of the interconnection link between the central and southern systems and the local system of the southern area for the period of PDP2010-2020
- ❖ To develop a basic design for the transmission lines / substations projects in the interconnection link between the central and southern systems and the local system of the southern area

### (2) Outputs of the Study

The outputs of the Study are as follows:

- ❖ To collect information on power supply-demand（development in mining and industrial parks, growth of commercial demand, progress of power development plan, etc.）
- ❖ To develop four realistic power development scenarios by analyzing information that can presently be obtained for the period of PDP2010-2020
- ❖ Based on the aforementioned scenarios, the power system analysis of the interconnection link between the central and southern systems and the local system in the southern area will be mainly carried out, and will bring to light the problems concerning system development
- ❖ To propose measures concerning problems of the aforementioned issues and create a concrete system development plan

### (3) Study Area

The Study covered the entire area of the Lao PDR territory.（Especially the interconnection link between the central and southern systems and the local system of the southern area. Concerning power supply-demand information, the information on the local system of the northern and central areas was also collected.）

The counterpart divided the system into three regions, North, Central and South, however, we divided the South system into two regions, South 1 and South 2 to distinguish the location at the sending point and at the receiving point of the interconnection targeted in this study.

**Table 1-1 Regions of Power Network System of Laos**

| Area | Provinces |
|---|---|
| North (N) | Phongsaly, Bokeo, Luang Namtha, Oudomxai, Huaphanh Xiengkhuang, Luang Prabang, Sayaboury |
| Central (C) | Vientiane Province, Vientiane Capital, Bolikhamxai |
| South 1 (S1) | Khammouan, Savannakhet |
| South 2 (S2) | Champasak, Saravan, Xekong, Attapeu |

### (4) Implementing Agencies of Lao PDR

- ❖ Supervisor Government Office: Department of Energy (DOE)
  Ministry of Energy and Mines (MEM)
- ❖ Implementing Agency: Electricité du Laos (EDL)

### (5) Contents of the Study

In order to accomplish the aforementioned objective, the Study Team set up four stages shown in Table 1-2 that were conducted as follows:

In STAGE-1, an inception report was created through domestic preparation work with the following tasks being carried out in the first field survey.

- ❖ Explanation and discussion of the inception report
- ❖ Collection and review of necessary information and data

In STAGE-2 (the first field survey), PDP2010-2020(draft) in the process of creation was reviewed in collaboration with the counterparts. At this stage, the power development project, which was proposed by the "THE STUDY ON THE POWER NETWORK SYSTEM PLAN IN LAO PDR (2010.1)", was reviewed in collaboration with the counterparts, because this is one of the candidate yen loan-financed projects. Moreover, the role and adequacy of the voltage class criteria such as the 500kV, 230kV and 115kV was discussed using the results of the demand forecast and the power system analysis, because it deems standardization as important with respect to the efficient planning of the future power system in Lao PDR.

At STAGE-3, based on the results of the first field survey, the following analyses were carried out.

- ❖ Development of some power development scenarios
- ❖ Implementation of the system analysis based on power development scenarios

- ❖ Specification of the problem for power system operations, and an examination of countermeasures
- ❖ Preparation and submission of a draft final report

At this stage, it strived to arrive at a decision of realistic power development scenarios. This is based on a realistic power demand forecast in consideration of the increase of power demand by the southern part mining development which will hit its stride from around 2015, and the special economic zone (SEZ) development in the Savannakhet prefecture, etc. Furthermore, the procedures required for commercialization, such as the feasibility study and a financial analysis was also confirmed.

The following STAGE-4 Finalization tasks were carried out in the second field survey.

- ❖ Specification of the problem for power system operations, and countermeasure proposals
- ❖ Preparation, explanation and discussion of the final report

**Table 1-2 Main Tasks of Study**

| STAGE | Main Tasks of Study |
|---|---|
| STAGE-1<br>Collection of information | a) Collection and review of necessary information and data【Domestic preparation work and first field survey】<br>b) Explanation and discussion of inception report【Domestic preparation work and first field survey】 |
| STAGE-2<br>Review of PDP2010-2020 | a) Review of power demand forecast【First field survey】<br>b) Review of power development plan【First field survey】<br>c) Review of power system development plan【First field survey】<br>d) Review of power system analysis【First field survey】<br>e) Discussion with organizations concerned【First field survey】 |
| STAGE-3<br>Power system analysis | a) Developing power development scenarios【First field survey and first domestic work】<br>b) Implementation of the power system analysis based on power development scenarios 【First field survey and first domestic work】<br>c) Specification of the problem for power system operations, and examination of countermeasures【First domestic work】<br>d) Preparation and submission of draft final report【First domestic work】 |
| STAGE-4<br>Finalization | a) Specification of the problems for power system operations, and proposal of countermeasures【Second field survey】<br>b) Preparation, explanation and discussion of the final report 【Second field survey and second domestic survey】 |

# Chapter 2 Review of PDP2010-2020

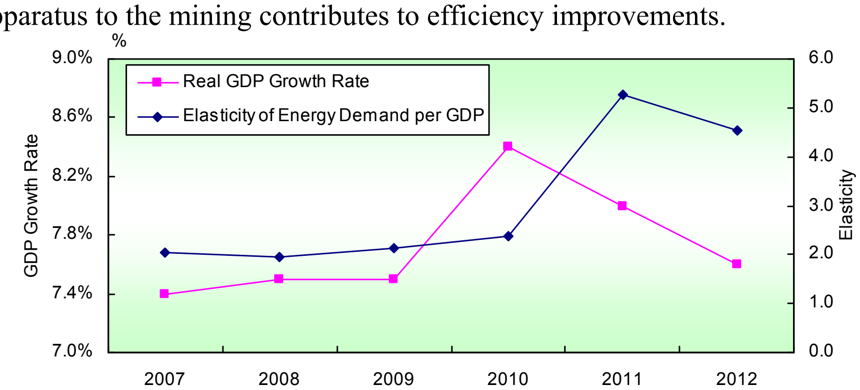
## 2.1 Demand forecast

EDL's power demand forecast is in the power development plan and it has been recognized by the government. However, there is no participation of an economic related government agency which assumes GDP at the power demand forecast stage. Moreover, large scale development projects, which are considered for other infrastructure such as a road and water services, are directly requested to EDL minus undergoing a comprehensive government examination. Since energy supply to large scale development projects which should be due to a national comprehensive development plan that exceeds the system scale of the present whole EDL is performed only by EDL, there is the serious problem concerning the decision for the power development plan.

### (1) Elasticity of Energy Demand per GDP

In the power demand forecast by EDL, the growth rate of the electric energy is 22.6% from 2010 to 2020 in the whole country. The demand of the large scale aluminum refining plants (SLACO) planned by the southern part is woven into this demand.

Figure 2-1 shows the real GDP growth rate and the elasticity of electric energy per GDP from 2007 to 2012. The real GDP was 8.4% in 2010 and the elasticity of electric energy per GDP was 2.38 in 2010. (The elasticity of electric energy per the GDP of Thailand was 1.36 in 2010.) The elasticity of electric energy per the GDP shows the efficiency which contributes to the GDP of electric power demand, and it can be estimated that the efficiency is high if it is low. The elasticity of electric energy per the GDP is improvable by introducing efficient apparatus. Generally the elasticity of electric energy per the GDP of developing countries can be made low based on the experience of developed countries. Especially in Laos, it seems that the application of efficient apparatus to the mining contributes to efficiency improvements.




(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011 and World Bank East Asia and Pacific Economic Update 2011)

**Figure 2-1 Real GDP Growth Rate and Elasticity of Electric Energy per GDP in Laos**

### (2) Assumption of Electric Energy

The electric energy in 2015 and afterwards is pushed up by the demand of the mines and metal refining plants which plan to start operations from around 2015. Although the situation of the mining development project varies with the conditions of a development subject or a mine, under present circumstances, many projects are under investigation. Especially large scale mining development is SLACO in the southern part 2 area. According to the information from DOE and EDL, SLACO is planning to start operations from 2015. The demand of SLACO is the assumption which occupies 30 percent of the national demand with electric energy in 2020, and the annual average growth of electric energy is pushed up 5% by SLACO. In the southern part 2, the annual average growth of electric energy is pushed up 18% by SLACO.

The electric power demand of SLACO assumes 900 MW and 6701.4 GWh. However, according to the information from DOE and EDL, it seems that the plan of SLACO is under investigation and there is a big deviation between the setting power rates by SLACO and the power rates which can be supplied. Although it asked for an offer of the information concerning plants and equipment of SLACO from the Laos side, only the minutes in which the information on application electric power (900 MW) and electric energy (8,500 GWh) were indicated was provided. It was corrected to 85% of the load factor although there is a deviation between the electric energy at the time of the application and the electric energy which EDL presently assumes.

**Table 2-1 Electric Energy Forecast by EDL**

(Unit: GWh)

| Areas | 2010 | 2015 | 2020 | Annual growth rate |
|---|---|---|---|---|
| Northern | 284.0 | 2,828.0 | 2,056.8 | 21.9% |
| Central | 1,634.8 | 4,909.5 | 7,060.4 | 15.8% |
| Southern1 | 786.7 | 1,814.4 | 3,417.4 | 15.8% |
| Southern2 | 261.2 | 2916.6 | 10,144.4 | 44.2% |
| Southern2（without SLACO） | 224.9 | 1823.6 | 2,396.8 | 26.7% |
| Total | 2,966.8 | 1,2468.5 | 22,679.0 | 22.6% |
| Total（without SLACO） | 2,930.4 | 1,1375.5 | 14,931.4 | 17.7% |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

### (3) Assumption of Peak Load

In EDL's power demand forecast, the growth of the peak load from 2010 to 2020 is 19.6% of the whole country. SLACO gives a large impact on the peak demand since it occupies 26 % of the whole demand. In the South 2 area, 2/3 is SLACO demand.

In the northern area, it is assumed that the load will peak in 2015 and will decrease in 2020. This is because the electric power for construction required for hydraulic power development is accumulated on the transformer capacity basis, and the non-isochrones of electric power demand is not taken into consideration. Since the detailed analysis of actual electric power at the time of hydraulic power station construction is not conducted, the slightly higher demand for the construction will be taken into account. Moreover, in the present electric power development plan, many projects will start commercial operations in 2015 and afterwards, and for this reason, much electric power demand for construction is assumed in about 2015. It is thought that this is the average progress of future Electric Power Development. If it is not concentrated over a short period of time, the influence decreases according to the growth of peak load. However, training the EDL staff is required regarding the assumption method in consideration of the non-isochrones of electric power demand.

**Table 2-2 Peak Load Forecast by EDL**

(Unit: MW)

| Areas | 2010 | 2015 | 2020 | Annual growth rate |
|---|---|---|---|---|
| Northern | 47.0 | 479.6 | 336.0 | 17.7% |
| Central | 318.0 | 869.2 | 1,273.9 | 14.8% |
| Southern1 | 136.8 | 363.8 | 558.2 | 15.5% |
| Southern2 | 56.3 | 415.8 | 1,298.7 | 36.1% |
| Southern2（without SLACO） | 56.3 | 315.8 | 398.7 | 21.0% |
| Total | 558.1 | 2,128.4 | 3,466.8 | 19.6% |
| Total（without SLACO） | 558.1 | 2,028.40 | 2,566.8 | 16.1% |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

### (4) Assumption of System Load Factor

It has a tendency to improve the system load factor as the development of mining and industry progresses. It is assumed that it will be 74% in 2020. Also in Thailand, the system load factor is 75%. Thus the system load factor of Laos was normal in 2010.

In the South 2 area, the system load factor will be nearly 90% by operation of SLACO in 2020. This means that the peak load has always arisen in the southern part 2 area. It is necessary to nearly maximize the supply of electric power all day and night also during the dry season, and much investment is needed for the measure against the system reliability fall via the forced outage of SLACO and the shortage of power in the dry season.

**Table 2-3 Assumption of System Load Factor**

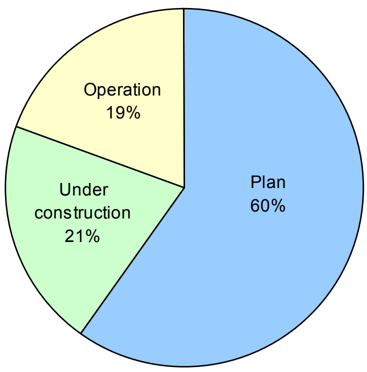
| Areas | 2010 | 2015 | 2020 |
|---|---|---|---|
| Northern | 49.2% | 67.3% | 69.9% |
| Central | 58.0% | 63.4% | 63.2% |
| Southern1 | 65.6% | 68.2% | 67.4% |
| Southern2 | 50.2% | 80.1% | 89.2% |
| Southern2（without SLACO） | 43.3% | 65.9% | 68.6% |
| Total | 58.0% | 68.3% | 74.2% |
| Total（without SLACO） | 57.3% | 65.5% | 65.9% |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

## 2.2 Power Development Plan

The draft PDP2010-2020 reflects and assumes the industrial promotion policy of the GOL, rapid demand growth in the southern region, reinforcement of the transmission system to supply demand in the southern region and facilitating domestic hydropower IPP project developments. A number of power plants are increased in the draft PDP2010-2020 by utilizing the IPP scheme compared to the last PDP2007-2016.

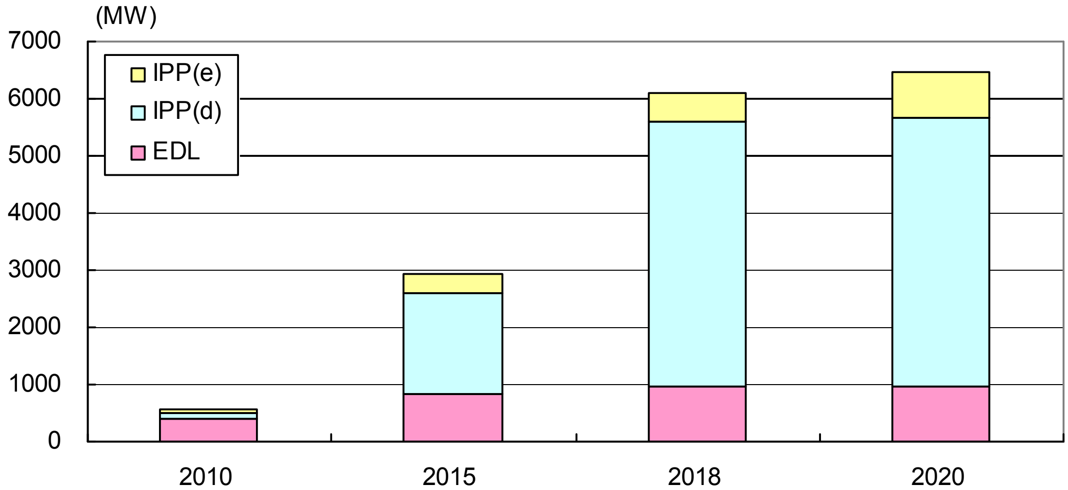
According to the draft PDP2010-2020, 19% of the power plants exist at present, 21% of the same are under construction and the majority are under plans among the power plants assumed in the year 2015 in the draft. This is to ensure that the power supply largely depends on the progress of the power plant developments under construction and planned.




(Source: EDL Power Development Plan June 2011)

**Figure 2-2 Power Development Project Status**

The following investments are assumed: direct investment by EDL is 17%, the investment by others is 71%, 12% of the investment is provided by the domestic portion of the IPP projects for power exports. The developments of EDL undergo a relative decrease. Though there is the advantage that EDL can avoid initial investment, EDL cannot control the progress of development easily. IPP plants are operated according to the PPA, it tends to become an operation of the constant output. In that case, the system operation will become difficult if an article to secure ancillary service is not included in the PPA.



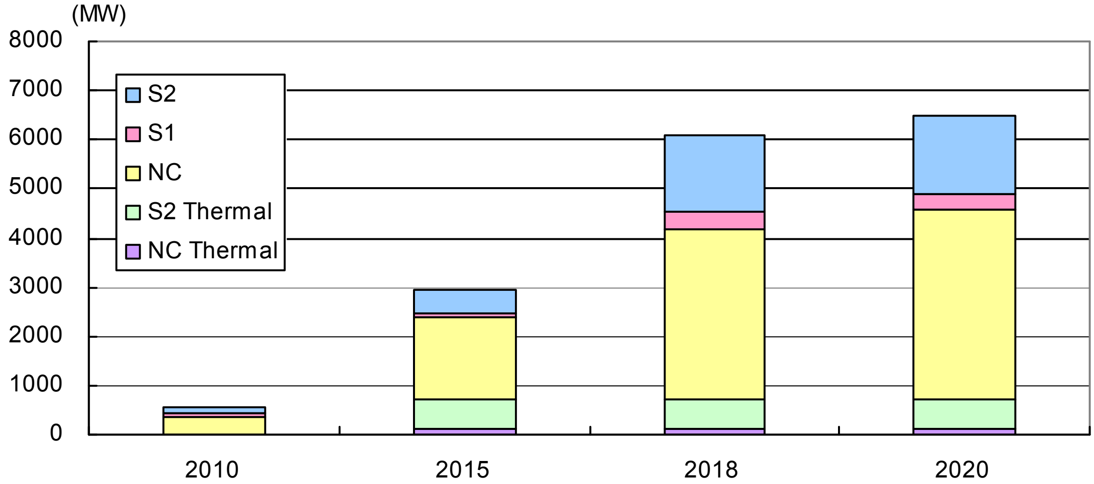

(Source: EDL Power Development Plan June 2011)

**Figure 2-3 Share of Power Plant Development by Investors**

The total amount of the power development in 2020 is 6,471MW which is larger than 3,488.4MW of the peak demand forecast including SLACO of 900MW. The firm power supply in consideration of the dry season outputs is 3,317MW which is less than the peak demand forecast, since almost all power supplies are hydropower plants.

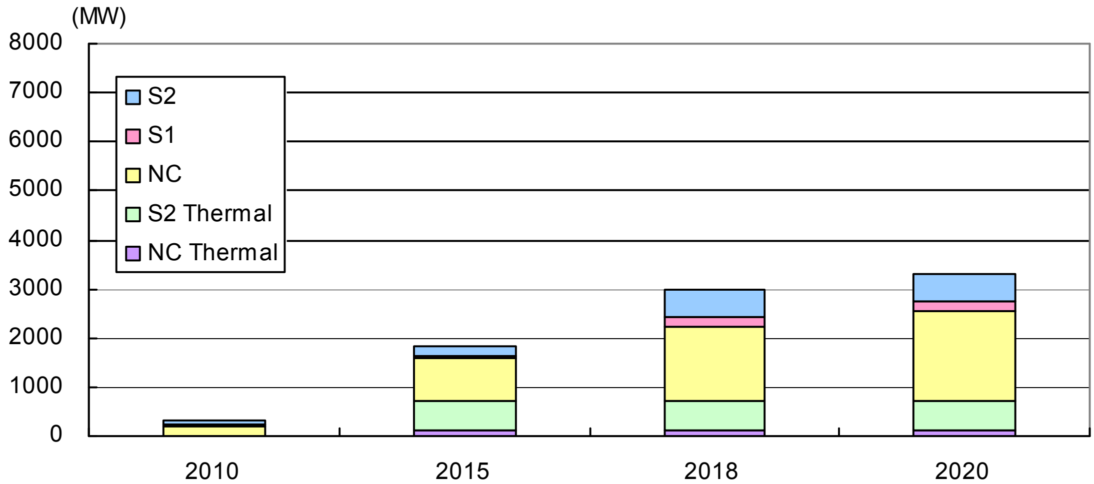
The installed capacity by region and the firm capacity by region (dry season) are shown in Figure 2-4 and Figure 2-5. The plan assumes a large amount of power development in the northern region, and a small amount of power development in the South 1 region due to a lack of hydropower development potential sites. The Hongsa thermal power plant (100MW) is planned for the northern region, and M Kaleum thermal power plant (300MWx2) is planned for the South 2 region. Thus far, there is no thermal power plant development plan in the other regions. The share of the thermal power capacity will be 11% in 2020.

There are a lot of hydropower development plans with a capacity factor over 60%. The power outputs of these plants can be improved by optimizing reservoir operations. A review of the plan should be necessary to avoid spilled water due to lack of space for absorbing output control.




(Source: EDL Power Development Plan June 2011)

**Figure 2-4 Power Development by Region**




(Source: EDL Power Development Plan June 2011)

**Figure 2-5 Firm Capacity by Region**

## 2.3 Power System Development Plan

Figure 2-6 shows the current power network system of Laos (PDP 2010-2020 Draft, Aug 2010). Figure 2-7 and Figure 2-8 show the power network system of 2015 and 2020 respectively. The construction of the transmission line from Thakhek to Pakbo was completed at the beginning of 2011 and from Pakxan to Thakhek in June 2011. While the transmission line project from Hinheup to Naxaythong is currently under construction as the first 230kV system in Laos, its construction work for transmission lines has been completed. Although the 230kV transmission line from Saravan to Seno was proposed in the JICA Study of Power Network System Plan in 2010 as the plan to be completed by 2030, it is under plans to be completed in 2015 in the latest PDP Draft. The plan of the 115 kV transmission line from Pakbo to Saravan that was proposed as the highest prioritized project in the JICA Study of Power System Network Plan was changed in the construction interval to Kengkok-Saravan. However, as explained later, DOE, EDL and JICA agreed to set out the interval as from Pakbo to Saravan in this study.

The construction of 115kV Pakbo-Saravan Transmission line was recommended to be urgently needed to contribute the reduction of imported power by utilizing the surplus power in the south (currently in the South 2) via the interconnection between the south and the central (currently South 1) in line with Power Sector Policy Statement of Lao PDR. (Stable and continuous domestic power supply at a reasonable price will be maintained and expanded to promote economic and social development.)

Table 2-4 to Table 2-8 show the transmission line and 500kV substation plans from 2010 to 2020.

The 115 kV substations plan is described in Table 4-9 and Table 4-10.

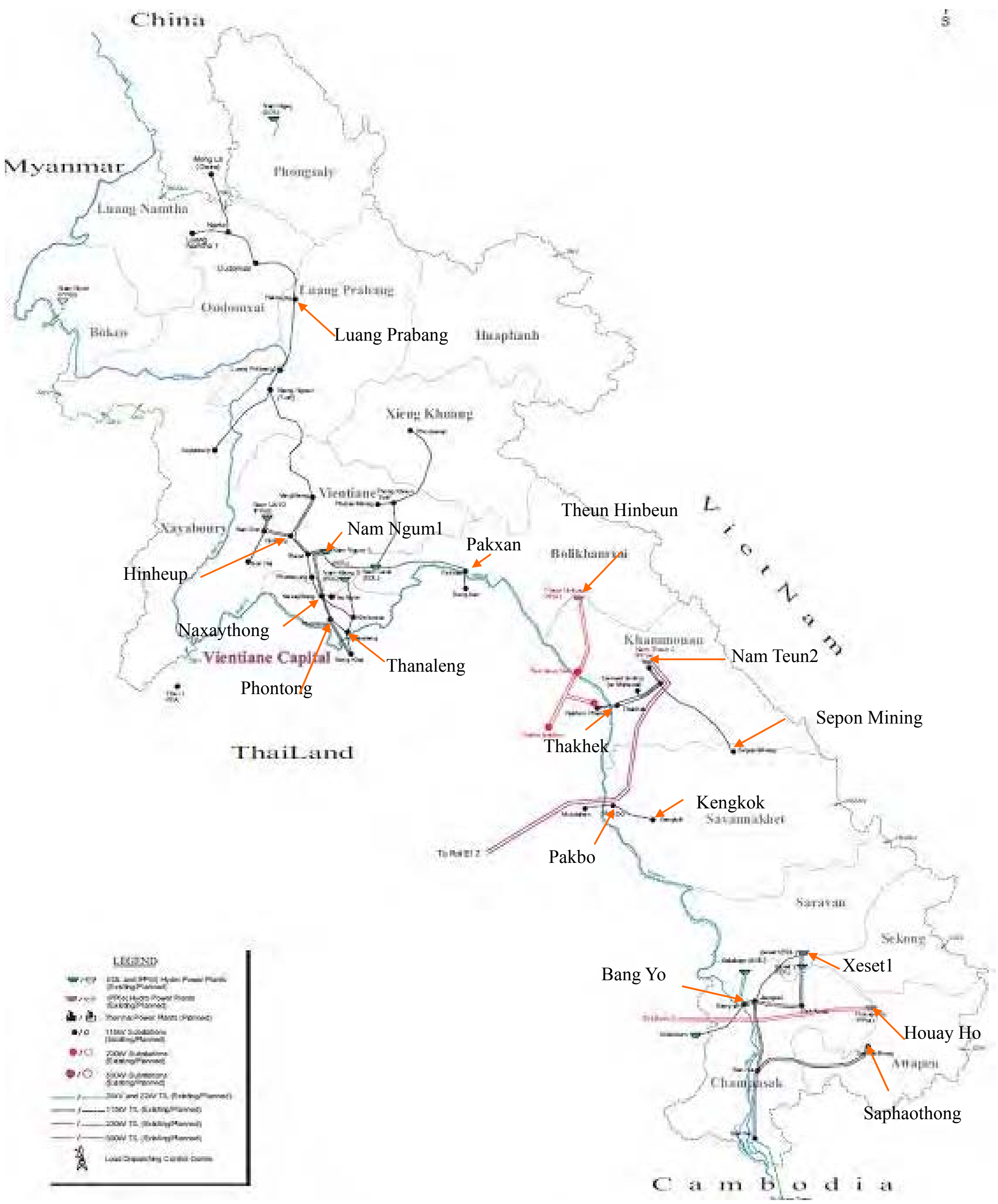



**Figure 2-6 Power System of Laos in 2010**

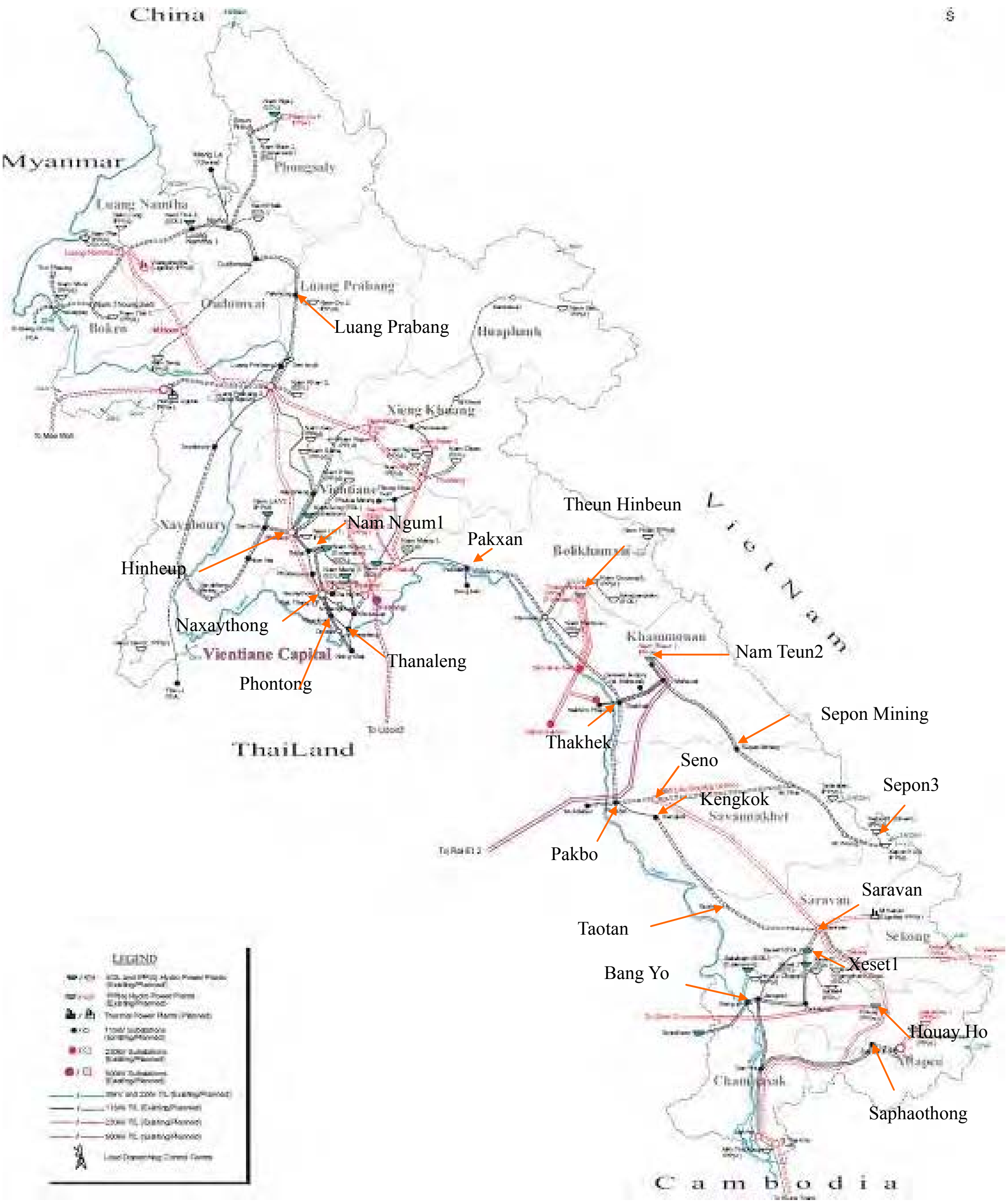



**Figure 2-7 Power System of Laos in 2015**

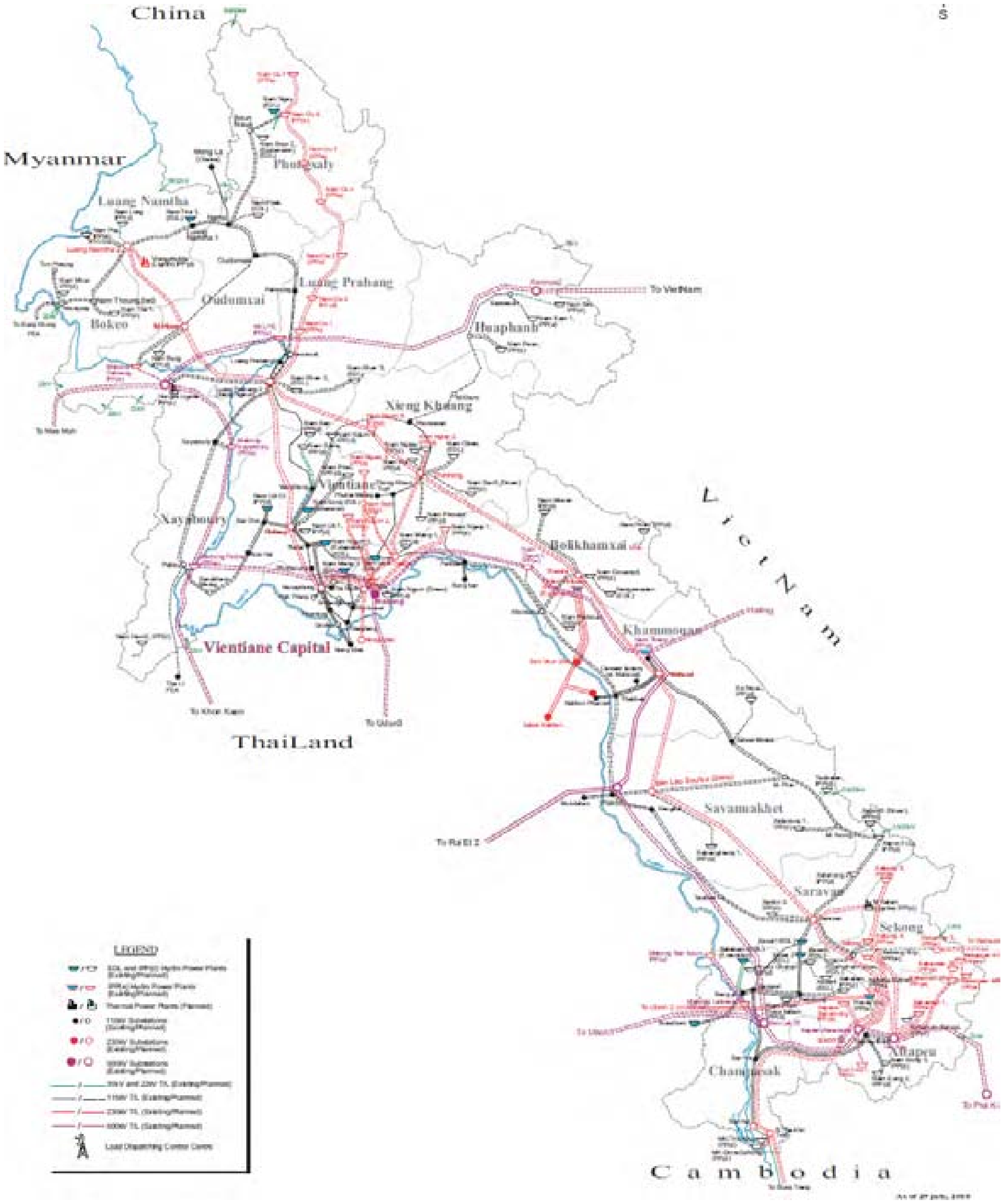



**Figure 2-8　Power System of Laos in 2020**

## Table 2-4 Plan of 115 kV and 230 kV Transmission Lines from 2010 to 2020 (North)

| No | From | To | Voltage | No. of Circuits | Conductor | Length (km) | Circuit Length (km) | Year | Owner | Loan | status | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Nam Nhon | Houayxay | 22 | 1 | 1X95 | 32 | 32 | 2008-2010 | IPP(d) | GMS | Constuction | Northern |
| 2 | Nam Ngum 5 | Phonsavan | 115 | 1 | 1X240 | 67 | 67 | 2008-2011 | EDL | Exim bank China | Constuction | Northern |
| 3 | Nam Ngum 5 | Vangvieng | 115 | 2 | 1X450 | 75 | 150 | 2008-2011 | EDL | Exim bank China | Constuction | Northern |
| 4 | Nam Tha 3 | Luangnamtha 1 | 22 | 1 | 1x150 | 5 | 5 | 2009-2011 | EDL | Lao Company | Discussion | Northern |
| 5 | M. Kham | Xam Nuea 1 | 115 | 1 | 1x240 | 120 | 120 | 2009-2012 | EDL | Exim Bank China | Constuction | Northern |
| 6 | Phonsavan | M. Kham | 115 | 1 | 1x240 | 56 | 56 | 2009-2012 | EDL | Exim Bank China | Constuction | Northern |
| 7 | Luangprabang 1 | Pakmong | 115 | 1 | 1x240 | 77 | 77 | 2009-2012 | EDL | Exim Bank Malaysia | Constuction | Northern |
| 8 | Pakmong | Oudomxai | 115 | 1 | 1x240 | 52 | 52 | 2009-2012 | EDL | Exim Bank Malaysia | Constuction | Northern |
| 9 | Oudomxai | Na Mo | 115 | 1 | 1x240 | 41 | 41 | 2009-2012 | EDL | Exim Bank Malaysia | Constuction | Northern |
| 10 | Sansouk | Pakmong | 115 | 1 | 2x240 | 1.7 | 1.7 | 2009-2012 | EDL | Kungthai Bank | Planned | Northern |
| 11 | Nam Long | Luangnamtha 2 | 22 | 1 | 1X95 | 44 | 44 | 2009-2012 | IPP(d) | Lao Company | Constuction | Northern |
| 12 | Paklay | Tha Li | 115 | 2 (1c) | 1x240 | 86 | 172 | 2009-2013 | EDL | ADB | Loan | Northern |
| 13 | Paklay | Sayaboury | 115 | 2 (1c) | 1x240 | 134 | 268 | 2009-2013 | EDL | ADB | Loan | Northern |
| 14 | Paklay | Non Hai | 115 | 2 (1c) | 1x240 | 104 | 208 | 2009-2013 | EDL | ADB | Loan | Northern |
| 15 | Na Mo | Boun Neua | 115 | 2 (1c) | 1x240 | 102 | 204 | 2009-2013 | EDL | ADB | Loan | Northern |
| 16 | M. Houn | Oudomxai | 115 | 1 | 1x240 | 83 | 83 | 2010-2013 | EDL | - | Planned | Northern |
| 17 | Nam Ham 2 | Paklay | 22 | 1 | 1X150 | 50 | 50 | 2010-2013 | EDL | Cobri / PEA | Planned | Northern |
| 18 | Nam Sim | Xam Nuea 1 | 22 | 1 | 1X150 | 50 | 50 | 2010-2013 | IPP(d) | NORAD | status | Northern |
| 19 | Luangprabang 1 | Luangprabang 2 | 115 | 1 | 1x240 | 15 | 15 | 2009-2014 | EDL | - | Planned | Northern |
| 20 | Luangprabang 1 | Luangprabang 2 | 115 | 1 | 1x240 | 15 | 15 | 2009-2014 | EDL | - | Planned | Northern |
| 21 | Hinheup | Luangprabang 2 | 230 | 2 | 1x630 | 210 | 420 | 2009-2014 | EDL | Exim Bank China | Constuction | Northern |
| 22 | Nam Khan 2 | Luangprabang 2 | 115 | 2 | 1x450 | 36 | 72 | 2011-2014 | EDL | Exim bank China | Constuction | Northern |
| 23 | Nam tha 1 | Nam Thoung | 115 | 2 | 1X300 | 42 | 84 | 2009-2014 | EDL | CSG | Planned | Northern |
| 24 | Nam Thoung | Houayxay | 115 | 2 | 1x450 | 40 | 80 | 2009-2014 | EDL | EDL | Planned | Northern |
| 25 | Nam Boun 2 | Boun Neua | 22 | 2 | 1X150 | 45 | 90 | 2011-2014 | EDL | - | Planned | Northern |
| 26 | Viengphouka Lignite | Luangnamtha 2 | 230 | 2 | 1X630 | 9 | 17 | 2011-2014 | EDL | - | Planned | Northern |
| 27 | Houayxay | Xieng Khong | 115 | 1 | 1x185 | 16 | 16 | 2010-2014 | EDL | - | Planned | Northern |
| 28 | Luangnamtha 2 | M. Houn | 230 | 2 | 2x630 | 96 | 192 | 2010-2014 | EDL | - | Planned | Northern |
| 29 | Thavieng | Tha Bok | 230 | 2 | 4x630 | 120 | 240 | 2010-2014 | EDL | - | Planned | Northern |
| 30 | Ton phueng | Houayxay | 115 | 2 | 1X240 | 62 | 124 | 2010-2014 | EDL | PEA & EDL | Planned | Northern |
| 31 | M. Houn | Luangprabang 2 | 230 | 2 | 2x630 | 80 | 160 | 2010-2014 | EDL | - | Planned | Northern |
| 32 | Nam Ngiew | Thavieng | 115 | 1 | 1X150 | 14 | 14 | 2011-2014 | IPP(d) |  | MOU EDL Share Holder | Northern |
| 33 | Nam Beng | M. Houn | 115 | 1 | 1X240 | 35 | 35 | 2011-2014 | IPP(d) | China | Planned | Northern |
| 34 | Nam Pot | Thavieng | 115 | 1 | 1X150 | 10 | 10 | 2011-2014 | IPP(d) | Lao Company | Planned | Northern |
| 35 | Nam Ken | Nam Sana | 22 | 1 | 1X150 | 16 | 16 | 2011-2014 | IPP(d) | - | Planned | Northern |
| 36 | Hongsa Lignite | Luangprabang 2 | 115 | 2 | 1X300 | 105 | 210 | 2010-2014 | IPP(d) | Banpu | Planned | Northern |
| 37 | Luangnamtha 1 | Nam Thoung | 115 | 2 | 1x240 | 91 | 182 | 2009-2015 | EDL | Kuwate | Loan | Northern |
| 38 | Na Mo | Luangnamtha 1 | 115 | 1 | 1x240 | 43 | 43 | 2009-2015 | EDL | Kuwate | Loan | Northern |
| 39 | Na Mo | Boun Neua | 115 | 1 | 1x240 | 98 | 98 | 2014-2015 | EDL | - | Planned | Northern |
| 40 | Nam Chien | Thavieng | 115 | 2 | 1X240 | 35 | 70 | 2012-2015 | EDL | - | Planned | Northern |
| 41 | Nam Phak | Na Mo | 115 | 1 | 1X240 | 29 | 29 | 2012-2015 | EDL | - | Planned | Northern |
| 42 | Luangprabang 2 | Nam Ngum 4 | 230 | 2 | 4x630 | 95 | 190 | 2012-2015 | EDL | - | Planned | Northern |
| 43 | Nam Ngum 4 | Thavieng | 230 | 2 | 4x630 | 56 | 112 | 2012-2015 | EDL | - | Planned | Northern |
| 44 | Nam Ou 6 | Boun Neua | 115 | 2 | 1X240 | 45 | 90 | 2012-2015 | IPP(d) | - | Planned | Northern |
| 45 | Nam Ngeip 2 | Thavieng | 230 | 2 | 1X630 | 19 | 37 | 2012-2015 | IPP(d) | - | Planned | Northern |
| 46 | Nam Pha | Luangnamtha 2 | 115 | 2 | 1X410 | 50 | 100 | 2012-2015 | IPP(d) | - | Planned | Northern |
| 47 | Nam Khan 3 | Nam Khan 2 | 115 | 2 | 1x150 | 45 | 90 | 2013-2016 | EDL | Exim bank China | Planned | Northern |
| 48 | Nam Xam1 | Xam Nuea 1 | 115 | 1 | 1x240 | 24 | 24 | 2013-2016 | IPP(e) | - | Planned | Northern |
| 49 | Luangprabang 2 | Sayabouly | 115 | 1 | 1X240 | 76 | 76 | 2014-2017 | EDL | - | Planned | Northern |
| 50 | Mekong Luangprabang | Sensouk | 115 | 2 | 1X410 | 16 | 32 | 2014-2017 | IPP(e) | - | Planned | Northern |
| 51 | Mekong Sayaboury | Sayabouly | 115 | 2 | 1X240 | 21 | 42 | 2014-2017 | IPP(e) | - | Planned | Northern |
| 52 | Nam San 3 (Down) | Thavieng | 115 | 1 | 1X240 | 16 | 16 | 2015-2018 | IPP(d) | - | Planned | Northern |
| 53 | Mekong Pakbeng | M. Houn | 115 | 2 | 1x410 | 43 | 86 | 2015-2019 | IPP(e) | - | Planned | Northern |
| 54 | Nam Ou 6 | Nam Ou 5 | 230 | 2 | 2x630 | 65 | 130 | 2010-2016 | IPP(d) | China | Planned | Northern |
| 55 | Nam Ou 5 | Nam Ou 2 | 230 | 2 | 4x630 | 198 | 396 | 2010-2016 | IPP(d) | China | Planned | Northern |
| 56 | Nam Ou 2 | Luangprabang 2 | 230 | 2 | 4x630 | 120 | 240 | 2012-2016 | IPP(d) | China | Planned | Northern |
| 57 | Nam Ou 6 | Nam Ou 7 | 230 | 2 | 1x630 | 55 | 110 | 2012-2018 | IPP(d) | China | Planned | Northern |

## Table 2-5 Plan of 115 kV and 230 kV Transmission Lines from 2010 to 2020 (Central)

| No | From | To | Voltage | No. of Circuits | Conductor | Length (km) | Circuit Length (km) | Year | Owner | Loan | status | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Pakxan | Thakhek | 115 | 2 | 1x240 | 198 | 396 | 2007-2011 | EDL | JBIC | Constuction | Central |
| 2 | Nam Song | Vangvieng | 22 | 1 | 1x150 | 28 | 28 | 2007-2011 | EDL | India+EDL | Constuction | Central |
| 3 | Hinheup | Naxaythong | 230 | 2 | 1x630 | 72 | 143 | 2007-2011 | EDL | CWE (China) | Constuction | Central |
| 4 | Naxaythong | Lukhin | 115 | 2 | 1x240 | 12 | 24 | 2009-2012 | EDL | Malaysia | Constuction | Central |
| 5 | Nam Gnuang 8 | Khonsong | 115 | 2 | 1X240 | 58 | 116 | 2009-2012 | EDL | THPC | Constuction | Central |
| 6 | Vangvieng | Hinheup | 115 | 1 | 1x240 | 41 | 41 | 2009-2012 | EDL | Exim Bank Malaysia | Constuction | Central |
| 7 | Nam Sana | Vangvieng | 22 | 2 | 1X150 | 40 | 80 | 2011-2013 | EDL | Kungthai Bank+EDL | Loan | Central |
| 8 | Phontong | Thanaleng | 115 | 1 | 1x240 | 18 | 18 | 2010-2013 | EDL | - | Planned | Central |
| 9 | Nam Ngum 1 | Naxaythong | 115 | 2 | 1x455 | 61 | 122 | 2011-2013 | EDL | - | Planned | Central |
| 10 | Naxaythong | Nabong 1 | 230 | 2 | 4x630 | 40 | 80 | 2009-2014 | EDL | - | Planned | Central |
| 11 | Ban Don | Non Hai | 115 | 1 | 1x240 | 54 | 54 | 2010-2014 | EDL | - | Planned | Central |
| 12 | Nam Lik 1 | Hinheup | 115 | 2 | 1X240 | 10 | 20 | 2011-2014 | IPP(d) | Thai | Planned | Central |
| 13 | Nam Mang 1 | Tha Bok | 115 | 1 | 1X240 | 12 | 12 | 2011-2014 | IPP(d) |  | Planned | Central |
| 14 | Khoksa at | Nabong 1 | 115 | 2 | 1x450 | 22 | 44 | 2010-2015 | EDL | - | Planned | Central |
| 15 | Tha Bok | Nabong 1 | 230 | 2 | 4x630 | 52 | 104 | 2010-2015 | EDL | - | Planned | Central |
| 16 | Nam Gnuang 8 | Kengseuaten | 115 | 1 | 1X240 | 20 | 20 | 2012-2015 | EDL | - | Planned | Central |
| 17 | Nabong 1 | Nong Khai 2 | 230 | 2 | 4x630 | 37 | 74 | 2010-2016 | EDL | - | Planned | Central |
| 18 | Nam Phai | Hinheup | 115 | 2 | 1X240 | 57 | 114 | 2012-2015 | IPP(d) | - | Planned | Central |
| 19 | Nam Bak | Tha Bok | 230 | 2 | 1X410 | 50 | 100 | 2012-2015 | IPP(d) | - | Planned | Central |
| 20 | Nam Theun 1 | Khonsong | 115 | 1 | 1X240 | 35 | 35 | 2014-2017 | IPP(d) | - | Planned | Central |
| 21 | Nam mouan | Thasala | 115 | 2 | 2X455 | 68 | 136 | 2014-2017 | IPP(d) | - | Planned | Central |
| 22 | Pakxan | Bung kan | 115 | 1 | 1x240 | 2 | 2 | 2015-2019 | EDL | - | Planned | Central |
| 23 | Nam Ngum (Down) | Nabong 1 | 115 | 2 | 1X240 | 18 | 36 | 2015-2018 | IPP(d) | - | Planned | Central |
| 24 | Nam Ngiep 1 | Pakxan | 115 | 1 | 1X240 | 35 | 35 | 2015-2018 | IPP(e) | - | Planned | Central |
| 25 | Nam Pouan | Thavieng | 115 | 2 | 1X240 | 38 | 76 | 2015-2019 | EDL | - | Planned | Central |

## Table 2-6 Plan of 115 kV and 230 kV Transmission Lines from 2010 to 2020 (South)

| No | From | To | Voltage | No. of Circuits | Conductor | Length (km) | Circuit Length (km) | Year | Owner | Loan | status | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bang Yo | Jiengxay-Pakxong | 115 | 2 | 1x240 | 10 | 20 | 2008-2010 | EDL | India | Contuction | Southern |
| 2 | Thakhek | Pakbo | 115 | 2 | 1x240 | 87 | 174 | 2007-2011 | EDL | JBIC | Contuction | Southern |
| 3 | Thakhek | Cement factory at Mahaxai | 115 | 1 | 1x240 | 27 | 27 | 2007-2011 | EDL | Malaysia | Contuction | Southern |
| 4 | Xeset 1 | Saravan | 115 | 2 | 1x240 | 25 | 50 | 2007-2011 | EDL | WB | Contuction | Southern |
| 5 | Xekaman 3 | Sekong | 115 | 1 | 1X240 | 100 | 100 | 2008-2011 | EDL | Kungthai Bank | Contuction | Southern |
| 6 | Mahaxai | Xepon Mining | 115 | 1 | 1x240 | 117 | 117 | 2008-2011 | IPP(d) | Sepon minning | Contuction | Southern |
| 7 | Tadsalen | M. Nong | 22 | 1 | 1X150 | 37 | 37 | 2008-2011 | IPP(d) | Exim Thai | Contuction | Southern |
| 8 | Saravan | Sekong | 115 | 2 | 1x450 | 50 | 100 | 2010-2012 | EDL | Kungthai Bank | Contuction | Southern |
| 9 | Hat Xan | Saphaothong | 115 | 2 | 1x240 | 51 | 102 | 2010-2013 | EDL | ADB + Viet | Planned | Southern |
| 10 | Xeset 3 | Pak Xong | 115 | 2 | 1x240 | 3 | 6 | 2011-2013 | EDL | China | Planned | Southern |
| 11 | Houaylamphan Gnai | Sekong | 115 | 2 | 1x240 | 18 | 36 | 2011-2014 | EDL | Exim bank China | Planned | Southern |
| 12 | Sirinthorn | Bang yo | 115 | 1 | 1x240 | 61 | 61 | 2010-2014 | EDL | - | Planned | Southern |
| 13 | Taothan | Saravan | 115 | 2 | 1x240 | 65 | 130 | 2008-2014 | EDL | JBIC | Planned | Southern |
| 14 | Kengkok | Taothan | 115 | 2 | 1x240 | 115 | 230 | 2008-2014 | EDL | JBIC | Planned | Southern |
| 15 | Pakbo | Ban Lao Suliya | 115 | 2 | 1x450 | 48 | 96 | 2010-2014 | EDL | - | Planned | Southern |
| 16 | Ban Hat | Stungtreng | 230 | 2 | 1x630 | 112 | 224 | 2010-2014 | EDL | - | Planned | Southern |
| 17 | HouayChampi | Salabam | 22 | 1 | 1X150 | 38 | 38 | 2011-2014 | IPP(d) | Lao Company | Planned | Southern |
| 18 | Saravan | Ban Hat | 230 | 2 | 2x630 | 315 | 630 | 2011-2015 | EDL | - | Planned | Southern |
| 19 | Pakbo | Mukdahan | 115 | 1 | 1x240 | 14 | 14 | 2014-2015 | EDL | - | Planned | Southern |
| 20 | Ban Lao Suliya | Saravan | 230 | 2 | 4x630 | 170 | 340 | 2013-2015 | EDL | - | Planned | Southern |
| 21 | Ban Lao Suliya | M. Phin | 115 | 2 | 1x240 | 140 | 280 | 2013-2015 | EDL | - | Planned | Southern |
| 22 | M. Phin | Sepon Mining | 115 | 2 | 1x240 | 56 | 112 | 2013-2015 | EDL | - | Planned | Southern |
| 23 | Nam Hinboun 1 | Khonsong | 115 | 1 | 1X240 | 15 | 15 | 2012-2015 | EDL | - | Planned | Southern |
| 24 | M. Phin | M. Nong | 115 | 2 | 1x240 | 89 | 178 | 2013-2015 | EDL | - | Planned | Southern |
| 25 | Xeset 3 | Xeset 4 | 115 | 1 | 1x150 | 8 | 8 | 2012-2015 | EDL | - | Planned | Southern |
| 26 | Sepon 3 (Up) | Sepon 3 (Down) | 115 | 1 | 1X240 | 6 | 6 | 2012-2015 | IPP(d) | - | Planned | Southern |
| 27 | Sepon 3 (Up) | M. Nong | 115 | 2 | 1X240 | 49 | 98 | 2012-2015 | IPP(d) | - | Planned | Southern |
| 28 | M. Kalum | Saravan | 230 | 2 | 1X630 | 46 | 92 | 2012-2015 | IPP(d) | - | Planned | Southern |
| 29 | Mekong Tha kho | Tha kho T-Off | 230 | 1 | 1x150 | 2 | 2 | 2012-2015 | IPP(d) | - | Planned | Southern |
| 30 | Thavieng | Thasala | 230 | 2 | 4x630 | 172 | 344 | 2013-2016 | EDL | - | Planned | Southern |
| 31 | Thasala | Mahaxai | 230 | 2 | 4x630 | 110 | 220 | 2013-2016 | EDL | - | Planned | Southern |
| 32 | Mahaxai | Ban Lao Suliya | 230 | 2 | 4x630 | 100 | 200 | 2013-2016 | EDL | - | Planned | Southern |
| 33 | Xekatam | Pak Xong | 115 | 2 | 1X240 | 35 | 70 | 2013-2016 | IPP(d) | - | Planned | Southern |
| 34 | Sekong 4 | Sekong | 115 | 2 | 1X240 | 25 | 50 | 2013-2016 | IPP(e) | Russia | Planned | Southern |
| 35 | Pak Xong | Ban Jiengxai | 115 | 1 | 1X240 | 45 | 45 | 2014-2017 | EDL | - | Planned | Southern |
| 36 | Nam Phak/Houaykatam | Pak Xong | 115 | 2 | 1X450 | 26 | 52 | 2014-2017 | IPP(d) | - | Planned | Southern |
| 37 | Mekong Donsahong | Thakho T-Off | 230 | 2 | 1X630 | 4 | 8 | 2014-2017 | IPP(d) | - | Planned | Southern |
| 38 | Xelanong 1 | M. Nong | 115 | 2 | 1X240 | 16 | 32 | 2015-2018 | IPP(d) | Norway | Planned | Southern |
| 39 | Xeneua | Sepon Mining | 115 | 1 | 1X240 | 60 | 60 | 2015-2018 | IPP(d) | - | Planned | Southern |
| 40 | Xelanong 2 | Saravan | 115 | 2 | 1X240 | 88 | 176 | 2015-2018 | IPP(d) | - | Planned | Southern |
| 41 | Xelanong 2 | Sepon 3 (Up) | 115 | 2 | 1X240 | 50 | 100 | 2015-2018 | IPP(d) | - | Planned | Southern |
| 42 | Xedon 2 | Saravan | 115 | 1 | 1X240 | 41 | 41 | 2015-2018 | IPP(d) | - | Planned | Southern |
| 43 | Nam Kong 2 | Nam Kong 3 | 115 | 2 | 1x240 | 10 | 20 | 2015-2019 | IPP(d) | - | Planned | Southern |
| 44 | Xebanghieng 1 | Ban Lao Suliya | 115 | 2 | 1X240 | 65 | 130 | 2015-2019 | IPP(d) | - | Planned | Southern |
| 45 | Nam Kong 3 | Saphaothong | 115 | 2 | 1x240 | 26 | 52 | 2015-2019 | IPP(d) | - | Planned | Southern |

## Table 2-7 Plan of 500 kV Transmission Lines from 2010 to 2020

| No | From | To | Voltage | No. of Circuits | Conductor | Length (km) | Circuit Length (km) | Year | Owner | Loan | status |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Nabong | Udon | 500 | 2 | 4x630 | 27 | 54 | 2000-2010 | Nam Ngum 2 | ADB+Nam Ngum 2 | Competed 100% |
| 2 | Hongsa | Mae Moh | 500 | 2 | 4x630 | 24 | 48 | 2000-2015 | EDL | | Planned |
| 3 | Ban Hat | Xan Pei Ku | 500 | 2 | 4x630 | 40 | 80 | 2006-2016 | EDL | ADB+Vietnam | Study |
| 4 | Luangprabang | Hongsa | 500 | 2 | 4x630 | 100 | 200 | 2011-2020 | EDL | | Planned |
| 5 | Hongsa | Sayabyry | 500 | 2 | 4x630 | 76 | 152 | 2011-2020 | EDL | | Planned |
| 6 | Sayabury | Paklay | 500 | 2 | 4x630 | 122 | 244 | 2011-2020 | EDL | | Planned |
| 7 | Paklay | Khon Ken | 500 | 2 | 4x630 | 48 | 96 | 2011-2020 | EDL | | Planned |
| 8 | Nabong | Namtheun 2 | 500 | 2 | 4x630 | 280 | 560 | 2011-2020 | EDL | | Planned |
| 9 | Namtheun 2 | Hating | 500 | 2 | 4x630 | 58 | 116 | 2011-2020 | EDL | | Planned |
| 10 | Savannaket | Ban Lak 25 | 500 | 2 | 4x630 | 252 | 504 | 2011-2020 | EDL | | Planned |
| 11 | Ban Lak 25 | Xepieng-Xenamnoy | 500 | 2 | 4x630 | 100 | 200 | 2011-2020 | EDL | | Planned |
| 12 | Ban Lak 25 | Ubon | 500 | 2 | 4x630 | 53 | 106 | 2011-2020 | EDL | | Planned |
| 13 | Xepieng-Xenamnoy | Ban Hat Xan | 500 | 2 | 4x630 | 34 | 68 | 2011-2020 | EDL | | Planned |
| 14 | Luangprabang | Xam Neua | 500 | 2 | 4x630 | 207 | 414 | 2011-2025 | EDL | | Planned |
| 15 | Xam Neua | Vietnam | 500 | 2 | 4x630 | 40 | 80 | 2011-2025 | EDL | | Planned |
| 16 | Paklay | Nabong | 500 | 2 | 4x630 | 151 | 302 | 2011-2025 | EDL | | Planned |

**Table 2-8 Plan of 500 kV Substations**

| No | Name | Year | Owner | Status |
|---|---|---|---|---|
| 1 | Nabong | 2006-2016 | Nam Ngum 2 | Completed 30% |
| 2 | Xam Neua | 2015-2017 | EDL | Planned |
| 3 | Ban Lak 25 | 2015-2018 | EDL | Planned |
| 4 | Hat Xan | 2015-2018 | EDL | Planned |
| 5 | Xepieng-Xenamnoy | 2015-2018 | EDL | Planned |

## 2.4 Power System Analysis

EDL carries out the study of power flow of the system planned in PDP based on the N-1 criteria using the PSS/E software (Power System Simulation for Engineering).

# Chapter 3 Support from Other Donors

Regarding the official development assistance in the development of the 115 kV transmission lines in Lao PDR, the World Bank mainly assists related projects in the country's southern region, while the Asian Development Bank assists those in the northern region. Considering that the Japanese Government mainly assists in projects in the central region and backbone transmission line projects, the development of the 115 kV network was conducted efficiently in Lao PDR. However, Thailand and China were developing positive support recently, thus the grasp concerning the trend of support is important. The trend of a project to especially be taken into consideration is described below at the time of the transmission line project between Pakbo S/S and Saravan S/S.

## 3.1 Plan of 230 kV Transmission Line Project between Seno S/S and Saravan S/S

There is the plan of the 230 kV transmission line project between Seno S/S and Saravan S/S. The outline is shown below.

- ❖ Donor :China
- ❖ Section : About 215km from Seno S/S to Saravan S/S
- ❖ Situation : MOU conclusion of the feasibility study
- ❖ Construction cost : About 162 million USD

China and EDL concluded the MOU of the feasibility study of a 230 kV transmission line project between Seno S/S and Saravan S/S, and have started investigation. Although there is no telling whether the project starts or not, the construction costs for the transmission line and substation seems to be about 162 million USD. However, it is a mountainous area and it seems that it will become over 162 million USD, if the UXO exclusion is taken into consideration.

## 3.2 Support by Other Donors

### (5) Plan of Nongdeun S/S Project

There is a plan for the Nongdeun S/S construction project to supply SEZ, which is located in SEZ No.359-360. (approx. 5km from Pakbo S/S) The outline is shown below.

- ❖ Donor : Thailand
- ❖ Capacity : 50 MVA and 30 MVA
- ❖ Situation : This term groundbreaking schedule

The design has completed Nongdeun S/S by A Engineering Construction and Supply Co., Ltd of Thailand. Construction work will be started this year and completion is planned for 2012 in

12 months. The loan agreement has also been completed and the related papers have been prepared. However, the Nongdeun S/S planned construction site is not developed at all. Figure 3-1 shows that site on June 20, 2011.

The EPC contract of the Nongdeun S/S is signed between EDL and a engineering construction and supply Co., Ltd of Thailand in July 26, 2011.



**Figure 3-1 Nongdeun S/S planned Construction Site**

### (6) Plan of 115kV Transmission Line Project between Nongdeun S/S and Seno S/S and M.Phin

Moreover, there is a plan for a 115 kV transmission line project between Nongdeun S/S and Seno S/S and M.Phin S/S. The outline is shown below.

- ❖ Donor : China
- ❖ Section : From Nongdeun S/S to Seno S/S to M.Phin S/S
- ❖ Situation : The land of Seno S/S and M.Phin S/S has been acquired

### (7) Plan of 230 kV Transmission Line Project between Cambodia and Laos(Ban Hat and Stung Treng)

There is no description of a System Interconnection with the neighboring country in PDP2010-2020 of EDL. However, there are plans to affect the supply-demand balance of the southern system and northern-central part.

As a plan to affect the southern supply-demand balance, there is a plan for a 230kV transmission line project between Cambodia and Laos (Ban Hat and Stung treng) by the World Bank. The plan will go into commercial operations in 2013 and 200 MW is planned to be transmitted to Cambodia from Laos. Now, the consultant selection of Laos is just going to be started in the Laos side. However, the World Bank has decided that Cambodia is an unqualified loan recipient, thus the plan on the Cambodian side has been discontinued.

- ❖ Donor : World Bank
- ❖ Section : From Ban Hat to Stung treng
- ❖ Situation : Under consultant selection in Laos side and under discontinuation in Cambodia side

### (8) Plan of 230 kV Transmission Line Project between China and Laos (Yunnan and Luangprabang)

According to PDP2010-2020 of EDL, the lack of power supply happens in the northern-central system till 2018. Thus, it is necessary to import power from the neighboring country.

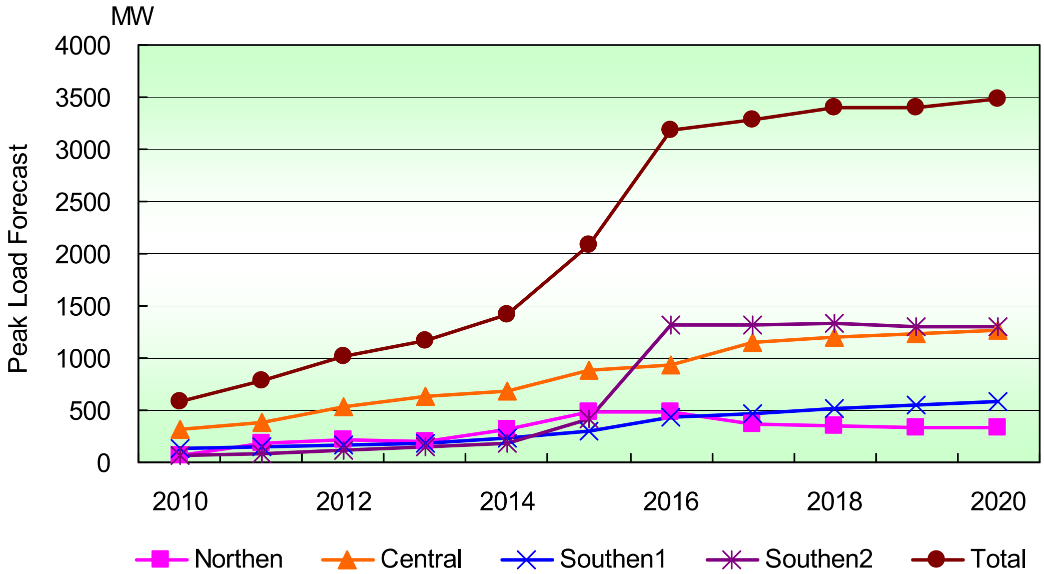
There is a plan for a 230 kV transmission line project between China and Laos as one of the important measures. 230 kV double circuits construction is planned from Yunnan to Luangprabang. According to EDL, the China side is under construction. (As of June, 2011) "

- ❖ Donor : China
- ❖ Section : From Yunnan to Luangprabang
- ❖ Situation :Under construction on the China side

# Chapter 4 Power Demand Forecast

## 4.1 Confirmation of Power Demand Forecast

Figure 4-1 shows the latest demand forecast in PDP2010-2020 which is under creation .It is estimated that the peak demand will grow to about 3,488 MW, which is about 10 times more than the 350 MW recorded in 2006. The growth rates during the period 2014-2016, 2010-2016 and 2010-2020 are 50%, 33% and 21% respectively. The reason why the growth rate of the first 6 years is the highest is that this forecast takes into account many specific loads by newly developed industries such as mining companies and special economic zones.




(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

**Figure 4-1 Peak Load**

**Table 4-1 Power Demand Forecast by EDL**

| Description | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy Demand (GWh) | 2,548 | 3,645 | 4,943 | 5,721 | 7,101 | 10,989 | 18,624 | 19,052 | 19,640 | 19,696 | 20,216 |
| System Losses (%) | 14% | 14% | 13% | 13% | 12% | 12% | 11% | 11% | 11% | 11% | 11% |
| Energy Demand (GWh) (Including System Losses) | 2,967 | 4,219 | 5,675 | 6,553 | 8,097 | 12,468 | 21,003 | 21,448 | 22,099 | 22,128 | 22,679 |
| Peak Load (MW) | 584 | 786 | 1,021 | 1,165 | 1,419 | 2,083 | 3,180 | 3,290 | 3,401 | 3,403 | 3,488 |
| Load Factor (%) | 58% | 61% | 63% | 64% | 65% | 68% | 75% | 74% | 74% | 74% | 74% |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

The EDL is analyzing four cases of the supply-demand balance. The difference in each case is based on the existence of the SLACO demand, and the existence of each plant of M Kaleum, Xekong 4 & 5, Nam Khon 1 and DonSahong-Thakho (Mekong). Xekong 4 & 5 and Nam Khon 1 shown in Table 5-2. Table 4-2 shows the classification of each case. Figure 4-2 to Figure 4-5 shows the supply-demand balance in the rainy season of each case.

**Table 4-2 Classification of Each Case**

| Case | M Kaleum | Xekong 4 & 5<br>Nam Khon 1 | DonSahong<br>Thakho<br>(Mekong) | SLACO |
|---|---|---|---|---|
| Case G1 | ✔ | | ✔ | |
| Case G2 | | ✔ | ✔ | ✔ |
| Case G3 | ✔ | ✔ | ✔ | ✔ |
| Case G4 | | | | ✔ |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

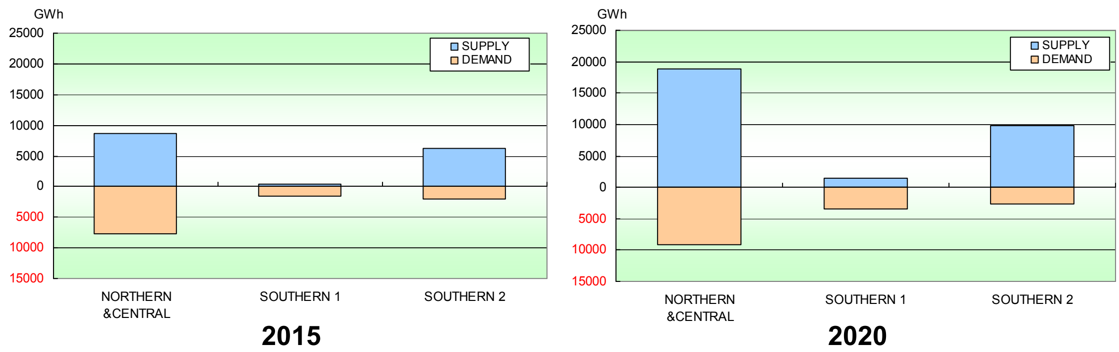



**Figure 4-2 Supply-Demand Balance（Case G1）**

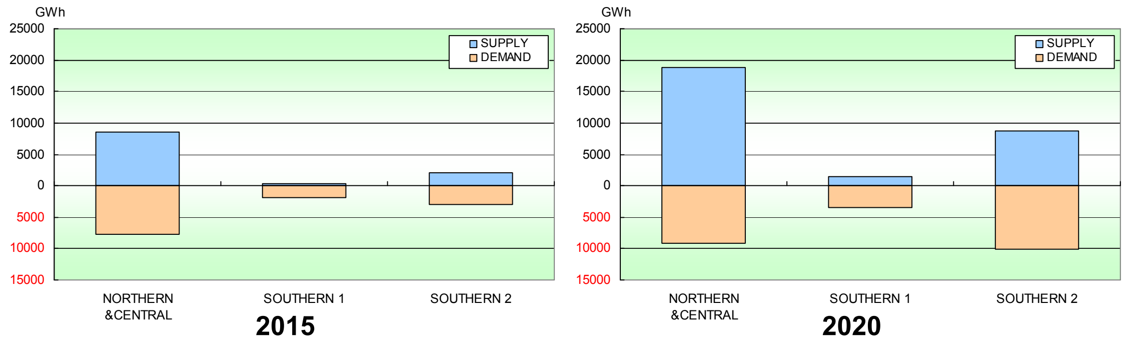



**Figure 4-3 Supply-Demand Balance（Case G2）**

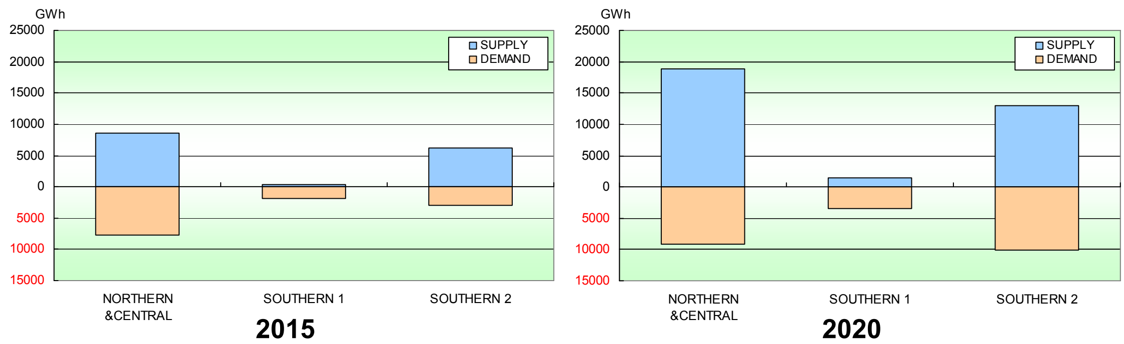
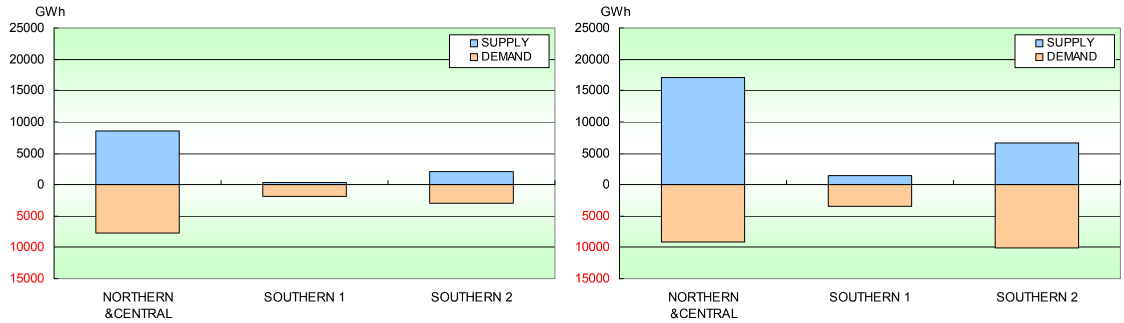



**Figure 4-4 Supply-Demand Balance（Case G3）**




**2015** **2020**

**Figure 4-5 Supply-Demand Balance（Case G4）**

The supply-demand balance of the South 1 is bad in all the cases, and it turns out that in the cases G2 and G4 without M Kaleum, there is no margin in the supply power also in the South 2. Table 4-3 shows the details of the supply-demand balance of the South 1 and 2.

**Table 4-3 Detailed Supply-Demand Balance of the South 1 and 2**

| M Kaleum | Region | | Item | 2015 | 2020 |
|---|---|---|---|---|---|
| Existing | S1 | | Generation Capacity (MW) | 86 | 339 |
| | | | Power Demand (MW) | 364 | 558 |
| | | | **Balance (MW)** | **-278** | **-219** |
| | S2 | No SLACO | Generation Capacity (MW) | 1079 | 1544 |
| | | | Power Demand (MW) | 316 | 399 |
| | | | **Balance (MW)** | **763** | **1145** |
| | | SLACO | Generation Capacity (MW) | 1079 | 2109 |
| | | | Power Demand (MW) | 416 | 1299 |
| | | | **Balance (MW)** | **663** | **810** |
| No | S1 | | Generation Capacity (MW) | 86 | 339 |
| | | | Power Demand (MW) | 364 | 558 |
| | | | **Balance (MW)** | **-278** | **-219** |
| | S2 | No SLACO | Generation Capacity (MW) | 479 | 704 |
| | | | Power Demand (MW) | 316 | 399 |
| | | | **Balance (MW)** | **163** | **305** |
| | | SLACO | Generation Capacity (MW) | 479 | 1269 |
| | | | Power Demand (MW) | 416 | 1299 |
| | | | **Balance (MW)** | **63** | **-30** |

Note) S1:Khammouan, Savannakhet

S2:Champasak, Saravan, Attapeu

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

## 4.2 Plan of Southern Mine Development

Table 4-4 shows the demand forecast about the southern part mining development which EDL made. The demand is quickly developed from 2015 and the peak is reached mostly in 2016. However, there are many indefinite elements in development.

**Table 4-4 Demand Forecast of Mining Development in Southern Area**

(Unit: MW)

| Province | Substation | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHAMPASAK | Aluminium at Paksong District(SLACO)for the entire mine | 0 | 0 | 7.5 | 15 | 30 | 100 | 100 | 100 | 100 | 100 | 100 |
| ATTAPEU | Aluminium at Sanamxai District(SLACO) for Alumina refinery | 0 | 0 | 0 | 0 | 0 | 100 | 900 | 900 | 900 | 900 | 900 |
| | Total | 0 | 0 | 7.5 | 15 | 30 | 200 | 1000 | 1000 | 1000 | 1000 | 1000 |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

According to the information from EDL, the following demand by the southern part mining development has been planned.

**Table 4-5 Planed Mining Development in Southern Area**

| Mine | Province | Capacity (MW) | Energy (GWh) | Load Factor (%) | Start Operation |
|---|---|---|---|---|---|
| Jiaxi Mining | Khammouane | 22 | 124 | 64 | 2015 |
| Metal Melting | Khammouane | 20 | 113.2 | 65 | 2016 |
| Xepon Gold/Cupper Ext. | Savanakhet | 30.5 | 225.3 | 84 | 2016 |
| SLACO at Paksong | Champasak | 100 | 744.6 | 85 | 2012 |
| SINOMA Aluminium | Champasak | 8 | 30.7 | 44 | 2012 |
| SINOMA Almina Refinery | Champasak | 20 | 145 | 83 | 2012 |
| Aluminium | Xekong | 40 | 245.3 | 70 | 2016 |
| Gold/Copper Mining | Attapeu | 50 | 350 | 80 | 2016 |
| SLACO Almina Refinery | Attapeu | 900 | 6701.4 | 85 | 2016 |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

72.5 MW additional demand by the southern part mining development is planned by 2016 in southern Khammouane and Savanakhet. And 1,118 MW of additional demand by the southern part mining development is planned from 2012 to 2016 in Champasak, Xekong, and Attapeu.

These mining demands have a high load factor, and constant supply is needed over the years. The mining developments submit to supply power. Especially the SLACO aluminum refining plant which is planned to be built in Attapeu, since 2/3 of the whole Laos demand is consumed only by this consumer, the influence of the power system plan is serious. According to DOE and EDL, the key to building the SLACO aluminum refining plant is low electric power prices, thus there is no telling whether the plan will be started or not. An analyzing scenario has set two cases which are with the SLACO demand or not because of this uncertain state.

## 4.3 Special Economic Zone (SEZ)

Many developing projects are planned in SEZ. Table 4-6 shows the demand forecast of the large scale developing projects.

**Table 4-6 Demand Forecast of Large Scale Developing Projects**

(Unit: MW)

| Name of Site | Category | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Savan City | Commercial | 0.00 | 1.00 | 2.32 | 3.98 | 6.31 | 9.63 | 13.61 | 17.93 | 22.58 | 27.56 | 33.20 |
| Logistic Park | Service | 0.00 | 0.11 | 0.26 | 0.44 | 0.70 | 1.07 | 1.51 | 1.99 | 2.51 | 3.06 | 3.69 |
| Savan Park | Industrial | 4.47 | 10.57 | 17.98 | 25.38 | 31.38 | 37.30 | 44.37 | 50.09 | 54.79 | 55.44 | 56.09 |
| Chansanh | Household | 0.00 | 0.06 | 0.13 | 0.22 | 0.35 | 0.53 | 0.75 | 0.99 | 1.25 | 1.53 | 1.84 |
| EPZ | Industrial | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.38 | 20.63 | 32.81 | 56.25 | 75.00 | 93.75 |
| | Total | 4.47 | 11.74 | 20.69 | 30.03 | 38.74 | 57.91 | 80.86 | 103.81 | 137.38 | 162.59 | 188.57 |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

Transtech Engineering Co. which is a Chinese building constructor is developing in Savan Park. A lot will be concluded with an acquisition. The construction of Nongdeun S/S is planned via internal 360 partition of this industrial complex for the power supply to SEZ. Table 4-7 shows the demand forecast of the Nongdeun S/S which EDL made. It is planned to start operations in 2012 and peak in two years mostly. However, in June 20, 2011, the developing situation of SEZ was almost the same as two years before as is shown in Figure 4-6 taken on June 20, 2011, and there are a few factories in SEZ. The power demand submits to the progress of welcome enterprises.

**Table 4-7 Demand Forecast of Nongdeun S/S**

(Unit: MW)

| Substation | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nongdeun | 0 | 0 | 10 | 53 | 133 | 111 | 111 | 111 | 121 | 121 | 121 |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

**Figure 4-6 Savan Park**

## 4.4 Power Demand Forecast of Each Substation

The results of the demand forecast of each substation in the whole country are described in this section.

### 4.4.1 Actual Power Demand Record of Each Substation

Table 4-8 shows the actual peak power demand of each substation in 2010.

**Table 4-8 Peak Power Demand of Each Substation in 2010**

| No | Substation | Province | Operation | MW |
|---|---|---|---|---|
| 1 | Luangnamtha 1 SS | Luangnamtha | 2009 | 6.4 |
| 2 | Oudomxay SS | Oudomxai | 2009 | 5.1 |
| 3 | Phonsvan SS | Xieng Khuang | 2003 | 7.9 |
| 4 | Luangprabang 1 SS | Luang Prabang | 1994 | 17.3 |
| 5 | Pakmong SS | Luang Prabang | 2009 | 3.8 |
| 6 | Sayaboury SS | Xayabuly | 2003 | 6.5 |
| 7 | Vangvieng SS | Vietiane Province | 1994 | 15.9 |
| 8 | Phonsoung SS | Vietiane Province | 1990 | 10.7 |
| 9 | Ban Don SS | Vietiane Province | 2003 | 2.8 |
| 10 | Non Hai SS | Vietiane Province | 2003 | 5.2 |
| 11 | Thalat SS | Vietiane Province | 2006 | 8.4 |
| 12 | Phontong SS | Vientiane Capital | 1968 | 100.5 |
| 13 | Thanaleng SS | Vientiane Capital | 1977 | 52.5 |
| 14 | Tha Ngon SS | Vientiane Capital | 1989 | 20.6 |
| 15 | Khok sa at SS | Vientiane Capital | 2004 | 32.0 |
| 16 | Naxaythong SS | Vientiane Capital | 2006 | 22.8 |
| 17 | Pakxan SS | Bolikhamxay | 2000 | 14.6 |
| 18 | Thakhek SS | Khammouan | 2003 | 24.0 |
| 19 | Mahaxai SS | Khammouan | 2009 | 5.4 |
| 20 | Nam Theun 2 SS | Khammouan | 2009 | 2.6 |
| 21 | Pakbo SS | Svannakhet | 1996 | 29.1 |
| 22 | Kengkhok SS | Svannakhet | 2004 | 15.7 |
| 23 | Saravan SS | Saravan | 2010 | 10.6 |
| 24 | Bang Yo SS | Champasak | 1991 | 29.7 |
| 25 | Ban Na SS | Champasak | 2005 | 6.6 |
| 26 | Ban Hat SS | Champasak | 2005 | 5.0 |
| 27 | Saphaothong SS | Attappeu | 2006 | 4.4 |
| | Total | | | 466.1 |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

### 4.4.2 Power Demand Forecast of Each Substation

Table 4-9 and Table 4-10 show the peak demand forecast of each substation from 2011 to 2020.

## Table 4-9 Power Demand Forecast of Each Substation

Unit: MW

| No | Name of Substations | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | PHONGSALI | 0.0 | 0.0 | 0.0 | 1.9 | 4.6 | 28.4 | 46.5 | 33.7 | 34.5 | 35.3 | 36.0 |
| | Boun Neua | | | | 1.9 | 2.3 | 2.6 | 2.9 | 3.4 | 4.0 | 4.5 | 5.0 |
| | Copper Mining 1at Yot Ou District | | | | | | 10.0 | 10.1 | 10.2 | 10.2 | 10.3 | 10.4 |
| | Copper Mining 2 at Yot Ou District | | | | | | | 20.0 | 20.2 | 20.3 | 20.5 | 20.6 |
| | Total Load during Construction of Hydro Power Plants | | | | | 2.3 | 15.8 | 13.5 | - | - | - | - |
| 2 | BOKEO | 0.0 | 0.0 | 0.0 | 9.2 | 9.4 | 29.4 | 29.8 | 30.1 | 30.7 | 31.1 | 31.7 |
| | Houayxay | | | | | 9.2 | 9.4 | 9.6 | 9.8 | 10.2 | 10.5 | 10.9 |
| | Dokngiewkham | | | | 0.2 | 0.2 | 20.0 | 20.2 | 20.3 | 20.5 | 20.6 | 20.8 |
| 3 | LUANGNAMTHA | 6.4 | 6.8 | 17.7 | 22.9 | 73.1 | 105.8 | 68.4 | 49.3 | 49.6 | 50.0 | 50.5 |
| | Luangnamtha 1 | 6.4 | 6.6 | 6.8 | 7.0 | 3.9 | 4.0 | 4.1 | 4.2 | 4.3 | 4.4 | 4.5 |
| | Copper Mining at Houay Mo, Long District | | | 10.0 | 10.1 | 10.2 | 10.2 | 10.3 | 10.4 | 10.5 | 10.6 | 10.7 |
| | Viengphoukha (Luangnamtha 2) | | | | | 3.3 | 3.4 | 3.5 | 3.7 | 3.8 | 4.0 | 4.3 |
| | Total Load during Construction of Hydro Power Plants | | 0.2 | 0.9 | 0.8 | 47.7 | 67.2 | 19.5 | | | | |
| | Economic Spacial Zone (Boten) | | | | 5.0 | 8.0 | 10.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| | Railway station | | | | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | Train running | | | | | | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| 4 | OUDOMXAI | 5.1 | 57.8 | 68.2 | 68.8 | 74.5 | 62.7 | 58.5 | 58.7 | 59.5 | 60.4 | 61.5 |
| | Oudomxay | 5.1 | 5.8 | 4.3 | 4.7 | 3.6 | 3.8 | 4.1 | 4.3 | 4.6 | 4.9 | 5.2 |
| | Iron melting factory at Phu Phan Village La District | | | | | | 10.0 | 10.1 | 10.2 | 10.2 | 10.3 | 10.4 |
| | Namo | | | 1.9 | 2.0 | 1.8 | 1.9 | 2.0 | 2.2 | 2.3 | 2.4 | 2.6 |
| | Cement Factory at Thong Na Village Namo District | | | 10.0 | 10.1 | 10.2 | 10.2 | 10.3 | 10.4 | 10.5 | 10.6 | 10.7 |
| | Copper Mining at Kiew Chep Village Namo District | | | | | | 20.0 | 20.2 | 20.3 | 20.5 | 20.6 | 20.8 |
| | Lead-Zinc Factory at Nam Pheng Village Namo District | | | | | | 5.0 | 5.0 | 5.1 | 5.1 | 5.2 | 5.2 |
| | Pakbeng | | | | | 1.8 | 1.9 | 2.0 | 2.2 | 2.3 | 2.4 | 2.6 |
| | Total Load during Construction of Hydro Power Plants | | | | | 5.1 | 5.9 | 0.8 | | | | |
| | Total Load during Construction of Railway | | 52.0 | 52.0 | 52.0 | 52.0 | | | | | | |
| | Railway station | | | | | | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5 | HUAPHANH | 0.0 | 0.0 | 5.6 | 7.6 | 8.4 | 7.8 | 17.5 | 18.1 | 9.6 | 10.2 | 10.8 |
| | Xam Neua 1 | | | 5.6 | 6.4 | 7.2 | 7.8 | 8.5 | 9.1 | 9.6 | 10.2 | 10.8 |
| | Total Load during Construction of Hydro Power Plants | | | | 1.2 | 1.2 | | 9.0 | 9.0 | | | |
| 6 | XIENG KHUANG | 7.9 | 26.7 | 27.2 | 9.8 | 16.3 | 109.0 | 103.8 | 32.4 | 33.0 | 33.7 | 34.6 |
| | Phonsvan | 7.9 | 8.7 | 6.0 | 6.4 | 6.7 | 5.5 | 6.4 | 6.6 | 6.9 | 7.2 | 7.6 |
| | Iron melting factory at Yot Pieng Village Pek District | | | | | | 10.0 | 10.1 | 10.2 | 10.2 | 10.3 | 10.4 |
| | M Kham | | | 3.2 | 3.4 | 3.6 | 3.3 | 3.5 | 3.6 | 3.8 | 3.9 | 4.1 |
| | Iron melting factory at Yot Pieng Village Pek District Khoun District | | | | | | 10.0 | 10.1 | 10.2 | 10.2 | 10.3 | 10.4 |
| | Thavieng | | | | | | 2.2 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 |
| | Total Load during Construction of Hydro Power Plants | | 18.0 | 18.0 | | 6.0 | 78.0 | 72.0 | | | | |
| 7 | LUANG PRABANG | 21.1 | 68.5 | 69.4 | 71.3 | 115.3 | 98.7 | 87.8 | 69.8 | 64.3 | 43.5 | 45.2 |
| | Luangprabang 1 | 17.3 | 18.0 | 17.0 | 16.5 | 12.3 | 12.8 | 13.3 | 13.9 | 14.7 | 15.5 | 16.3 |
| | Pakmong | 3.8 | 3.9 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.1 | 3.3 |
| | Cement factory at Many Village Nambak District | | 7.0 | 7.1 | 7.1 | 7.2 | 7.2 | 7.3 | 7.3 | 7.4 | 7.5 | 7.5 |
| | Sansouk | | | 3.4 | 4.7 | 4.9 | 5.1 | 5.3 | 5.6 | 5.9 | 6.2 | 6.5 |
| | Gold Mining at Phapon Village Pak Ou District | | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| | Luangprabang 2 | | | | | 4.9 | 5.1 | 5.3 | 5.6 | 5.9 | 6.2 | 6.5 |
| | Total Load during Construction of Hydro Power Plants | | | | | 42.9 | 60.9 | 48.9 | 29.6 | 22.5 | | |
| | Total Load during Construction of Railway | | 39.6 | 39.6 | 39.6 | 39.6 | | | | | | |
| | Railway station | | | | | | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 8 | XAYABULY | 6.5 | 6.9 | 7.4 | 8.4 | 17.2 | 37.8 | 73.8 | 69.3 | 70.9 | 63.8 | 65.7 |
| | Sayaboury | 6.5 | 6.9 | 7.4 | 7.9 | 10.0 | 10.7 | 9.4 | 10.0 | 10.7 | 11.4 | 12.2 |
| | Paklay | | | | | 6.7 | 7.1 | 6.0 | 6.4 | 6.8 | 7.3 | 7.8 |
| | Copper Mining at Pang Kham Paklay District | | | | | | 5.0 | 40.0 | 40.3 | 40.6 | 41.0 | 41.3 |
| | Hongsa | | | | | | | 3.4 | 3.6 | 3.8 | 4.1 | 4.4 |
| | Total Load during Construction of Hydro Power Plants | | | | 0.5 | 0.5 | 15.0 | 15.0 | 9.0 | 9.0 | | |
| | Total Northen Area Demand | 47.0 | 166.7 | 195.5 | 199.9 | 318.8 | 479.6 | 486.1 | 361.4 | 352.1 | 328.0 | 336.0 |
| 9 | VIETIANE PROVINCE | 75.0 | 105.0 | 178.5 | 215.0 | 260.4 | 432.1 | 461.9 | 625.5 | 603.9 | 621.8 | 631.3 |
| | Vangvieng | 15.9 | 16.9 | 18.0 | 19.2 | 20.5 | 22.0 | 23.6 | 25.4 | 27.7 | 30.4 | 33.4 |
| | Houaysai Gold/copper Mining Vangvieng District | | | 20.0 | 20.2 | 20.3 | 20.5 | 20.6 | 20.8 | | | |
| | Iron melting factory at Vangvieng District | | | | 12.0 | 12.1 | 12.2 | 12.3 | 12.4 | 12.5 | 12.6 | 12.7 |
| | Phonsoung | 10.7 | 11.4 | 10.7 | 11.4 | 12.2 | 13.1 | 14.0 | 15.1 | 16.5 | 18.1 | 19.9 |
| | Ban Don | 2.8 | 3.0 | 3.9 | 4.1 | 4.4 | 4.7 | 5.1 | 5.5 | 6.0 | 6.6 | 7.2 |
| | Gold/Copper Mining at Maipakphoun Village Sanakham District | | | | | | | 40.0 | 40.3 | 40.6 | 41.0 | 41.3 |
| | Non Hai | 5.2 | 5.5 | 4.9 | 5.2 | 5.5 | 5.9 | 6.4 | 6.9 | 7.5 | 8.2 | 9.0 |
| | Thalat | 8.4 | 8.9 | 9.7 | 10.4 | 11.1 | 11.9 | 12.7 | 13.7 | 15.0 | 16.4 | 18.1 |
| | Hinheup | | | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.1 | 2.2 | 2.5 | 2.7 |
| | Iron melting factory at Vangvieng District (sinhouang) | | | 30.0 | 50.0 | 50.0 | 200.0 | 200.0 | 390.0 | 390.0 | 390.0 | 390.0 |
| | Phubia Gold/copper Mining (Existing) | 32.0 | 33.0 | 43.0 | 43.3 | 43.7 | 44.0 | 44.4 | 44.7 | 45.1 | 45.5 | 45.8 |
| | Total Load during Construction of Hydro Power Plants | | 0.9 | 0.9 | 1.2 | 17.0 | 48.8 | 33.0 | | | 9.0 | 9.0 |
| | Thongkhoun 2 | | | 10.5 | 11.0 | 11.5 | 12.0 | 12.5 | 13.0 | 5.0 | 5.5 | 6.0 |
| | Iron mine at Nam chan Village (sinhouang) | | | | | 25.0 | 25.2 | 25.4 | 25.6 | 25.8 | 26.0 | 26.2 |
| | Total Load during Construction of Railway | | 25.4 | 25.4 | 25.4 | 25.4 | | | | | | |
| | Railway station | | | | | | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

## Table 4-10 Power Demand Forecast of Each Substation (Continued)

Unit: MW

| No | Name of Substations | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | VIENTIANE CAPITAL | 228.4 | 251.2 | 300.4 | 363.8 | 380.3 | 397.6 | 426.7 | 458.0 | 505.3 | 548.9 | 583.8 |
| | Phontong | 100.5 | 101.0 | 102.0 | 99.1 | 102.3 | 108.8 | 116.0 | 118.0 | 120.0 | 128.0 | 134.0 |
| | Gold Mining at Khok Pheung Village Sangthong District | | | 5.0 | 5.0 | 5.1 | 5.1 | 5.2 | 5.2 | 5.2 | 5.3 | 5.3 |
| | Thanaleng | 52.5 | 55.3 | 58.3 | 37.5 | 39.8 | 42.3 | 45.1 | 48.2 | 52.8 | 53.9 | 59.6 |
| | Tha Ngon | 20.6 | 21.6 | 22.8 | 21.4 | 22.7 | 24.2 | 25.8 | 27.6 | 30.2 | 33.2 | 36.7 |
| | Khok sa at | 32.0 | 33.6 | 35.5 | 34.8 | 36.9 | 39.3 | 41.9 | 44.8 | 49.0 | 53.9 | 59.6 |
| | Kea Potash Factory at Thongmang Village Saythany District | | 8.0 | 8.1 | 8.1 | 8.2 | 8.3 | 8.3 | 8.4 | 8.5 | 8.5 | 8.6 |
| | Japanese Industy Zone | | | | | | | 9.0 | 17.8 | 23.5 | 29.3 | 29.3 |
| | Naxaythong | 22.8 | 28.8 | 34.8 | 17.4 | 18.5 | 19.6 | 20.9 | 22.4 | 24.5 | 27.0 | 29.8 |
| | Pak Thang | | | | 13.4 | 14.2 | 15.1 | 16.1 | 17.2 | 18.9 | 20.7 | 22.9 |
| | Nong Viengkham | | | | 13.7 | 14.5 | 15.4 | 16.4 | 17.6 | 19.2 | 21.2 | 23.4 |
| | Don Koi | | | | 24.6 | 26.1 | 28.7 | 29.0 | 35.0 | 42.0 | 48.0 | 56.0 |
| | Na Bong 1 | | | | 5.9 | 9.1 | 8.8 | 11.0 | 13.8 | 20.5 | 28.9 | 36.6 |
| | Iron melting factory at Ban Hai Village (Tha Ngon) Xaythany District | | | 31.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 |
| | Load during railway construction /Railway station | | 2.9 | 2.9 | 2.9 | 2.9 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| | Total Load during Construction of Hydro Power Plants | | | | | | | | | 9.0 | 9.0 | |
| 11 | BOLIKHAMXAY | 14.6 | 15.7 | 29.9 | 31.0 | 30.9 | 39.5 | 53.7 | 72.6 | 82.6 | 62.5 | 58.8 |
| | Pakxan | 14.6 | 15.5 | 15.5 | 16.5 | 17.6 | 16.3 | 17.5 | 18.9 | 20.6 | 22.6 | 24.9 |
| | Tha Bok | | | | | | 3.8 | 4.0 | 4.4 | 4.8 | 5.2 | 5.7 |
| | Khonsong | | | 3.1 | 3.3 | 3.5 | 2.5 | 2.6 | 2.8 | 3.1 | 3.4 | 3.7 |
| | Metal Melting Factory at Nong Choon-Borneng Village Hinboon District | | | | | | | 20.0 | 20.2 | 20.3 | 20.5 | 20.6 |
| | Thasala | | | 2.1 | 2.2 | 2.3 | 2.6 | 2.8 | 3.0 | 3.3 | 3.6 | 3.9 |
| | Total Load during Construction of Hydro Power Plants | | 0.2 | 9.2 | 9.0 | 7.5 | 14.3 | 6.8 | 23.3 | 30.5 | 7.2 | |
| | Total Central Area Demand | 318.0 | 371.9 | 508.8 | 609.8 | 671.6 | 869.2 | 942.3 | 1156.1 | 1191.8 | 1233.2 | 1273.9 |
| 12 | KHAMMOUAN | 49.0 | 51.0 | 53.2 | 55.5 | 78.0 | 113.8 | 192.9 | 192.7 | 213.9 | 219.6 | 219.7 |
| | Thakhek | 24.0 | 25.5 | 27.1 | 27.3 | 29.1 | 31.1 | 33.2 | 35.6 | 38.9 | 42.6 | 46.6 |
| | Jiaxi Mining at Thakhek District | | | | | | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 |
| | Cement Factory at Nakham Village Thakhek District (Existing) | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.1 | 17.3 | 17.4 | 17.6 | 17.7 |
| | Cement Factory at Nakham Village Thakhek District (Phase2) | | | | | | | 43.0 | 43.3 | 43.7 | 44.0 | 44.4 |
| | Mahaxai | 5.4 | 5.8 | 5.8 | 6.2 | 6.6 | 7.0 | 7.5 | 8.0 | 8.8 | 9.6 | 10.5 |
| | Potassium at Yang Koung Village (Ngom Ma Lat) Thakhek District | | | | | 20.0 | 20.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |
| | Nam Theun 2 (Substation) | 2.6 | 2.7 | 3.3 | 5.0 | 5.3 | 5.7 | 6.1 | 6.5 | 7.1 | 7.8 | 8.5 |
| | Total Load during Construction of Hydro Power Plants | | | | | | 6.0 | 6.0 | | 6.0 | 6.0 | |
| | Economic Spacial Zone | | | | | | 5.0 | 8.0 | 10.0 | 20.0 | 20.0 | 20.0 |
| 13 | SVANNAKHET | 87.8 | 92.6 | 106.7 | 160.4 | 245.0 | 250.0 | 285.8 | 292.3 | 319.7 | 337.6 | 338.5 |
| | Pakbo | 29.1 | 31.6 | 34.3 | 44.0 | 47.0 | 46.9 | 50.1 | 53.6 | 58.2 | 63.3 | 68.8 |
| | Keng Kok | 15.7 | 17.0 | 18.4 | 19.9 | 21.5 | 12.0 | 12.9 | 14.0 | 15.4 | 16.9 | 18.6 |
| | Nongdeun | | | 10.0 | 53.0 | 133.0 | 111.0 | 111.0 | 111.0 | 121.0 | 121.0 | 121.0 |
| | Ban na (Seno) | | | | | | 31.3 | 32.0 | 32.9 | 34.0 | 35.1 | 36.4 |
| | Residential | | | | | | 9.3 | 10.0 | 10.9 | 12.0 | 13.1 | 14.4 |
| | SAZE | | | | | | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 |
| | M Phin | | | | | | 3.3 | 3.6 | 3.9 | 4.3 | 4.7 | 5.2 |
| | M Nong | | | | | | 2.0 | 2.2 | 2.3 | 2.6 | 2.8 | 3.1 |
| | Xepon Gold/Copper Minning at Vilabury District (Existing) | 43.0 | 43.5 | 43.5 | 43.5 | 43.5 | 43.5 | 74.0 | 74.6 | 75.2 | 75.8 | 76.4 |
| | Total Load during Construction of Hydro Power Plants | | 0.5 | 0.5 | | | | | | 9.0 | 18.0 | 9.0 |
| | Total Southen1 Area Demand | 136.8 | 143.6 | 159.9 | 215.9 | 323.0 | 363.8 | 478.7 | 485.0 | 533.6 | 557.2 | 558.2 |
| 14 | SARAVAN | 10.6 | 24.0 | 24.9 | 25.9 | 27.7 | 43.8 | 44.2 | 30.5 | 47.7 | 49.5 | 35.9 |
| | Saravan | 10.6 | 11.4 | 12.3 | 13.3 | 10.0 | 10.8 | 11.6 | 12.5 | 13.7 | 15.0 | 16.3 |
| | Cement Factory at Ta Leo Village Saravan District | | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 |
| | Taothan | | | | | 4.3 | 4.6 | 5.0 | 5.4 | 5.9 | 6.4 | 7.0 |
| | Total Load during Construction of Hydro Power Plants | | | | | 0.8 | 15.8 | 15.0 | | 15.5 | 15.5 | |
| 15 | SEKONG | 0.0 | 0.0 | 4.4 | 14.7 | 28.5 | 64.4 | 100.8 | 56.5 | 48.4 | 49.5 | 50.5 |
| | Sekong | | | 4.4 | 5.1 | 5.7 | 6.2 | 6.8 | 7.2 | 7.8 | 8.5 | 9.2 |
| | Aluminium at Daklan Village Dakjung District | | | | | | | 40.0 | 40.3 | 40.6 | 41.0 | 41.3 |
| | Total Load during Construction of Hydro Power Plants | | | | 9.6 | 22.8 | 58.2 | 54.0 | 9.0 | | | |
| 16 | CHAMPASAK | 41.3 | 44.1 | 82.7 | 98.1 | 117.5 | 200.4 | 216.0 | 267.9 | 274.9 | 227.7 | 235.1 |
| | Bang Yo | 29.7 | 27.4 | 29.3 | 31.3 | 33.5 | 35.9 | 38.5 | 41.4 | 45.2 | 49.4 | 54.0 |
| | Ban Na | 6.6 | 6.6 | 7.1 | 7.6 | 8.1 | 8.7 | 9.3 | 10.0 | 10.9 | 11.9 | 13.1 |
| | Ban Hat | 5.0 | 4.0 | 4.2 | 4.5 | 4.9 | 5.2 | 5.6 | 6.0 | 6.6 | 7.2 | 7.8 |
| | Pakxong | | 3.5 | 3.8 | 4.0 | 4.3 | 4.6 | 5.0 | 5.3 | 5.8 | 6.4 | 7.0 |
| | Aluminium at Paksong District(SLACO)for the entire mine | | | 7.5 | 15.0 | 30.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Aluminium at Paksong District(SINOMA) for the entire mine | | | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| | Aluminium at Paksong District(SINOMA) for Alumina refinery | | | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| | Ban Jiangxai | | 2.6 | 2.8 | 3.0 | 3.2 | 3.5 | 3.7 | 4.0 | 4.4 | 4.8 | 5.2 |
| | Total Load during Construction of Hydro Power Plants | | | | 4.7 | 5.5 | 9.5 | 17.9 | 63.2 | 54.0 | | |
| | Economic Spacial Zone (Bolaven plateau) | | | | | | 5.0 | 8.0 | 10.0 | 20.0 | 20.0 | 20.0 |
| 17 | ATTAPEU | 4.4 | 8.7 | 9.2 | 6.0 | 6.6 | 107.2 | 957.8 | 958.9 | 960.1 | 966.8 | 977.2 |
| | Saphaothong | 4.4 | 4.9 | 5.4 | 6.0 | 6.6 | 7.2 | 7.8 | 8.5 | 9.3 | 10.3 | 11.3 |
| | Gold/Copper Mining at Vangtun Village Xanxai District | | | | | | | 50.0 | 50.4 | 50.8 | 51.2 | 51.6 |
| | Aluminium at Sanamxai District(SLACO) for Alumina refinery | | | | | | 100.0 | 900.0 | 900.0 | 900.0 | 900.0 | 900.0 |
| | Total Load during Construction of Hydro Power Plants | | 3.8 | 3.8 | | | | | | | 5.3 | 14.3 |
| | Total Southen2 Area Demand | 56.3 | 76.8 | 121.2 | 144.7 | 180.3 | 415.8 | 1318.8 | 1313.8 | 1331.1 | 1293.5 | 1298.7 |
| | Total | 583.8 | 786.4 | 992.6 | 1167.4 | 1482.0 | 2015.8 | 2313.2 | 2403.1 | 2503.6 | 2506.1 | 2561.1 |

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

# Chapter 5 Power Development Plan

## 5.1 Power Development Plan

Developers of power development for Laos domestic usage are categorized into the following three investors, i) EDL, ii) IPP for domestic supply, iii) power export IPP of domestic supply portions. The power development plan is described in Table 5-1 to Table 5-3. The progress status of the power development project is caught up from the status of authorization from the Laos government. First of all, a developer creates a MOU with the DOE for conducting a feasibility study (FS) of a power plant development project after the developer proposed the project to the Laos government. After the DOE approves the FS report, the DOE approves the PDA to the project and the developer can start negotiations between the PPA and EDL. After the conclusion of the PPA, the DOE approves the CA to the developer in examining the project plan. Consequently, the power development project will progress onto the construction stage and then onto the operation stage.

## 5.2 Current Status of M Kaleum Development

The Phonesack group has already acquired the development right of the M Kaleum coal mining. It plans to export high quality coal and generate electricity by using middle-low quality coal. It consists of three phases and 600MW generation is planed to be developed in each phase (1,800MW in total). The electricity generation project in M Kaleum is basically approved by the Lao government, but there is no Power Development Agreement and/or Memorandum of Understanding for the generation project. The detailed planning and EIA of the project have not been implemented yet and it is still seeking investors.

The current demand in the southern area is very low. This generation project will be an IPP project to supply the electricity to the aluminum refining plants and to export power to Cambodia. However, it has uncertainty of the developments of these aluminum refining plants. If these projects are aborted, the developer needs to seek other customers to sell their products. This leads to difficulty of the development.

The generation cost in the southern area in Laos is approximately 6 cent/kWh. The project will be approved, only if the cost is equivalent to or less than 6 cent/kWh according to the Energy Promotion and Development Department of MEM. It will take at least 5 years from the financial decision (1 year) to construction and commissioning (4 year).

### Table 5-1 Power Development Plan for Domestic by EDL

| Region | Plant | Inst. Cap. (MW) | Firm Cap. (MW) | Gen. Eng. (GWh/Y) | Capacity Factor (%) | COD | Status |
|---|---|---|---|---|---|---|---|
| Northern | Nam Dong | 1.0 | 0.3 | 5 | 53.7% | 1969 | Operation |
| Northern | Nam Ko | 1.5 | 0.5 | 8 | 60.4% | 1996 | Operation |
| Northern | Nam Ngay | 1.2 | 0.4 | 8 | 76.1% | 2006 | Operation |
| Northern | Nam Boun 2 | 15.0 | 8.0 | 80 | 60.9% | 2014 | FS |
| Northern | Nam Chiene | 80.0 | 36.0 | 330 | 47.1% | 2015 | FS |
| Northern | Nam Khan 2 | 130.0 | 43.3 | 558 | 49.0% | 2015 | Under Construction |
| Northern | Nam Phak | 30.0 | 15.0 | 170 | 64.7% | 2015 | FS |
| Northern | Nam Khan 3 | 47.0 | 32.3 | 222 | 53.9% | 2016 | FS |
| Central | Nam Ngum 1 | 155.0 | 97.3 | 1003 | 73.9% | 1971 | Operation |
| Central | Nam Leuk | 60.0 | 22.4 | 218 | 41.5% | 2000 | Operation |
| Central | Nam Mang 3 | 40.0 | 12.8 | 150 | 42.8% | 2005 | Operation |
| Central | Nam Song (Ex) | 6.0 | 2.6 | 25 | 47.6% | 2011 | Under Construction |
| Central | Nam Sana | 14.0 | 4.5 | 50 | 40.4% | 2013 | Under Construction |
| Central | Nam Ngum 1 (Ex) | 40.0 | 18.0 | 88 | 25.1% | 2014 | FS |
| Central | Kengseuaten | 54.0 | 30.0 | 214 | 45.1% | 2016 | Study |
| Central | Nam Hinboun | 40.0 | 25.0 | 220 | 62.8% | 2016 | Study |
| Southern 2 | Xelabam | 5.0 | 0.6 | 21 | 49.0% | 1969 | Operation |
| Southern 2 | Xeset 1 | 45.0 | 8.4 | 134 | 34.0% | 1991 | Operation |
| Southern 2 | Xeset 2 | 76.0 | 30.4 | 310 | 46.6% | 2009 | Operation |
| Southern 2 | Selabam (Ex) | 7.7 | 3.1 | 37 | 54.9% | 2013 | FS |
| Southern 2 | Xeset 3 | 23.0 | 8.9 | 86 | 42.7% | 2013 | Study |
| Southern 2 | Houay LamphanGnai | 88.0 | 43.4 | 495 | 64.2% | 2014 | Under Construction |
| Southern 2 | Xeset 4 | 10.0 | 5.0 | 40 | 45.7% | 2015 | MOU |
| **Operation** | | 385.0 | 173.0 | 1857 | | | |
| **Under Construction** | | 238.0 | 94.0 | 1128 | | | |
| **Plan** | | 347.0 | 181.0 | 1487 | | | |
| **Total** | | 969.0 | 448.0 | 4471 | | | |

Note) Development status as following order: MOU, Study (FS on going), FS, PDA, PPA, CA, Under Construction, Operation

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

## Table 5-2 Power Development Plan by Domestic IPP

| Region | Plant | Inst. Cap. (MW) | Firm Cap. (MW) | Gen. Eng. (GWh/Y) | Capacity Factor (%) | COD | Status |
|---|---|---|---|---|---|---|---|
| Northern | Nam Nhon | 2.4 | 1.0 | 12 | 55.1% | 2011 | Under Construction |
| Northern | Nam Tha 3 | 1.3 | 0.5 | 6 | 50.2% | 2011 | Repair |
| Northern | Nam Ngum 5 | 120.0 | 84.0 | 500 | 47.6% | 2012 | Under Construction |
| Northern | Nam Ham 2 | 5.0 | 3.0 | 16 | 36.5% | 2013 | CA |
| Northern | Nam Long | 5.0 | 5.0 | 37 | 84.5% | 2013 | Under Construction |
| Northern | Nam Ngiew | 20.0 | 10.0 | 63 | 36.0% | 2014 | Study |
| Northern | Nam Beng | 34.0 | 13.5 | 137 | 46.0% | 2015 | FS |
| Northern | Nam Ngiep 2 | 180.0 | 81.0 | 723 | 45.9% | 2015 | PDA |
| Northern | Nam Pha | 130.0 | 65.0 | 720 | 63.2% | 2015 | FS |
| Northern | Nam Pot | 15.0 | 10.0 | 71 | 53.7% | 2015 | FS |
| Northern | Nam Sim | 8.6 | 3.2 | 33 | 43.3% | 2015 | PPA/CA |
| Northern | Nam Ou 2 | 120.0 | 54.0 | 546 | 51.9% | 2016 | PDA |
| Northern | Nam Ou 5 | 240.0 | 72.0 | 1156 | 55.0% | 2016 | PDA |
| Northern | Nam Ou 6 | 180.0 | 40.5 | 818 | 51.9% | 2016 | PDA |
| Northern | Nam Tha 1 | 168.0 | 75.6 | 721 | 49.0% | 2016 | PDA |
| Northern | Nam Seung 1 | 42.0 | 12.6 | 167 | 45.4% | 2017 | FS |
| Northern | Nam Seung 2 | 134.0 | 40.2 | 621 | 52.9% | 2017 | FS |
| Northern | Nam Ou 1 | 160.0 | 48.0 | 799 | 57.0% | 2018 | PDA |
| Northern | Nam Ou 3 | 150.0 | 45.0 | 710 | 54.0% | 2018 | PDA |
| Northern | Nam Ou 4 | 116.0 | 34.8 | 569 | 56.0% | 2018 | PDA |
| Northern | Nam Ou 7 | 190.0 | 57.0 | 915 | 55.0% | 2018 | PDA |
| Northern | Nam Ngum 4 | 33.0 | 11.0 | 165 | 57.1% | 2019 | FS |
| Northern | Namma 1,2,3,4,5 | 22.4 | 6.7 | 76 | 38.7% | 2019 | FS |
| Central | Nam Lik 1/2 | 100.0 | 70.0 | 435 | 49.7% | 2010 | Operation |
| Central | Nam Phao | 1.6 | 0.7 | 9 | 60.6% | 2012 | MOU |
| Central | Nam Kene | 5.0 | 2.0 | 20 | 45.0% | 2014 | FS |
| Central | Nam Lik 1 | 60.0 | 30.0 | 256 | 48.7% | 2014 | PPA/CA |
| Central | Nam Bak | 160.0 | 100.0 | 744 | 53.1% | 2015 | FS |
| Central | Nam Mang 1 | 64.0 | 35.0 | 225 | 40.1% | 2015 | PDA/PPA |
| Central | Nam Phai | 60.0 | 27.0 | 280 | 53.3% | 2015 | FS |
| Central | Nam Phouan | 30.0 | 15.0 | 140 | 53.3% | 2015 | FS |
| Central | Nam San 3 | 48.0 | 30.0 | 325 | 77.3% | 2015 | FS |
| Central | Nam Ngum (Down) | 60.0 | 27.0 | 300 | 57.1% | 2018 | FS |
| Central | Nam San 3 (Down) | 30.0 | 20.0 | 120 | 45.7% | 2018 | FS |
| Southern1 | Sepon 3 (Down) | 30.0 | 21.0 | 150 | 57.1% | 2016 | MOU |
| Southern1 | Sepon 3 (Up) | 70.0 | 49.0 | 280 | 45.7% | 2016 | MOU |
| Southern1 | Xeneua | 53.0 | 20.3 | 209 | 45.0% | 2018 | FS |
| Southern1 | Xe Lanong 1 | 60.0 | 27.0 | 300 | 57.1% | 2018 | FS |
| Southern2 | Tadsalen | 3.2 | 1.3 | 17 | 60.6% | 2013 | Under Construction |
| Southern2 | Xenamnoy1 | 15.0 | 10.0 | 100 | 76.1% | 2013 | PDA |
| Southern2 | Houay Champi | 5.0 | 1.6 | 27 | 62.3% | 2014 | MOU |
| Southern2 | Houay Kaphuek | 5.0 | 2.0 | 21 | 47.9% | 2014 | MOU |
| Southern2 | M Kaleum (Coal) | 300.0 | 300.0 | 2100 | 79.9% | 2014 | Study |
| Southern2 | Nam Kong 2 | 66.0 | 27.0 | 263 | 45.5% | 2015 | PDA |
| Southern2 | Nam Kong 3 | 42.0 | 9.0 | 158 | 42.8% | 2015 | PDA |

| Region | Plant | Inst. Cap. (MW) | Firm Cap. (MW) | Gen. Eng. (GWh/Y) | Capacity Factor (%) | COD | Status |
|---|---|---|---|---|---|---|---|
| Southern2 | M Kaleum (Coal) | 300.0 | 300.0 | 2100 | 79.9% | 2015 | Study |
| Southern2 | Nam Kong 1 | 75.0 | 50.0 | 469 | 71.4% | 2016 | FS |
| Southern2 | Nam Phak/Houay katam | 45.0 | 30.0 | 307 | 77.9% | 2016 | PDA |
| Southern2 | Xekong 4 | 300.0 | 180.0 | 1901 | 72.3% | 2016 | FS |
| Southern2 | Xekong 5 | 190.0 | 100.0 | 1131 | 68.0% | 2016 | FS |
| Southern2 | Thakho (Mekong) | 50.0 | 22.5 | 360 | 82.2% | 2016 | FS |
| Southern2 | Donsahong | 240.0 | 185.0 | 1756 | 83.5% | 2017 | PDA |
| Southern2 | Xekatam | 75.0 | 45.0 | 381 | 58.0% | 2017 | PPA |
| Southern2 | Xe don 2 | 20.0 | 15.0 | 80 | 45.7% | 2018 | MOU |
| Southern2 | Xe Lanong 2 | 45.0 | 28.0 | 170 | 43.1% | 2018 | MOU |
| **Operation** | | 100.0 | 70.0 | 435.0 | | | |
| **Under Construction** | | 132.0 | 92.0 | 571.0 | | | |
| **Plan** | | 4453.0 | 2402.0 | 23705.0 | | | |
| **Total** | | 4684.0 | 2564.0 | 24712.0 | | | |

Note) Development status as following order: MOU, Study (FS on going), FS, PDA, PPA, CA, Under Construction, Operation

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

**Table 5-3 Power Development Plan for Domestic by Export IPP**

| Region | Plant | Inst. Cap. (MW) | Firm Cap. (MW) | Gen. Eng. (GWh/Y) | Capacity Factor (%) | COD | Status |
|---|---|---|---|---|---|---|---|
| Northern | Hongsa (Local) | 100.0 | 100.0 | 701 | 80.0% | 2015 | Under Construction |
| Northern | Nam Xam 1 (Local) | 47.0 | 30.0 | 143 | 34.7% | 2016 | PDA |
| Northern | Xayabury | 60.0 | 30.0 | 420 | 79.9% | 2019 | CA |
| Northern | Laung Prabang | 150.0 | 108.0 | 660 | 50.2% | 2020 | PDA |
| Northern | Pak Beng | 114.0 | 80.0 | 599 | 60.0% | 2020 | PDA |
| Central | Nam Gnuang 8 | 60.0 | 42.0 | 316 | 60.1% | 2012 | Under Construction |
| Central | Nam Ngiep1 | 22.0 | 8.1 | 122 | 63.3% | 2018 | PDA |
| Central | Nam Theun 1 | 50.0 | 9.1 | 250 | 57.1% | 2018 | PDA |
| Southern 2 | Nam Theun 2 | 75.0 | 52.5 | 300 | 45.7% | 2010 | Operation |
| Southern 2 | Theun Hinboun (Local) | 8.0 | 3.0 | 25 | 35.7% | 1998 | Operation |
| Southern 2 | Houay Ho (Local) | 2.1 | 2.1 | 8 | 44.6% | 1999 | Operation |
| Southern 2 | Xekaman 3 (Local) | 25.0 | 15.0 | 96 | 43.8% | 2012 | Under Construction |
| Southern 2 | XeKaman 1 +Xanxai | 64.0 | 31.5 | 240 | 42.8% | 2014 | Under Construction |
| Southern 2 | Sepian-Xenamnoy | 40.0 | 20.0 | 179 | 51.0% | 2016 | PDA |
| **Operation** | | 85.0 | 58.0 | 333.0 | | | |
| **Under Construction** | | 249.0 | 189.0 | 1353.0 | | | |
| **Plan** | | 483.0 | 285.0 | 2373.0 | | | |
| **Total** | | 817.0 | 531.0 | 4059.0 | | | |

Note) Development status as following order: MOU, Study (FS on going), FS, PDA, PPA, CA, Under Construction, Operation

(Source: Data for preparing PDP 2010-2020 provided by EDL, June 2011)

## 5.3 Interconnection Transmission Lines with Neighboring Countries

The team and the EDL counterpart personnel visited the EGAT dispatching center in Khon Kean and EGAT HQs, to discuss the interconnection plan with the EDL system and conditions of the interconnection tie line operation, which deeply affects the supply and demand balancing act in the Southern region of Laos.

The capacities of the interconnection lines between the EDL southern system and EGAT were described in the following table.

**Table 5-4 Interconnection Capacities EDL Southern System and EGAT**

| EGAT | EDL | kV | Circuit | Capacity (MW) | Conductor |
|---|---|---|---|---|---|
| Nakhon Phanom | Thakhek | 115 | 2 | 100<br>70 | ACSR 477 MCM<br>ACSR 336.4 MCM |
| Mukdahan | Pakbo | 115 | 1 | 100 | ACSR 477 MCM |
| Sirindhom | Bang Yo | 115 | 1 | 100 | ACSR 477 MCM |

The interconnection between EDL Thakhek SS and EGAT Nakhon Phanom SS consists of double circuits. The capacity of the interconnection is limited to up to 70MW with N-1 criteria, because there is an imbalance among them. According to the EGAT HQs planning office, there is not a power supply to the EDL system via an interconnection between the EGAT Sirindhorn SS and EDL Bang Yo SS due to EGAT system constraints and severe conditions of supply and power balance in the Sirindhorn area. There is no plan in the EGAT PDP of reinforcing the interconnection to EDL system. The EGAT will study the interconnection reinforcements with EDL, when EDL requests reinforcements. There is little room for exports to EDL because of electricity demand increase and limited power development in the northeast Thailand.

According to EGAT, they were not requested to supply SLACO and not proposed to export power from M Kaleum thermal power plant in Laos. The 500kV system reinforcement in EGAT should be required to receive 600MW of imported power and 900MW of exported power. The 500kV system reinforcement will not be achieved within several years.

# Chapter 6 Power Development Scenarios

## 6.1 Scenarios for the Study

The scenarios of the Case G1 to Case G4 for the study are assumed through discussions with DOE and EDL as shown in Table 4-2. The scenarios were considered with and without the conditions following the issues, the large consumer SLACO, the large thermal power plant M Kaleum, Mekong main stream hydropower Don Sahong hydropower plant and Xekong 4, 5 & Nam Khon 1 hydropower as power suppliers to SLACO. These cases are set up based on the draft PDP 2010-2020 (as of June 2011) that was studied by EDL. The power supply shortage that could have occurred in the PDP draft EDL. EDL assumed that the deficit of supply power should be compensated by power import from China.

### (1) Case G1

This case is that SLACO (900MW) and Xekong4, 5 & Nam Khon 1 (75 MW) which are expected to supply to SLACO are not developed from the draft PDP2010-2011 by EDL. The power shortage in the S2 region is expected in the case G1.

### (2) Case G2

This case is that the large thermal power plant M Kaleum (600MW) has not been developed from the draft PDP2010-2020 by EDL. The power supply deficit for the SLACO demand is expected. It is assumed that the deficit power supply should be provided from China, CSG. The power supply from China to SLACO is assumed with the HVDC system from China directly.

### (3) Case G3

This case is same as the draft PDP2010-2011 by EDL. The imported power from China is assumed in the north & central system.

### (4) Case G4

This case does not assume the power development of M Kaleum thermal power plant (600MW), Don Sahong hydropower plant (240MW) and Xekong 4, 5 & Nam Khon 1(565MW). The power supply deficit still remains, when SLACO is supplied from China directly. The remaining supply power deficit is assumed by supplying via the transmission line of SLACO supply.

## 6.2 Conditions of yearly Supply and Demand Balancing Simulation

The interconnection capacities of EGAT and CSG are assumed in the supply and demand balancing simulation. The conditions of supply and demand of EGAT and CSG are assumed by the study team based on the JICA Indochina study and in consideration of the present situations obtained through a series of interviews. The simulations have been conducted in the years 2015, 2018 and 2020[1].

### (1) System Configuration for Supply and Demand Simulation

The following figure shows the system configuration for the supply and demand balancing simulation. The Laos system is divided into three systems, the north & central system、the South 1 system, the South 2 system, and they are assumed to be connected to the Thai northeast system in consideration of the present situations and the plan. The direct interconnections with the China CSG are assumed to settle the supply power deficit in the northern & central system and the South 2 system in Laos following the EDL proposal.

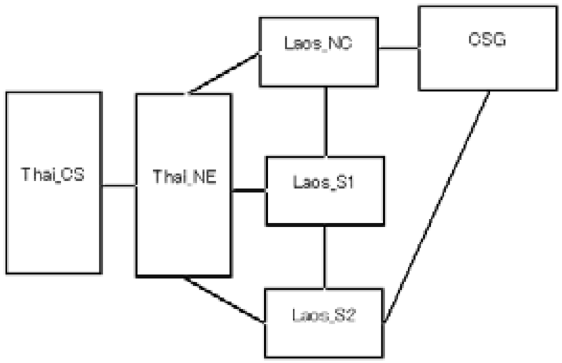



**Figure 6-1 System Configuration of Supply/Demand Balancing Simulation**

The capacities of the interconnections in Cases G1 - G4 are illustrated in the table below respectively. The interconnection patterns between S1 and S2 are assumed by the cases below in the definitions in section 8.2.

Case TA: 115kV Pakbo-Saravan transmission line installed in 2015

Case TB: 230kV Seno-Saravan transmission line installed in 2015, instead of the 115kV Pakbo-Saravan transmission line

Cases TA and TB have the same interconnection capacity. Although EDL Bang Yo SS in the S2 system and EGAT Sirindorn SS are connected by the interconnection line, the power cannot be supplied from EGAT to EDL around the area due to tight supply and demand balance and EGAT system constraints. The study assumes power supply from EDL to EGAT only via this interconnection.

There is no interconnection between S2 to CSG in Cases G1 and G3. There are

[1] Simulations have been conducted by PDPATII software.

interconnections between S2 to CSG to supply SLACO demand in Cases G2 and G4.

### Table 6-1 Interconnection Capacities of Each Case

(Unit: MW)

| Case | G1 & G3 | | | G2 & G4 | | |
|---|---|---|---|---|---|---|
| Area | 2015 | 2018 | 2020 | 2015 | 2018 | 2020 |
| N&C-S1 | 100 | 100 | 100 | 100 | 100 | 100 |
| S1-S2 | 100 | 250 | 250 | 100 | 250 | 250 |
| EGAT-N&C | 200 | 200 | 200 | 200 | 200 | 200 |
| EGAT-S1 | 160 | 160 | 160 | 160 | 160 | 160 |
| EGAT<-S2 | 100 | 100 | 100 | 100 | 100 | 100 |
| CSG-N&C | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 |
| CSG-S2 | 0 | 0 | 0 | 1,100 | 1,100 | 1,100 |

## (2) System Conditions for Supply and Demand Simulation

(a) Peak demand and Energy consumption

The following tables show the peak demand and energy consumption by systems.

### Table 6-2 Peak Demands by Systems

(Unit: MW)

| System | 2015 | 2018 | 2020 |
|---|---|---|---|
| Northern & Central | 1,348.8 | 1,543.9 | 1,609.9 |
| Southern1 | 363.8 | 533.6 | 558.2 |
| Southern2 | 415.8 | 1,331.1 | 1,298.7 |
| S1 without SLACO | 315.8 | 431.1 | 398.7 |

### Table 6-3 Energy Consumptions by Systems

(Unit: GWh)

| System | 2015 | 2018 | 2020 |
|---|---|---|---|
| Northern & Central | 7,737.5 | 8,678.5 | 9,117.2 |
| Southern1 | 1,814.4 | 3,074.0 | 3,417.4 |
| Southern2 | 2,916.6 | 10,346.4 | 10,144.4 |
| S1 without SLACO | 1,823.6 | 2,552.4 | 2,396.8 |

(b) Daily load curve at peak demand

The following figures show the daily load curves. These load curves have been assumed by the study team based on the hourly demand data of Phontong SS, Thakhek SS and Vangvieng SS provided by EDL in the JICA Laos system master plan study and in consideration of the latest demand forecasts and load factors. The daily load curve in the S2 system becomes flat due to the SLACO demand.

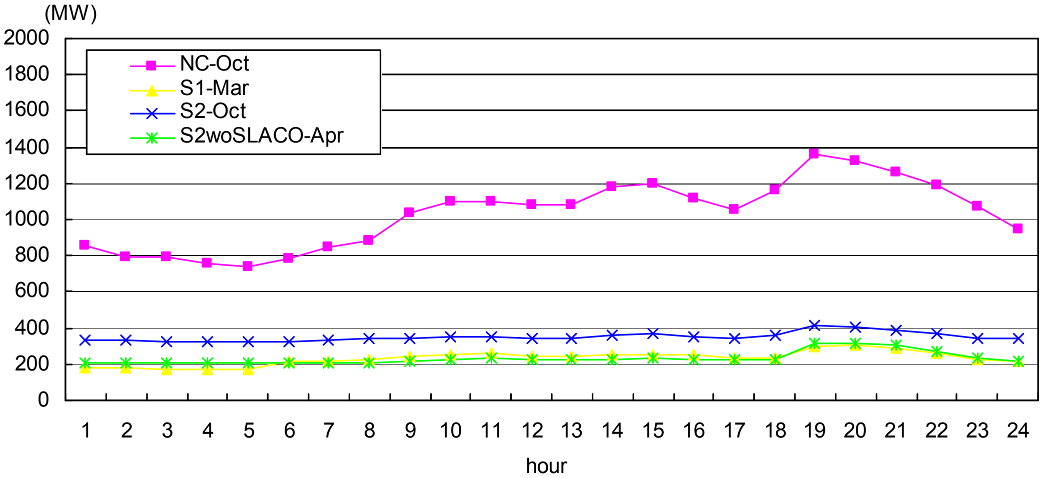



**Figure 6-2 Daily Load Curves by Systems in 2015**

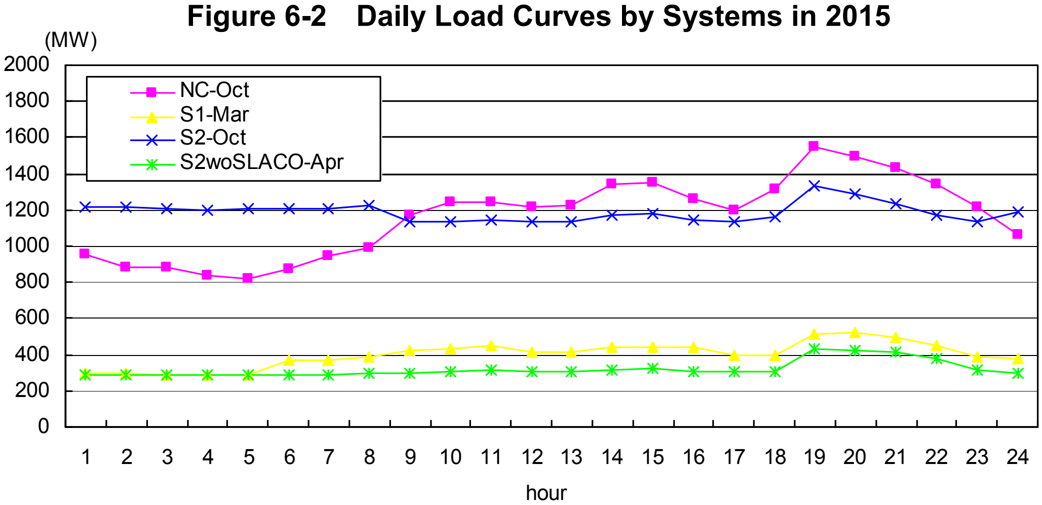



**Figure 6-3 Daily Load Curves by Systems in 2018**

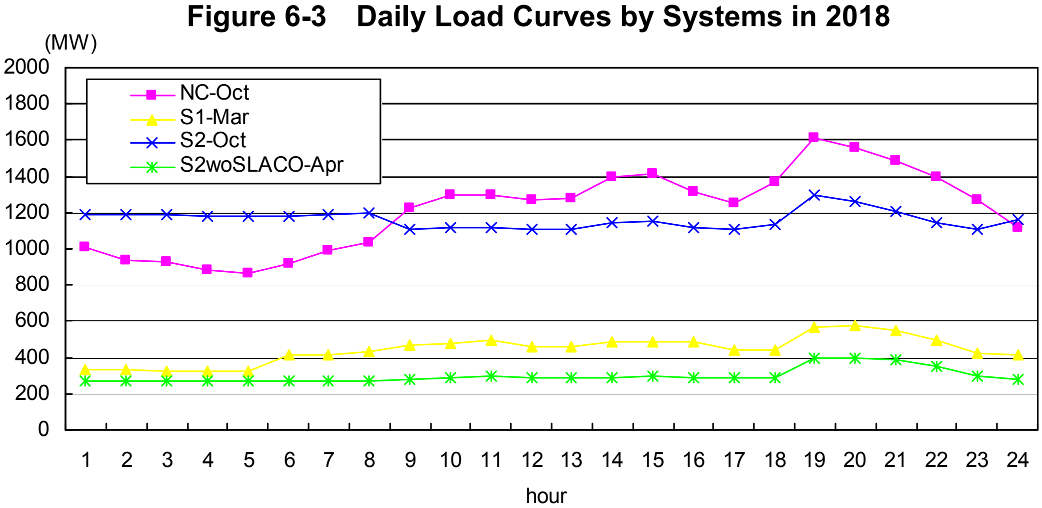



**Figure 6-4 Daily Load Curves by Systems in 2020**

(c) Power Development Plan

Power development plans are assumed based on the EDL PDP and under the cases aforementioned, as with and without SLACO, M Kaleum thermal plant, Don Sahong hydropower in Mekong main stream and Xekong 4, 5 & Nam Khon 1 which are expected to supply to SLACO.

(d) Hydropower Plant outputs

Hydropower plant outputs are assumed monthly based on the planned yearly generating energy, installed capacity and firm capacity in the dry season by plants in referred actual records from existing hydropower plants. Nam Ngum 1 hydropower plant output is referred to the north & central system plants. Xeset 1 hydropower output is referred to the S1 system and S2 system. The data is restricted to the year 2010. The average water in the flow data could not be utilized in the simulations.

Examples of hydropower plant outputs are illustrated in the following figures. Outputs in dry season decrease in reflecting the actual output records.

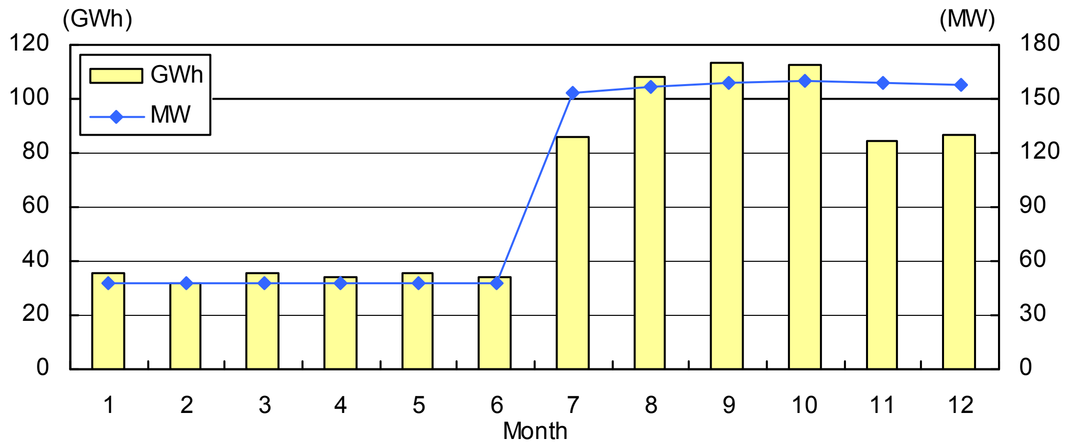



**Figure 6-5 Nam Ou1 Monthly Outputs (North System)**

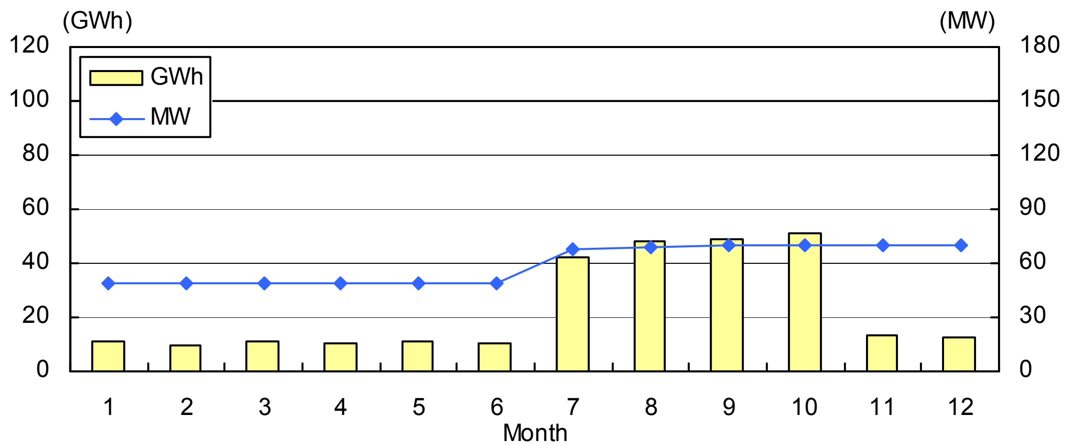



**Figure 6-6 Xepon3 (Up) Monthly Outputs (South System)**

## 6.3 Supply and Demand Balancing by Cases

The supply and demand balancing simulation of Cases G1 to G4 will be conducted in 2015, 2018 and 2020. There is no difference in the interconnection capacities between Case TA, 115kV transmission line first installation case and Case TB, 230kV transmission line first installation case. Thus, there is no difference of the supply and demand balance between Case TA and Case TB.

### (1) Supply and Demand Balancing of Case G1

There is no SLACO (900MW) and Xekong 4,5 & Nam Khon 1 (75MW) which are expected to supply SLACO in the Case G1.

(a) Supply and demand balance in 2015

The supply and demand balance results by the systems in 2015 is illustrated in the following figure. The black line represents monthly peak demand. The red line represents supply power. The green part represents imported power. The right blue part represents hydropower supply. The yellow part represents coal power supply. The numbers on the upper part of the figure are monthly reserve margin rates. The supply power of the north & central system during a dry season can be secured by importing power from neighboring countries. The power imports in November and December are utilized to supply the South 1 system.

A large share of the power supply of the South 1 system is power imports from neighboring systems. Reserve margin rates are low throughout the year. The supply and demand balancing in the South 1 system cannot be secured without interconnection lines. Surplus power supply is in the South 2 system. The interconnection transmission line is necessary to supply the surplus power to other systems.

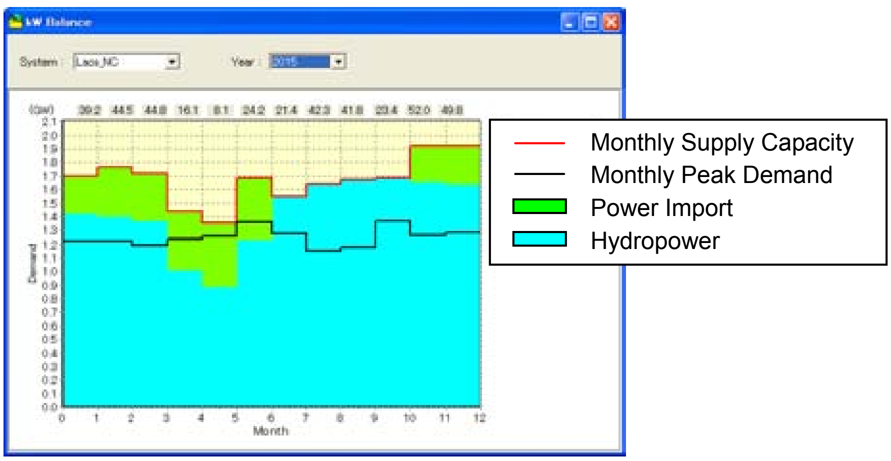



**Figure 6-7 Supply and Demand Balancing of the North & Central System (CaseG1 2015)**

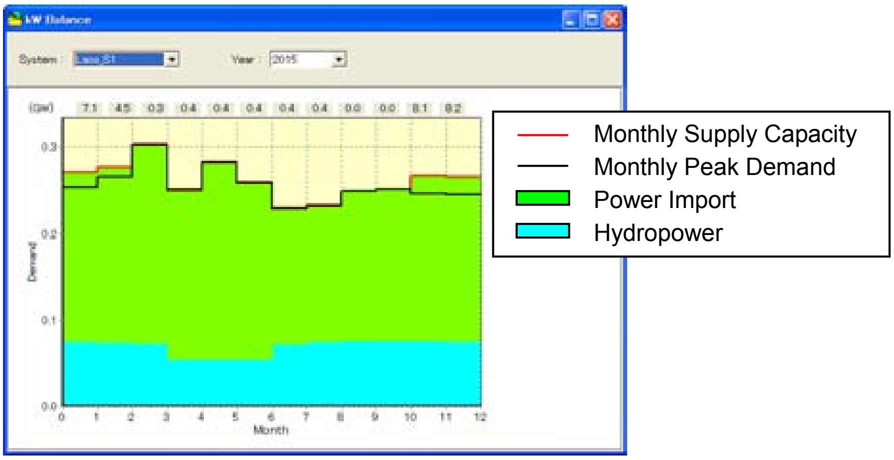



**Figure 6-8 Supply and Demand Balancing of the South 1 System (CaseG1 2015)**

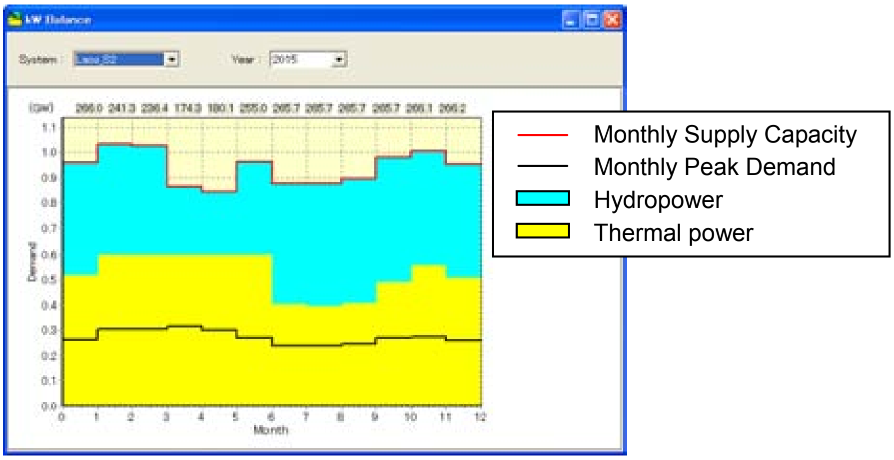



**Figure 6-9 Supply and Demand Balancing of the South 2 System (CaseG1 2015)**

(b) Supply and demand balance in 2020

Supply and demand balance of systems in 2020 is illustrated in the following figures.

The supply and demand balance is secured in the north & central system and the South 2 system minus imported power. The surplus power is caused in the rainy season due to a lot of hydropower plants in the systems. The interconnecting transmission lines are required to utilize the surplus power among interconnected systems efficiently. Supply and demand balance can be secured with the interconnection transmission line in the South 1 system.

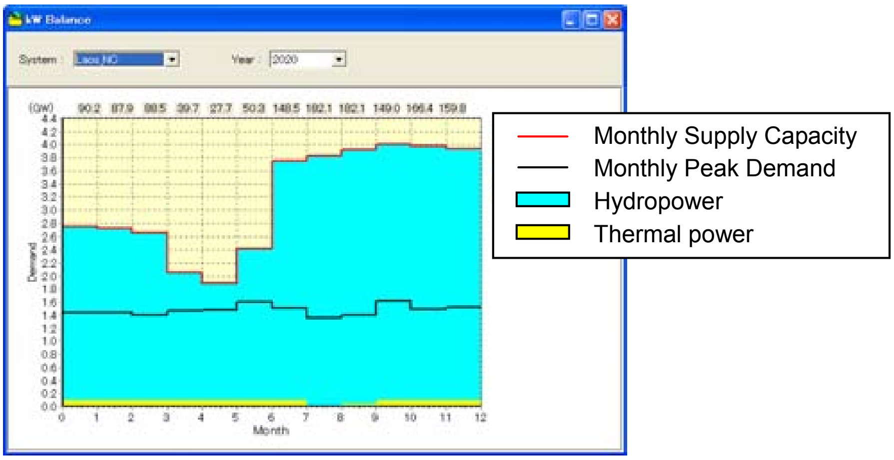



**Figure 6-10 Supply and Demand Balancing of the North & Central System (Case G1 2020)**

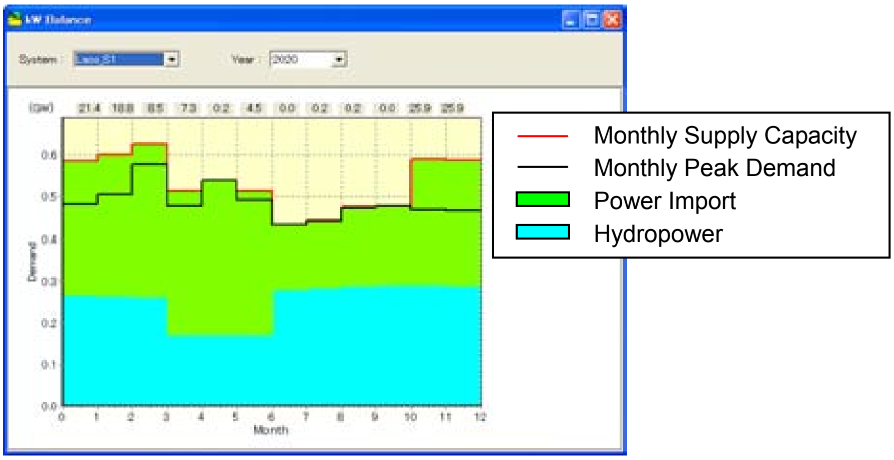



**Figure 6-11 Supply and Demand Balancing of the South 1 System (CaseG1 2020)**

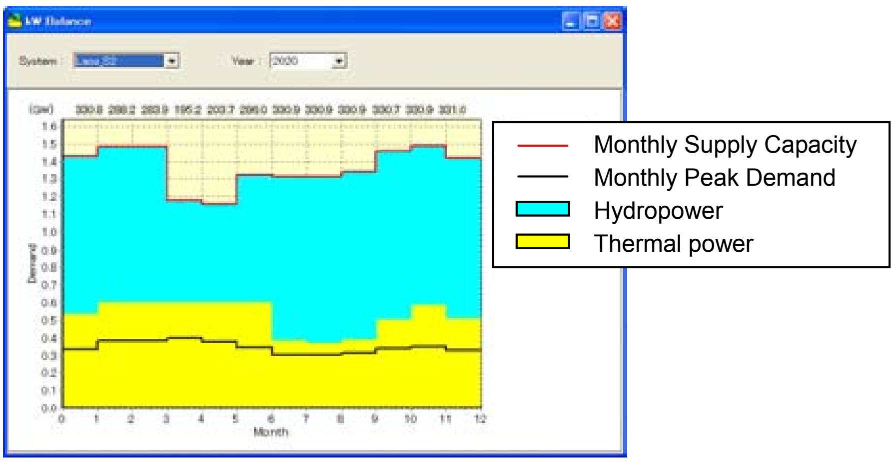



**Figure 6-12 Supply and Demand Balancing of the South 2 System (CaseG1 2020)**

(c) Power exchange of CaseG1 in 2020

The following figure illustrates the electricity energy power exchange of CaseG1 in 2020.

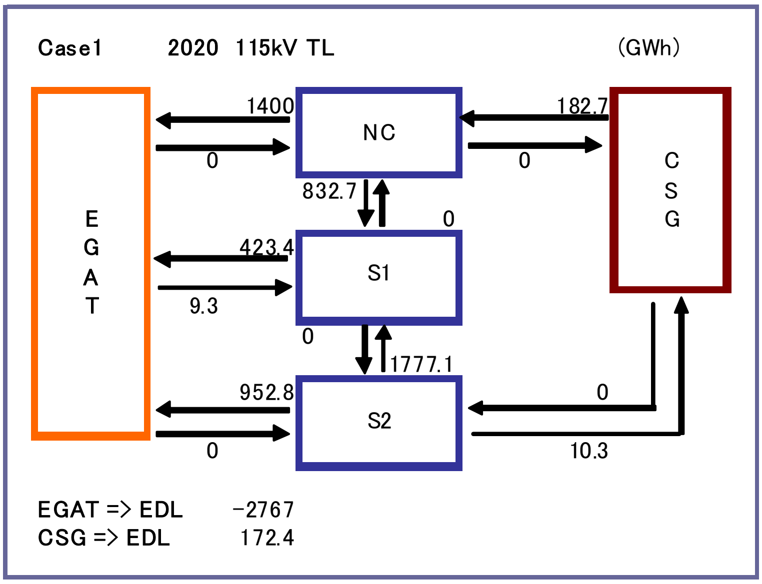



**Figure 6-13 Electricity Energy Power Exchange of CaseG1 in 2020**

### (2) Supply and demand balancing of CaseG2

This case is the zero development of a large thermal power plant of M Kaleum. This case causes deficit in power to SLACO. The supply to SLACO is assumed to be imported power directly from China through the HVDC or the 500kV transmission line.

(a) Supply and demand balancing in 2015

The supply and demand balancing of the north & central system in the dry season is secured by imported power from neighboring countries. The imported power in November and December are utilized to supply the South 1 system.

A large share of power supply of the South 1 system is imported power from neighboring systems. The reserve margin rates are low throughout the year. The supply and demand balance in the South 1 system cannot be secured without interconnection lines.

The surplus of supply power is in the South 2 system. However, there is a power shortage at peak demand during May and the dry season in the southern system 2. Power imports from EGAT cannot be conducted due to the present constraints of the EGAT system. It is necessary to secure power supply in the South 2 system, by developing 100MW of power plants in the South 2 system or by importing power supply from the EGAT system by negotiating with EGAT until 2015.

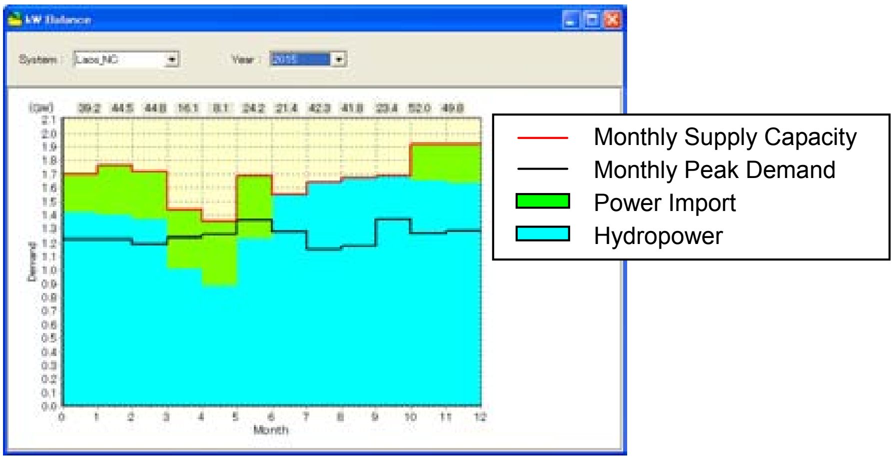



**Figure 6-14 Supply and Demand Balancing of the North & Central System (CaseG2 2015)**

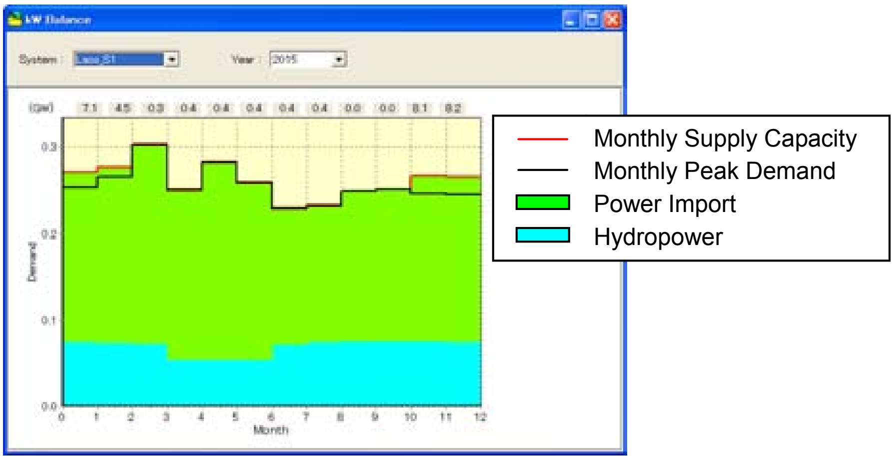



**Figure 6-15 Supply and Demand Balancing of the South 1 System (CaseG2 2015)**

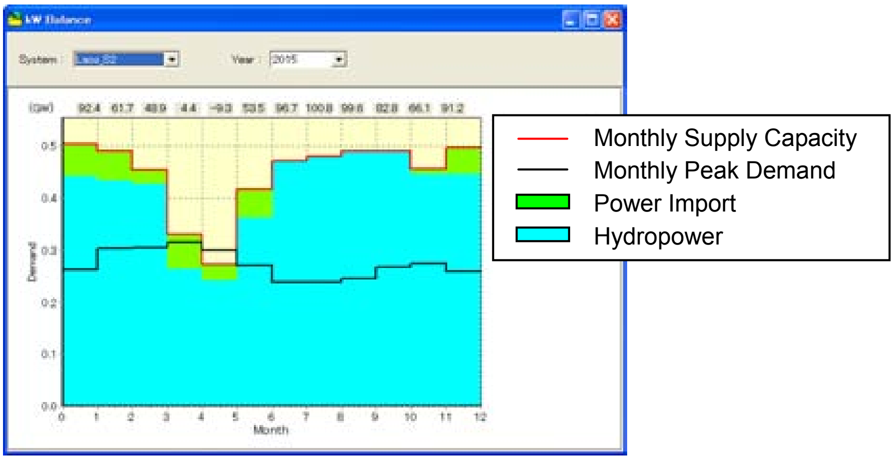



**Figure 6-16 Supply and Demand Balancing of the South 2 System (CaseG2 2015)**

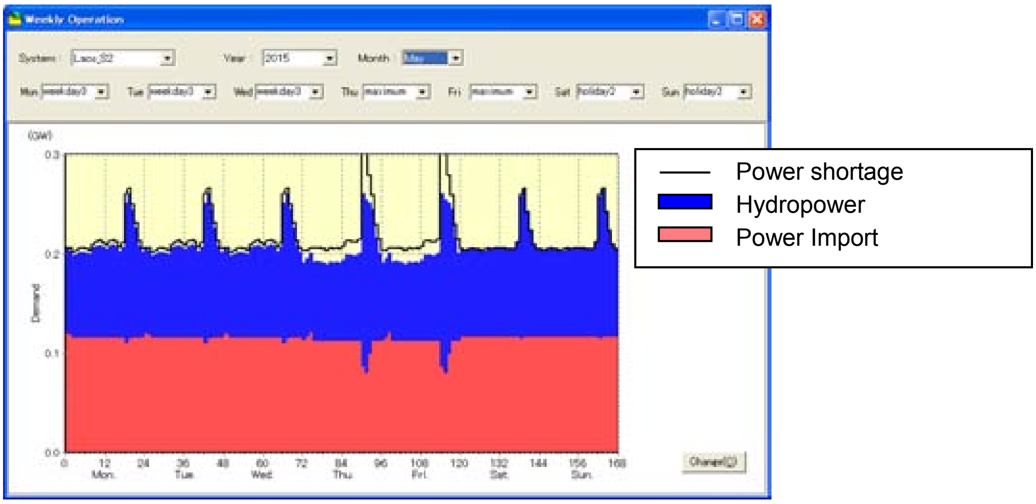



**Figure 6-17 Daily Operation in the South 2 System (May 2015 CaseG2)**

(b) Supply and demand balancing in 2020

The simulation results of the supply and demand balance of systems in 2020 are illustrated in the following figures. The supply and demand balance can be secured minus imported power in the north & central system and the South 2 system. Surplus supply power is in the systems. The interconnection transmission line is necessary to supply surplus power to other systems. The supply and demand balance in the South 1 system can be secured with interconnection lines.

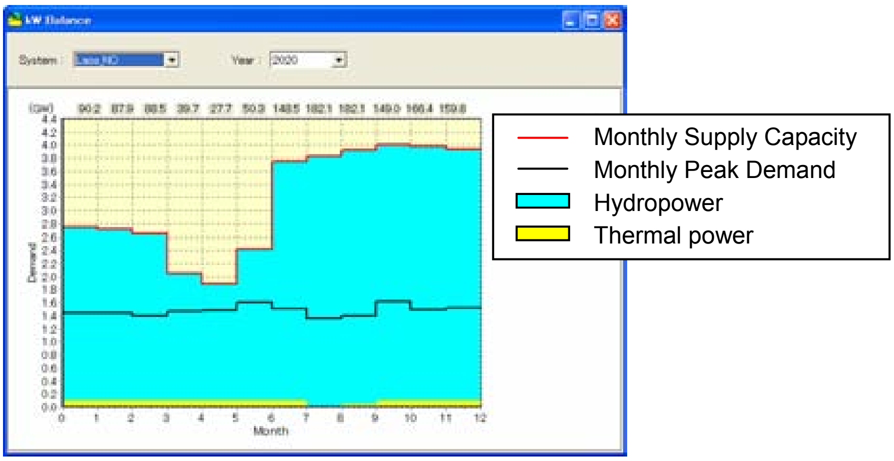



**Figure 6-18 Supply and Demand Balancing of the North & Central System (CaseG2 2020)**

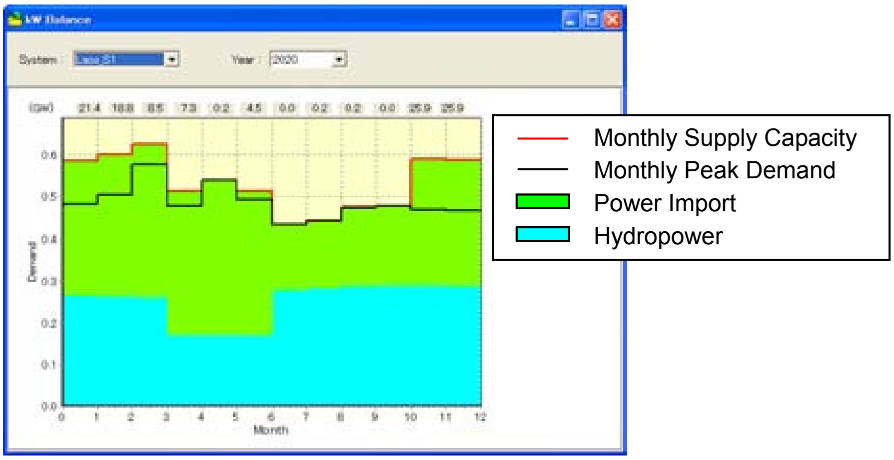



**Figure 6-19 Supply and Demand Balancing of the South 1 System (CaseG2 2020)**

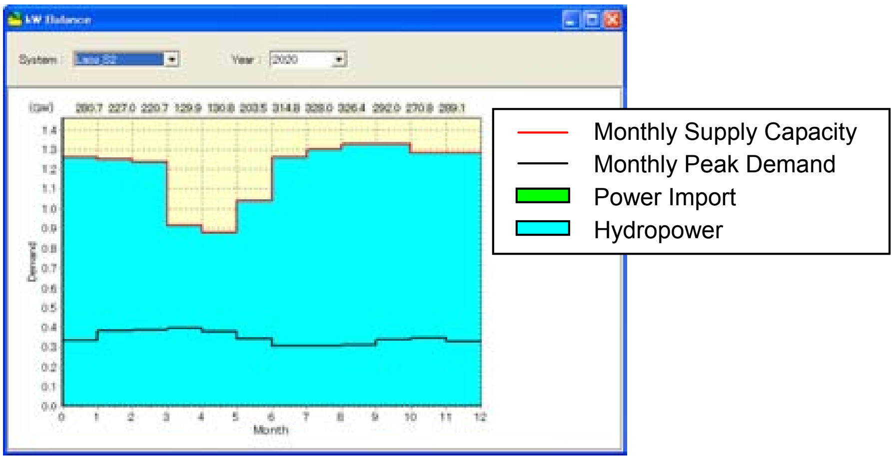



**Figure 6-20 Supply and Demand Balancing of the South 2 System (CaseG2 2020)**

(c) Power exchange of CaseG2 in 2020

The following figure illustrates the electricity energy power exchange of CaseG2 in 2020.

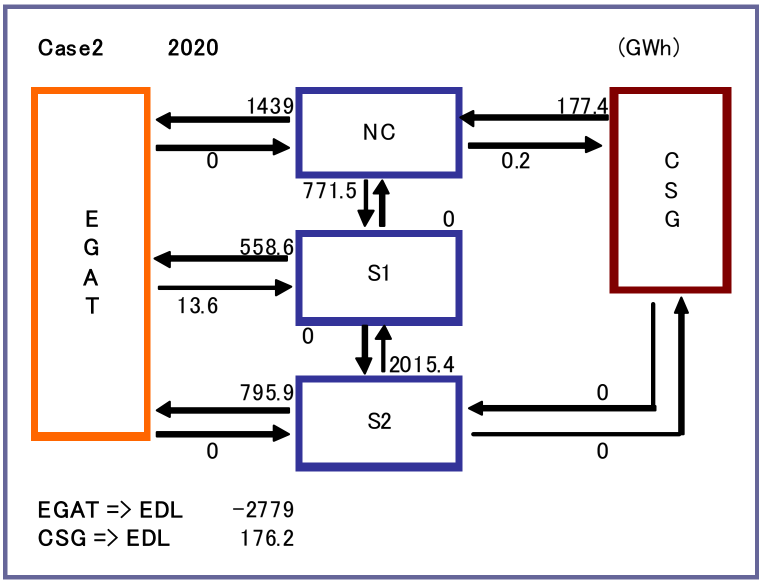



**Figure 6-21 Electricity Power Exchange of Case 2 in 2020**

## (3) Supply and demand balancing of CaseG3

This case is the same as the draft PDP2010-2011 by EDL. Imported power from China is assumed in the north & central system.

(a) Supply and demand balance of 2015

The simulation results of the supply and demand balance of Case G3 in 2015 are illustrated in the following figures.

The supply and demand balance of the north & central system and the South 1 system can be secured by power exchange with other systems and power imports from neighboring countries. A large share of power supply of the South 1 system is power imports and power exchanges from other systems and a little supply reserve margin capacity. There is surplus power in the South 2 system because SLACO will not yet be fully operational in 2015.

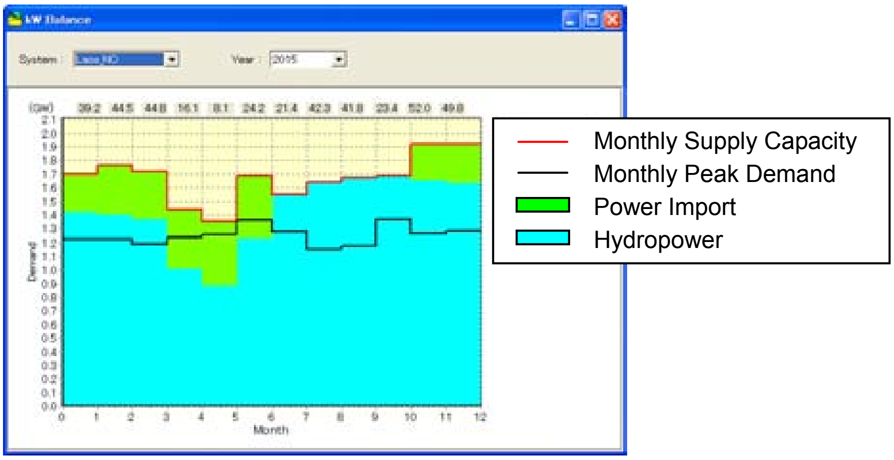



**Figure 6-22 Supply and Demand Balancing of the North & Central System (CaseG3 2015)**

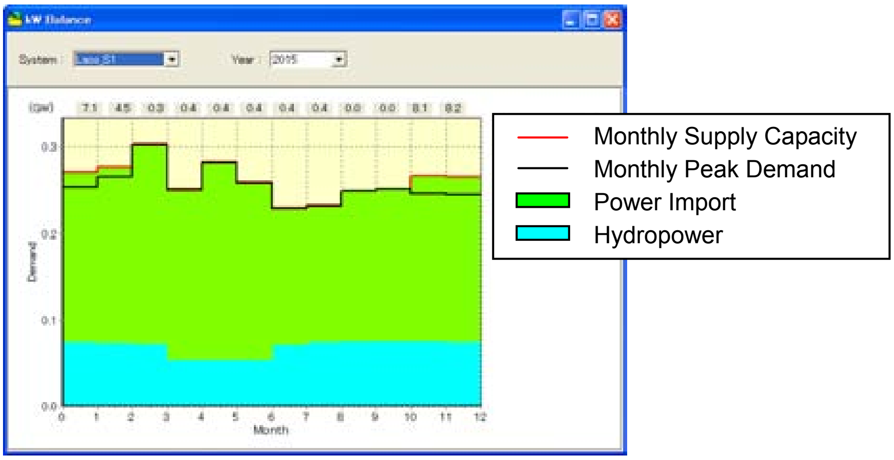



**Figure 6-23 Supply and Demand Balancing of the South 1 System (CaseG3 2015)**

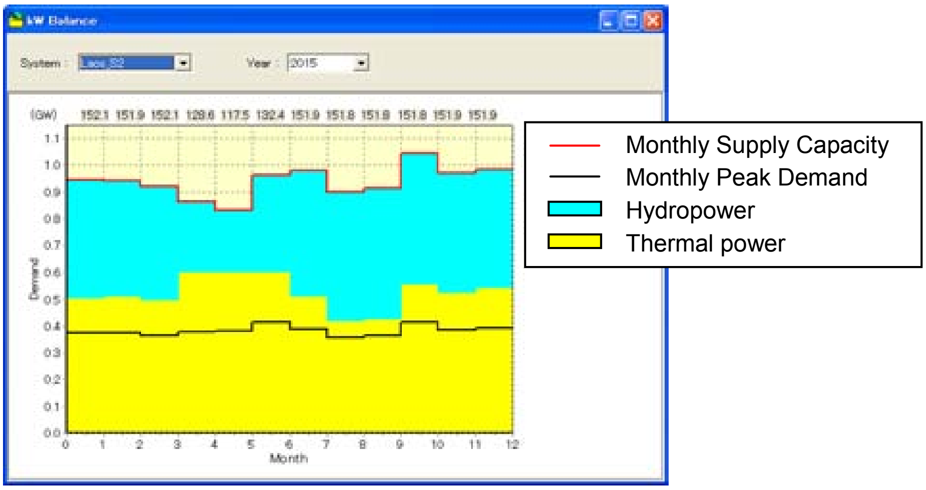



**Figure 6-24 Supply and Demand Balancing of the South 2 System (CaseG3 2015)**

(b) Supply and demand balance in 2020

The simulation results of the supply and demand balance of CaseG3 in 2020 are illustrated in the following figures.

The supply and demand balance of the north & central system can be secured, without power imports and power exchanges. There is surplus power during the rainy season in the systems due to a lot of hydropower generators. The supply and demand balance in the South 1 system can be secured by power imports and power exchanges from interconnected systems. There are high demands nearing peak demand throughout the year in the South 2 system due to SLACO full operation. The power should be imported to secure the balance between supply and demand in the South 2 system through the transmission line for the SLACO direct supply from China. The load factor of SLACO is high at a planned 85%. The load factor is higher than the thermal power plant at 80%. The high load factor cases a deficit of energy. The deficit energy cases of power shortage around 200MW in considering power plants forced outage rates (assumed Coal thermal power plants; 7%, hydropower plants; 2%) and water in flow fluctuation in the dry season. It is necessary to settle the power shortage to develop additional coal thermal plants or power imports from neighboring countries.

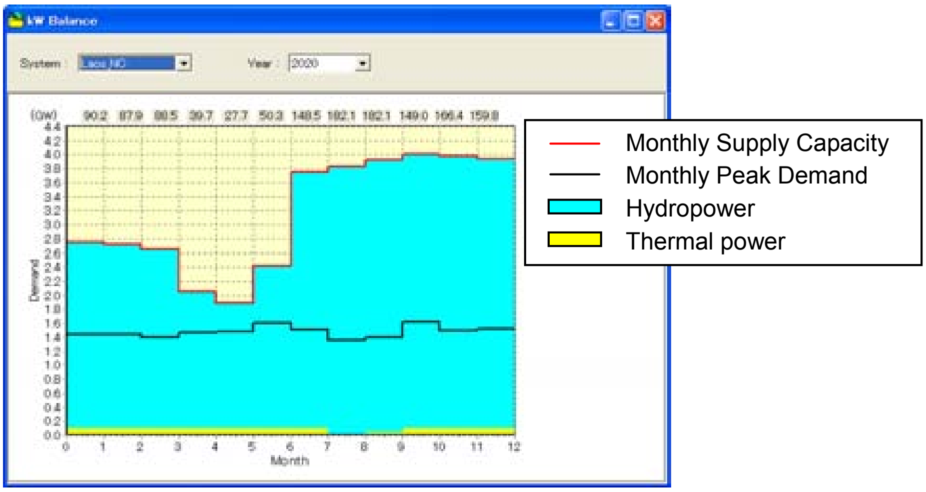



**Figure 6-25 Supply and Demand Balancing of the North & Central System (CaseG3 2020)**

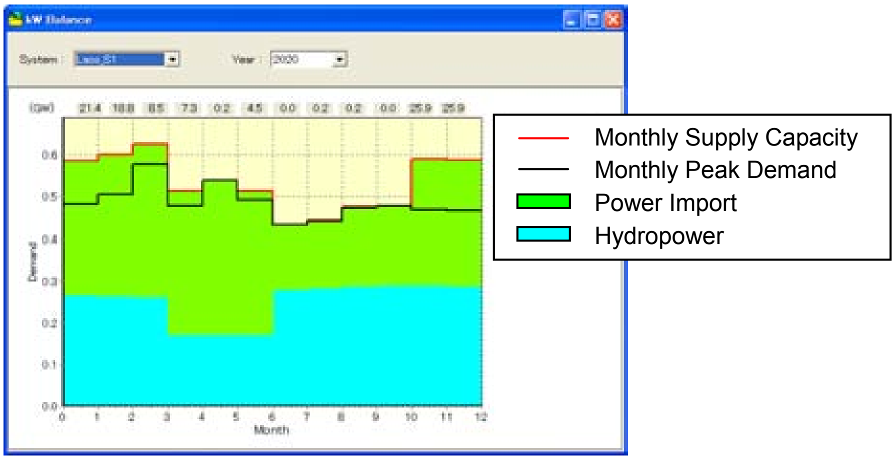



**Figure 6-26 Supply and Demand Balancing of the South 1 System (CaseG3 2020)**

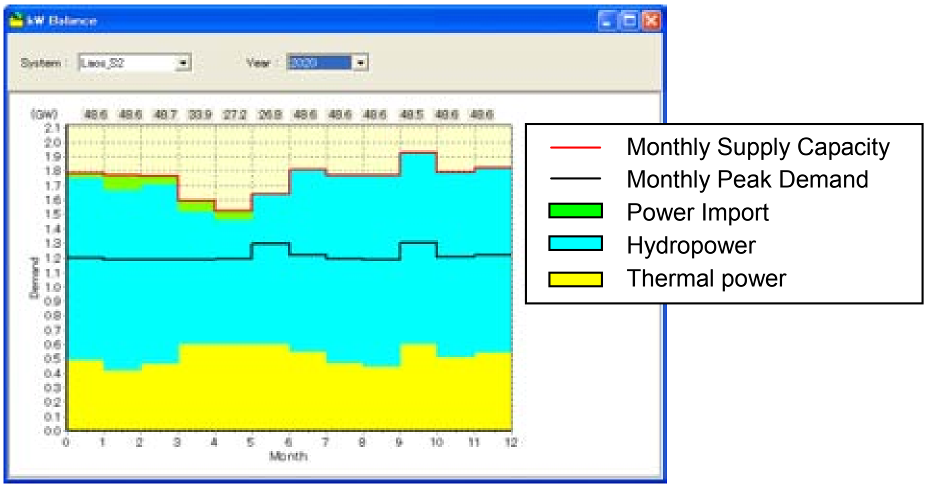



**Figure 6-27 Supply and Demand Balancing of the South 2 System (CaseG3 2020)**

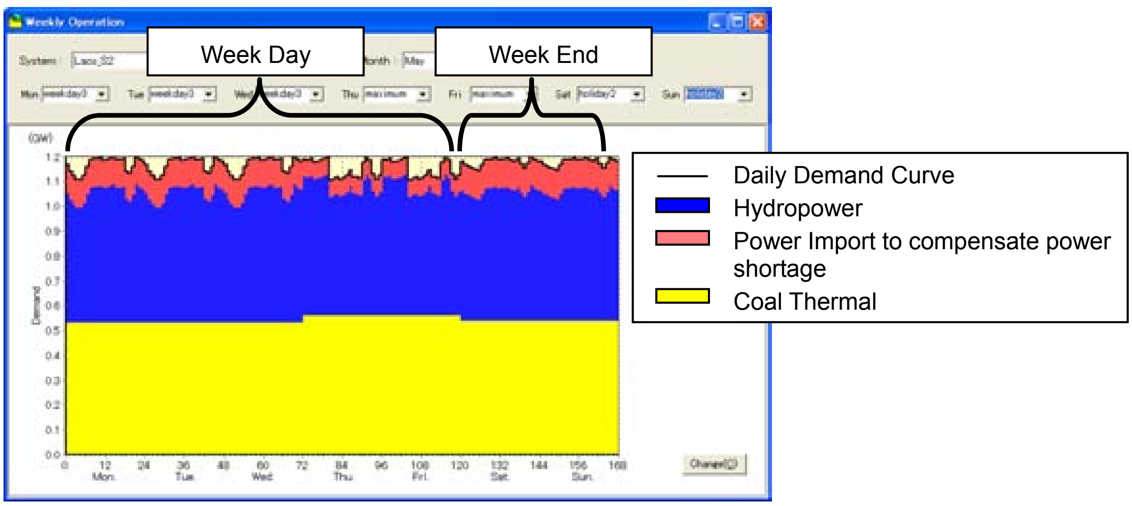



**Figure 6-28 Daily Operation in the South 2 System (CaseG3 May 2020)**

(c) Electricity Energy Power Exchange of CaseG3 in 2020

The following figure illustrates the electricity energy power exchange of CaseG3 in 2020.

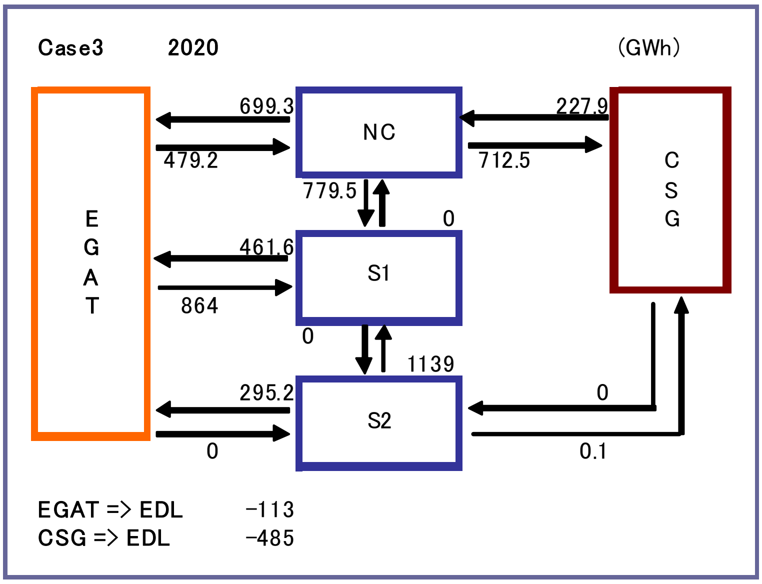



**Figure 6-29 Electricity Energy Power Exchange of CaseG3 in 2020**

## (4) Supply and Demand Balancing of CaseG4

This case is without the large thermal power plant of M Kaleum (600MW) and Don Sahong hydropower plant (240MW) which is Mekong main stream development and Xekong4,5 & Nam Khon1 (75MW) that are expected to supply to SLACO. The case causes a deficit of power supply when SLACO is supplied direct from China. The deficit power supply is assumed to supply from China through the transmission line of supplying SLACO.

(a) Supply and demand balance in 2015

The simulation results of the supply and demand balance of systems of CaseG4 in 2015 are illustrated in the following figures.

There are deficit power supplies in every system of Laos due to a lack of power development. Supply and demand can be balanced with import power from neighboring countries.

Thus, it is important for securing balance between supply and demand to negotiate EAGT and CSG, when power development projects were delayed, and mining projects and factory development projects proceeded.

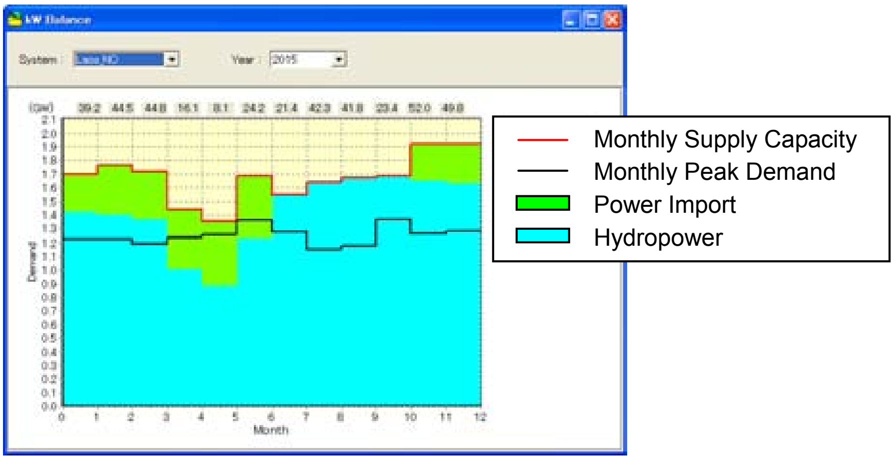



**Figure 6-30 Supply and Demand Balancing of the North & Central System (CaseG4 2015)**

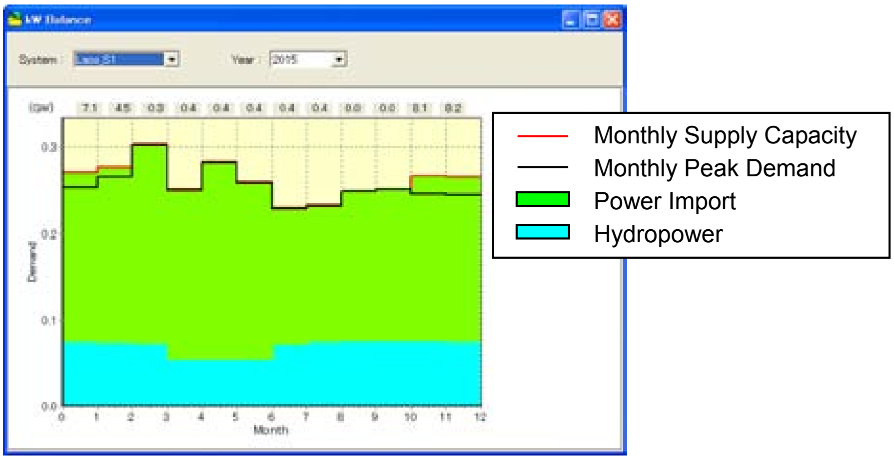



**Figure 6-31 Supply and Demand Balancing of the South 1 System (CaseG4 2015)**

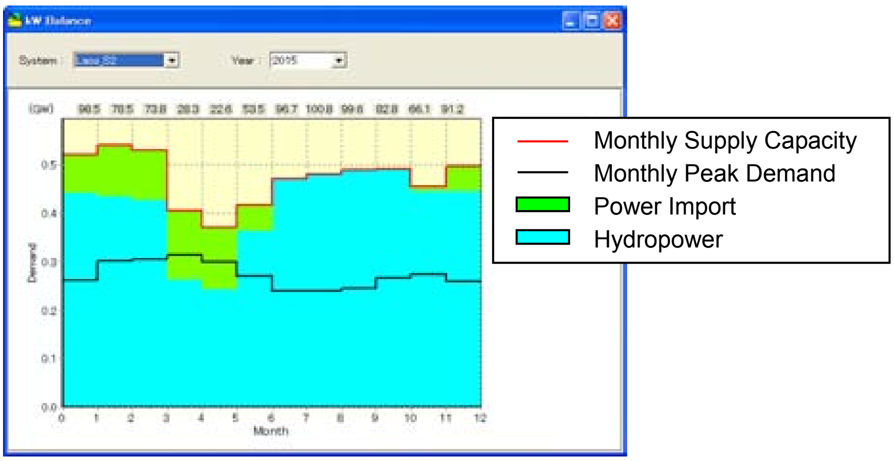



**Figure 6-32 Supply and Demand Balancing of the South 2 System (CaseG4 2015)**

(b) Supply and demand balance in 2020

The simulation results of the supply and demand balance of Case G4 in 2020 are illustrated in the following figures.

The supply and demand balance in the north & central system can be secured itself. The supply and demand balance in the South 1 system can be secured with power imports and power exchanges from other systems. The supply and demand balance of the South 2 system in the dry season can be secured with power imports and power transfers from other systems.

Consequently, the interconnection transmission lines should be constructed in the southern systems. The interconnection transmission lines in the north & central system should be installed to improve system operation and power development investment efficiency in utilizing the surplus power during the rainy season into the other systems.

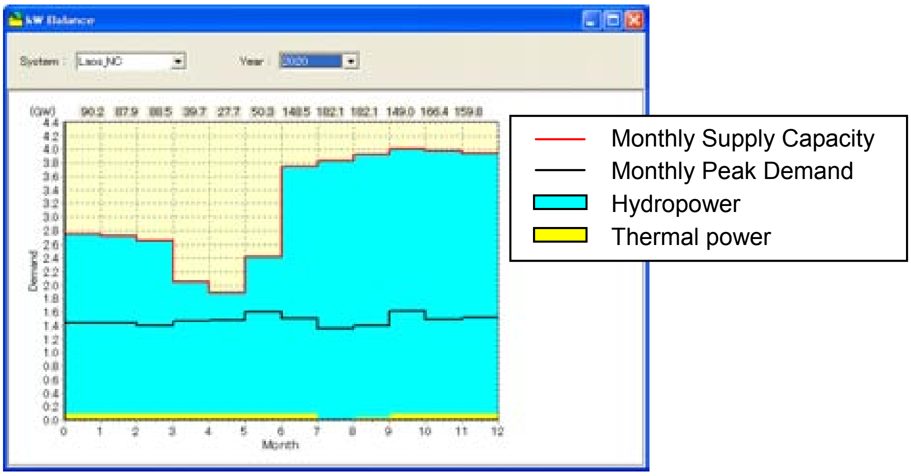



**Figure 6-33 Supply and Demand Balancing of the North & Central System (CaseG4 2020)**

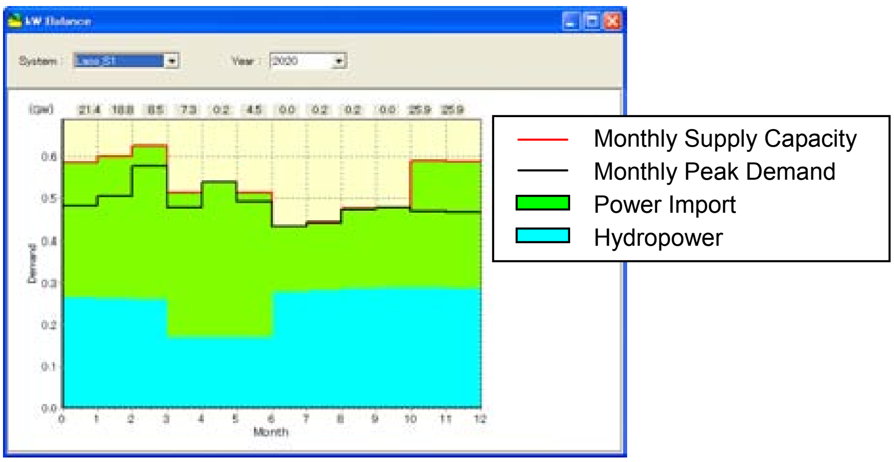



**Figure 6-34 Supply and Demand Balancing of the South 1 System (CaseG4 2020)**

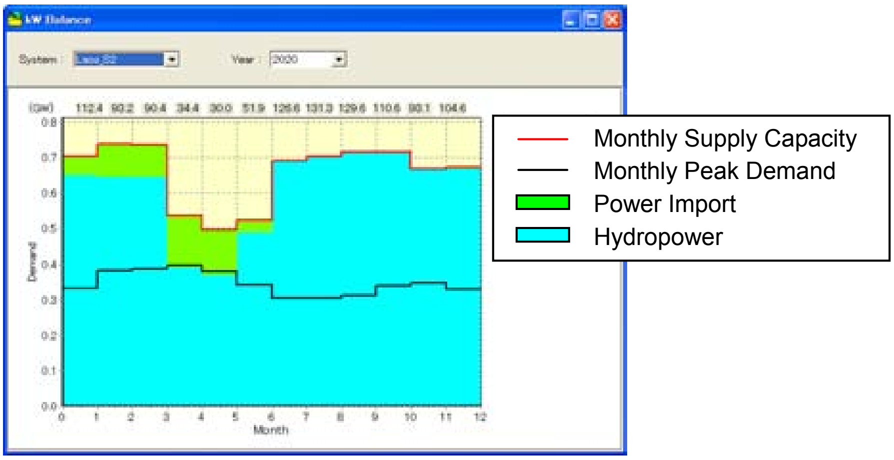



**Figure 6-35 Supply and Demand Balancing of the South 2 System (CaseG4 2020)**

(c) Electricity Energy Power Exchange of CaseG4 in 2020

The following figure illustrates the electricity energy power exchange of CaseG4 in 2020.

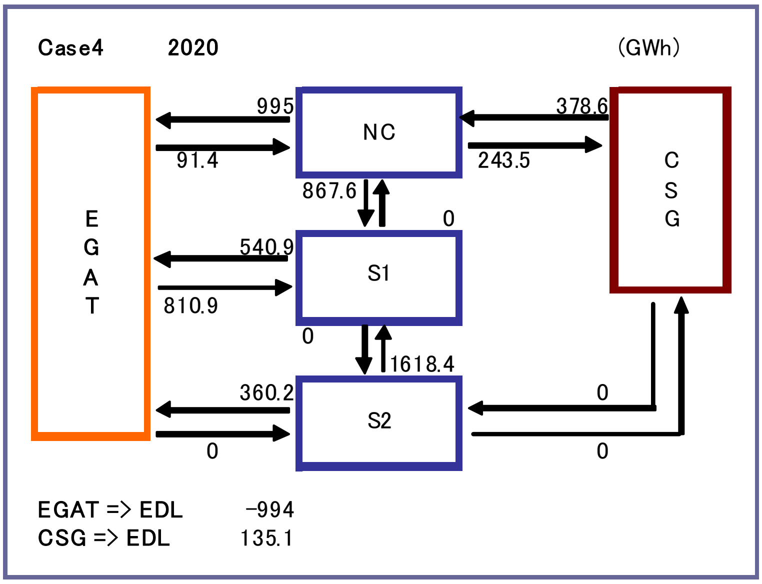



**Figure 6-36 Electricity Energy Power Exchange of CaseG4 in 2020**

## 6.4 Benefits from Interconnection Transmission Line in the Southern System

The benefits from the interconnection transmission line construction between the South 1 system and the South 2 system are calculated in comparison with the supply and demand balance between with and without the 115kV transmission line.

There will be a power shortage of 1GWh from 2015 to 2019 in the South 1 system if the 115kV transmission line is not constructed. In the power transfer between EDL and EGAT, power imports would decrease and power exports during the rainy season would increase. There is spilled water in the flow reduction mainly in the South 2 system. Coal consumption can curtail around 2GW/year equivalent to the Hongsa coal thermal plant during 2016 to 2019.

A reduction in CO2 emissions from coal consumption curtailment is calculated to be the equivalent of 2000 t-CO2/year.[2]

**Table 6-4 Benefits of 115kV Transmission Line**

(Unit: GWh)

| Items | 2015 | After 2020 |
|---|---|---|
| Power Shortage | -1 | – |
| Power Import Reduction | -436.9 | -1.2 |
| Power Export Increment | 552.8 | 287.9 |
| Spilled Water in flow Reduction | -1008 | -291 |

The project can activate the power trade avoiding the spilled water of hydropower plants, which brings the reduction in power import and the increase in power export. The change in power import/export is estimated in accordance with the power exchange rate between EGAT of the power import tariff, 6.5UScent/kWh at peak and the power export tariff, 4.3UScent/kWh at off peak.[3]

**Table 6-5 Benefits of 115kV Transmission Line (Import Export Expense Difference)**

(Unit: Million USD)

| Items | 2015 | After 2020 |
|---|---|---|
| Power Import Reduction | -28.4 | -0.1 |
| Power Export Increment | 23.8 | 12.4 |

[2] Lignite of CO2 emission unit is assumed as 1kg-CO2/kWh. 2GWh is equivalent of 2000t-CO2.
[3] Power trade tariff between EGAT: Power export tariff 4.3UScent/kWh at off-peak is 1.2THB/kWh, Power import tariff 6.5UScent/kWh at peak is 1.79THB/kWh. The conversion rates are 83JPY/USD, 3JPY/THB, 27.7THB/USD.

# Chapter 7 Power System Issues

## 7.1 Regional Power Demand and Power Supply Ability

Table 7-1 shows the surplus power represented by MW in N&C, the Target Area and S2 regions in the case of full generation (the full power output of power generation during the wet seasons) and in case of firm generation (the securable power output of power generation in the dry seasons). Negative values indicate the deficit in power to be compensated by the power from other regions. N&C would have the deficit in power until 2014 even during wet seasons. After 2016, although N&C and S2 regions would have a lot of surplus power even during the dry seasons, S1 would have experience a power deficit throughout the year. Thus, it is necessary to make power transmission plans to S1 from other areas and the power evacuation of surplus power occurring in N&C and S2.

### Table 7-1 Surplus Power of Laos in Wet and Dry Seasons up to 2020

Power Balance Including SLACO (Unit: MW)

| Gen Pattern | Area | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Full | N&C | -6.3 | -170.2 | -154.3 | -226.7 | -276.4 | 434.8 | 1,251.2 | 1,338.0 | 2,089.7 | 2,264.7 | 2,480.0 |
| | Target Area | -61.8 | -68.6 | -84.9 | -140.9 | -248.0 | -288.8 | -303.7 | -310.0 | -245.6 | -269.2 | -270.2 |
| | S2 | 79.8 | 59.3 | 39.9 | 65.3 | 491.7 | 674.2 | 463.2 | 783.2 | 868.9 | 906.5 | 901.3 |

| Gen Pattern | Area | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Firm | N&C | -161.3 | -308.0 | -297.8 | -318.3 | -423.5 | -190.6 | 118.3 | 113.2 | 383.2 | 479.2 | 653.4 |
| | Target Area | -84.3 | -91.1 | -107.4 | -163.4 | -270.5 | -311.3 | -356.2 | -362.5 | -363.8 | -387.4 | -388.4 |
| | S2 | -11.8 | -32.3 | -61.7 | -61.9 | 281.0 | 386.5 | 11.5 | 246.5 | 287.2 | 324.8 | 319.6 |

## 7.2 Situations of Power Supply and Demand in Target Area

Figure 7-1 shows the surrounding area of South 1. The area illustrated by a dotted line was set out following the conditions described below. We call this area the "Target Area" because the transmission line targeted by this study supplies power to this area.

- Power consumers supplied from the substations located in S1
- Sepon (D), Sepon(U) and Xelanong 1 hydropower stations in S2. Those power stations are planned to be connected to Xepon Mining and Pakbo substation located in S1 via 115 kV transmission lines.
- The power stations located in S1 excluding Nam Hinboun that was once connected to the transmission line in Central and sent from Central (Nam Theun 2)

Table 7-2 shows the balance between the power supply ability and peak power demand in the Target Area. Full Generation indicates a case of full power outputs of hydropower generators in the wet seasons and the Firm Generation indicates the case of secured power outputs of hydro power generators even during dry seasons. The Target Area has an energy deficit in all cases. Thus, it is needed to supply power from other areas to the Target Area.

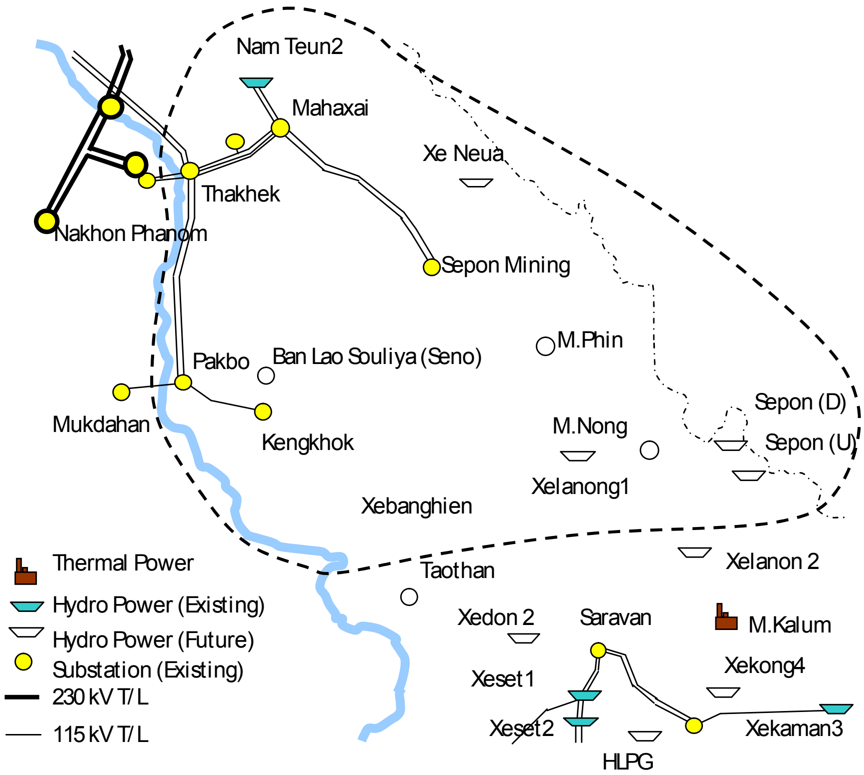



**Figure 7-1 Power System in Target Area**

### Table 7-2 Balance between Power Supply Ability and Peak Power Demand in Target Area

(Unit: MW)

| Item | Area | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Peak Demand | Khammouan | 49.0 | 51.0 | 53.2 | 55.5 | 78.0 | 113.8 | 192.9 | 192.7 | 213.9 | 219.6 | 219.7 |
| | Savannakhet | 87.8 | 92.6 | 106.7 | 160.4 | 245.0 | 250.0 | 285.8 | 292.3 | 319.7 | 337.6 | 338.5 |
| | **Sub Total** | **136.8** | **143.6** | **159.9** | **215.9** | **323.0** | **363.8** | **478.7** | **485.0** | **533.6** | **557.2** | **558.2** |
| Full Generation | Nam Theun 2 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| | Xeneua | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 53.0 | 53.0 | 53.0 |
| | Xe Lanong 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 60.0 | 60.0 | 60.0 |
| | Sepon 3 (Down) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| | **Sub Total** | **75.0** | **75.0** | **75.0** | **75.0** | **75.0** | **75.0** | **105.0** | **105.0** | **218.0** | **218.0** | **218.0** |
| | **Surplus** | **-61.8** | **-68.6** | **-84.9** | **-140.9** | **-248.0** | **-288.8** | **-373.7** | **-380.0** | **-315.6** | **-339.2** | **-340.2** |
| Firm Generation | Nam Theun 2 | 52.5 | 52.5 | 52.5 | 52.5 | 52.5 | 52.5 | 52.5 | 52.5 | 52.5 | 52.5 | 52.5 |
| | Xeneua | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.3 | 20.3 | 20.3 |
| | Xe Lanong 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 27.0 | 27.0 | 27.0 |
| | Sepon 3 (Down) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 |
| | **Sub Total** | **52.5** | **52.5** | **52.5** | **52.5** | **52.5** | **52.5** | **73.5** | **73.5** | **120.8** | **120.8** | **120.8** |
| | **Surplus** | **-84.3** | **-91.1** | **-107.4** | **-163.4** | **-270.5** | **-311.3** | **-405.2** | **-411.5** | **-412.8** | **-436.4** | **-437.4** |

## 7.3 Methodology of Power Supply to Target Area

As mentioned before, Target Area has experienced a power deficit throughout the years. At present, this area imports power from EGAT at Thakhek and Pakbo substations and begins to take power from the Central region after the completion of the 115 kV Pakxan-Pakbo transmission line. However, the power supply to the Target Area will not be enough only by those transmission lines due to an increase in power demand around 2015. The available power via the Pakxan- Thakhek 115 kV transmission line is around 100 MW at maximum. Imported power from EGAT at the Thakhek and Pakbo substations are restricted following the limitations shown in the table below.

### Table 7-3 Thermal Capacities of Interconnection Lines

| Interval | Conductor | Thermal Capacity |
|---|---|---|
| Nakhon Phanom (EGAT) -Thakhek 115 kV 2cct | ACSR 477 MCM 1cct | Around 100 MW |
| | ACSR 336.4 MCM 1cct | Around 70-80 MW |
| Mukdahan (EGAT)-Pakbo 115 kV 1cct | ACSR 477 MCM1cct | Around 100 MW |

The limitation of power transmission from Nakhon Phanom (EGAT) to Thakhek with 2 circuits is around 70 to 80 MW when the N-1 criteria is applied due to the capacity of the small conductor. A re-conductoring a circuit of the transmission lines from Nakhon Phanom (EGAT) to Thakhek is one way to increase its capacity. The power flow from Nakhon Phanom to Thakhek reaches its limit faster than from Mukdahan to Pakbo when the power imported from EGAT is increased because more power is flowing from Nakhon Phanom than from Mukdahan to Pakbo. Thus, controlling the power at Thakhek and Pakbo substations by installing the phase shifters at Pakbo or Thakhek substations is considered as one of the effective measures for utilizing the capacity of conductors. Actually, the PDP 2010-2020 Draft mentioned the installation of the phase shifter at Pakbo substation. In this study, we assume that the limitation of the power received at Thakhek and Pakbo from EGAT was 160 MW in consideration of the capacities of the two circuits remaining while a circuit from EGAT to Thakhek/Pakbo was damaged.

In the Target Area, in spite of a few power stations planned, there is a lot of power consumption of substations and large mining/ industrial loads. As mentioned above in this section, the Target Area will have a power deficit throughout the years regardless of the seasons at present and for the future. The power deficit in the Target Area in 2015 will be around 300 MW during the dry season and exceed the ability of power-transmission to the Target Area via the existing transmission line. Thus, a new transmission line is needed to supply power to the Target Area in around 2015. Given that the distance from the location of power sources in the North and Central to the Target Area is over 300 km long, it is considered effective to transmit the power through the interconnections to the Target Area from the South 2 area where a certain amount of surplus power will be expected.

## 7.4 Role of 500kV/230kV/115kV and Power Supply to SLACO

In general, 500 kV power transmission lines take on the role of power transmission exceeding around 1,000 MW, 230 kV more than 150 MW and 115 kV more than 20-30 MW although the selection of the voltage levels of power transmission lines largely depends on their distance and the number of circuits.

Figure 7-2 shows the amount of peak loads of substations and large power consumers in Laos in 2010. Their total amount is 558 MW. The largest load is around 100 MW of the Phontong substation located in Vientiane. The load of Phontong and the second largest load of Thanaleng around 50 MW occupies a fourth of the total loads of Laos. The third one is the load of Khoksaat around 30 MW and the fourth one is Tha Ngon around 20 MW. The total amount of loads summarizing the first to fourth reaches around 200 MW. The power network system for domestic power supply in Laos has a scale composed of 115 kV transmission lines or one or two routes of 230 kV transmission lines that can supply a group of substations in Vientiane.

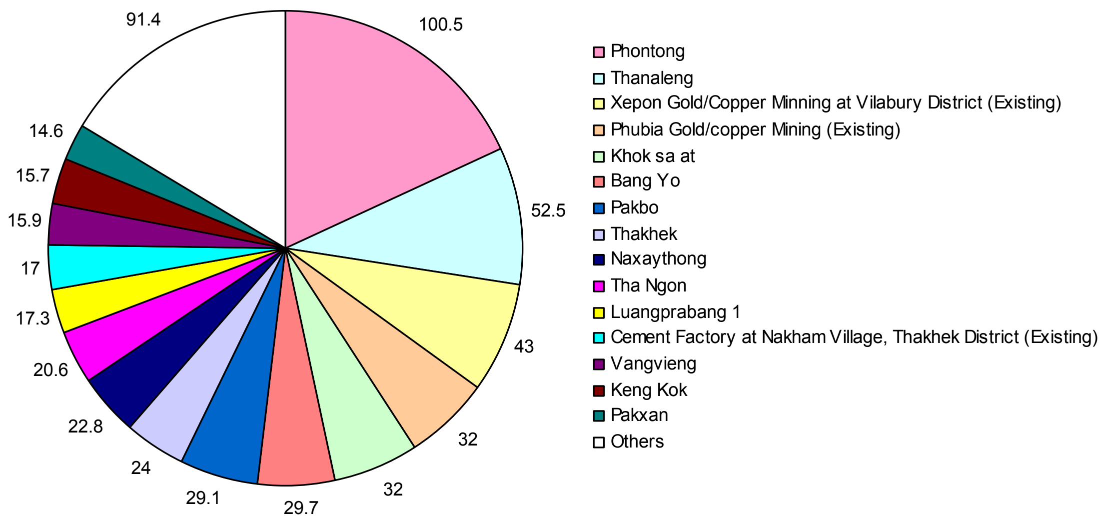



**Figure 7-2 Amount of Power Demand of Substations and Large Power Consumers of Laos in 2010**

Figure 7-3 shows the amount of peak loads of substations and large power consumers in Laos in 2020. The total amount is 3,435 MW. The largest load is around 900 MW of SLACO, an aluminum industrial load, occupying around a third of Laos's power demand. The 230 kV is considered as the voltage used for the power transmission for this amount of loads with several ten km because stability isn't an issue. However, a 500 kV transmission line is needed to transmit the power for this amount of loads with a distance of more than 100 km.

The second largest load is the Iron Melting Factory of 390 MW that can be supplied via the 230 kV transmission lines with multiple circuits.

The total amount of those two loads occupies a third of Laos's power demand. Those two loads are extremely larger than other loads, thus, their power supply methodology is different from others. Their power system should be studied independently.

Many of the loads of other substations reach around 100 MW. It is considered efficient to supply those substations with 230 kV transmission lines with multiple routes. In this case, those 230 kV transmission systems will serve as the "back-bone" of Laos's power network system.

The 115 kV transmission lines are considered to play a role in distributing power to the substation with peak loads of around 10 to 100 MW via multiple routes from the 230 kV system or the area of small scale power sources.

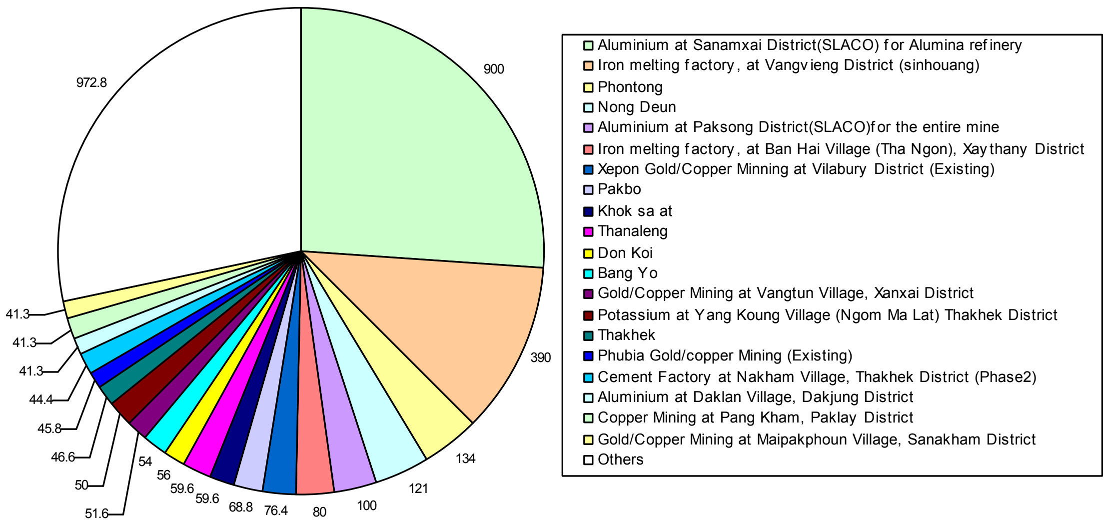



**Figure 7-3 Amount of Power Demand of Substations and Large Power Consumers of Laos in 2020**

**Voltage of Transmission Lines and Their Lengths**

The limitation of power transmission within a short distance is determined via the thermal capacity of conductors. However, in the case of long distance power transmission with a large power flow, the difference of the AC voltage phases become large between the sending end and the receiving end of a transmission line caused by its reactance. In this case the system sometimes becomes unstable due to the difficulty with synchronized operation of connected generators. Thus, when the length of the power transmission line is large, the limitation of power transmission determined via the system stability tends to become smaller than the limitation of the thermal capacity of conductors. A stability analysis requires a precise simulation of the dynamic behavior of generators and the model of generators and their control system. However, as a rough estimation of the stable power transmission abilities, sometimes the methodology of using SIL (Surge Impedance Load that means the amount of power able to be transmitted without voltage drops) is applied. For example, the following target is discussed.

(Source: Analytical Development of Loadability Characteristics for EHV and UHV Transmission Lines," R.D. Dunlop, R. Gutman and P.P. Marchenko, IEEE Transactions on Power Apparatus and Systems, Vol. PAS-98, No. 2, March/April 1979.)

SIL of 230 kV transmission line: 132 MW

Limitation of stable power transmission (per circuit)

60 miles (around 100 km): 2.7 times of SIL, around 356 MW
100 miles (around 160 km): 2 times of SIL, around 264 MW
200 miles (around 320 km): 1.3 times of SIL, around 170 MW
300 miles (around 480 km): 1 times of SIL, around 132 MW

SIL of the 500 kV transmission line: 910 MW

Limitation of stable power transmission (per circuit)

60 miles (around 100 km): 2.7 times of SIL, around 2,547 MW
100 miles (around 160 km): 2 times of SIL, around 1,820 MW
200 miles (around 320 km): 1.3 times of SIL, around 1,183 MW
300 miles (around 480 km): 1 times of SIL, around 910 MW

The load of SLACO is 900 MW and its power supply requires many circuits of 230 kV transmission lines resulting in an uneconomical system. The power supply to SLACO requires 500 kV class transmission lines.

In general, the DC (direct current) transmission line is cheaper than the AC transmission line. In case of applying the transmission line with a large distance such as more than 1,000 km, it is said that the cost saving achieved by DC transmission lines becomes more than the cost of installation of AC-DC converter stations. The power transmission from hydropower stations with extremely large distance often uses DC transmission system.

# Chapter 8 Scenarios of Power System Plan in South Region

## 8.1 Power Development Scenarios

The four scenarios of power development were set out through the discussion of DOE and EDL regarding the existence of the M Kaleum thermal power plant, hydropower plants located at Mekong Main River, Xekong 4&5, Nam Khon 1 hydropower stations and SLACO as stated in Chapter 6. According to the DOE's opinion, although there are two hydropower stations planned at the Mekong Main River, Thakho and Don Sahong, both of them will be developed and if its development is realized, Don Sahong hydropower station will be developed. Thus, all the cases do not take into consideration the development of Thakho. The power development scenarios are shown in Table 4-2.

Via discussions with the DOE and EDL, in the case of insufficient power sources in the South region, SLACO in the Attepeu province was assumed to be supplied directly from China via 500 kV transmission lines or DC lines. When surplus power becomes too large to export via the existing interconnection to EGAT, the power exports to China or Cambodia was assumed possible to be possible. Figure 8-1 shows the Target Area and the locations of the power stations and the large power consumers in the South region described in the PDP.

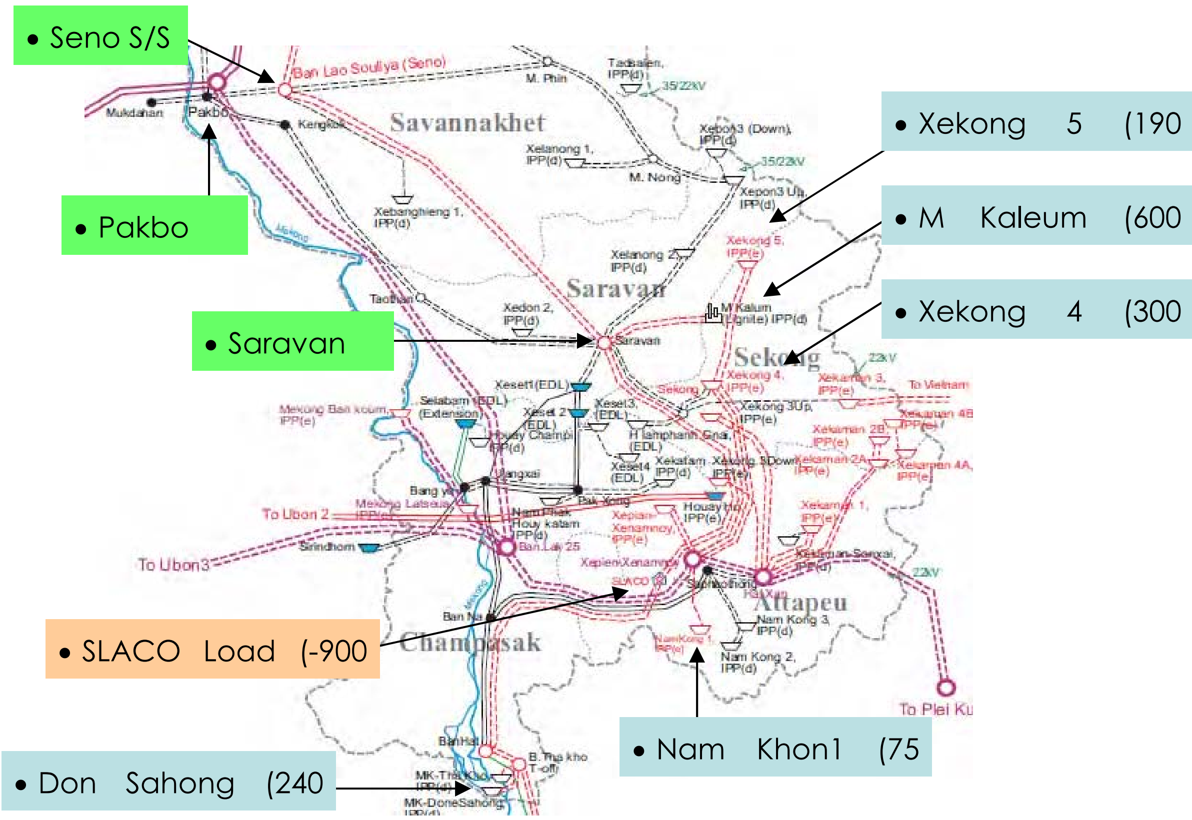



Figure 8-1 Location of Power Stations and Large Power Consumers

## 8.2 Cases of Power Network System Plans

Two cases of power network system plans corresponding with the power development scenarios were set out to examine the justification of the 115 kV Pakbo-Saravan transmission line as follows.

- TA: Construction of 115 kV Pakbo-Saravan in 2015
- TB: Construction of 230 kV Seno-Saravan in 2015 instead of 115 kV Pakbo-Saravan

The power flow limitations from the other regions to the Target Area were set out as shown in Table 8-1 from the viewpoints of the thermal capacity of transmission lines. The power flow limitations restricted via the system stability were set out as shown in Table 8-2 which is explained in the latter sections.

**Table 8-1 Power Flow Limitation from Other Regions to Target Area**

| Transmission line | Limit |
|---|---|
| EGAT- Thakhek 2 circuits + EGAT-Pakbo 2 circuits | 160 MW |
| 115 kV Pakbo-Saravan 2 circuits | 100 MW |
| 115 kV Pakxan-Thakhek 2 circuits | 100 MW |

**Table 8-2 Power Flow Limitation from Other Regions to Target Area (Restriction by Transient Stability)**

| Transmission line | Limit |
|---|---|
| 115 kV Pakbo-Saravan 2 circuits + 230 kV Seno-Saravan 2circuits (operated at 115 kV) | 250 MW |
| 230 kV Seno-Saravan 2circuits | 250 MW |

In this study, through the discussion with DOE and EDL, the deficit in power was assumed to be compensated by imported power from EGAT via the existing interconnections around Vientiane and from China via the newly constructed transmission lines.

## 8.3 Study Cases

### 8.3.1 Application of Case TA to Case G1 (Construction of the 115 kV Pakbo-Saravan Transmission Line in 2015)

In Case G1, although without Xekong 4, 5 and Nam Khon 1, surplus power occurs in the South 2 area due to a lack of SLACO of 900 MW. In 2015, the deficit in power in the Target Area will be eliminated by power transmission via the 115 kV Pakbo-Saravan transmission line from the South 2 area simultaneously by transferring power from the 115 kV EGAT-Thakhek/Pakbo interconnections and the 115 kV Pakxan–Thakhek transmission line.

In 2018, the 230 kV designed Seno–Saravan transmission line will be constructed in parallel with the 115 kV Pakbo–Saravan transmission line to correspond with an increase in the power supply from the South 2 area to the Target Area where the deficit in power will be increased. Table 8-3 shows the amount of surplus power in 2015, 2018 and 2020 in each area and Figure 8-2 illustrates the image of the correspondence by Case TA to the Case G1.

**Table 8-3 Regional Surplus Power of Case G1**

(Unit: MW)

| Case | Projects | Generation | Area | 2015 | 2018 | 2020 |
|---|---|---|---|---|---|---|
| Case G1 | M Kaleum ✔; Xekong 4, 5 & Nam Khon 1; Mekong ✔; SLACO | Full Gen. | China | | | |
| | | | N&C | 434.8 | 2,089.7 | 2,480.0 |
| | | | Target Area | -288.8 | -245.6 | -270.2 |
| | | | S2(Excl.SLACO) | 874.2 | 1,303.9 | 1,336.3 |
| | | Firm Gen. | China | | | |
| | | | N&C | -190.6 | 383.2 | 653.4 |
| | | | Target Area | -311.3 | -363.8 | -388.4 |
| | | | S2(Excl.SLACO) | 586.5 | 809.2 | 841.6 |

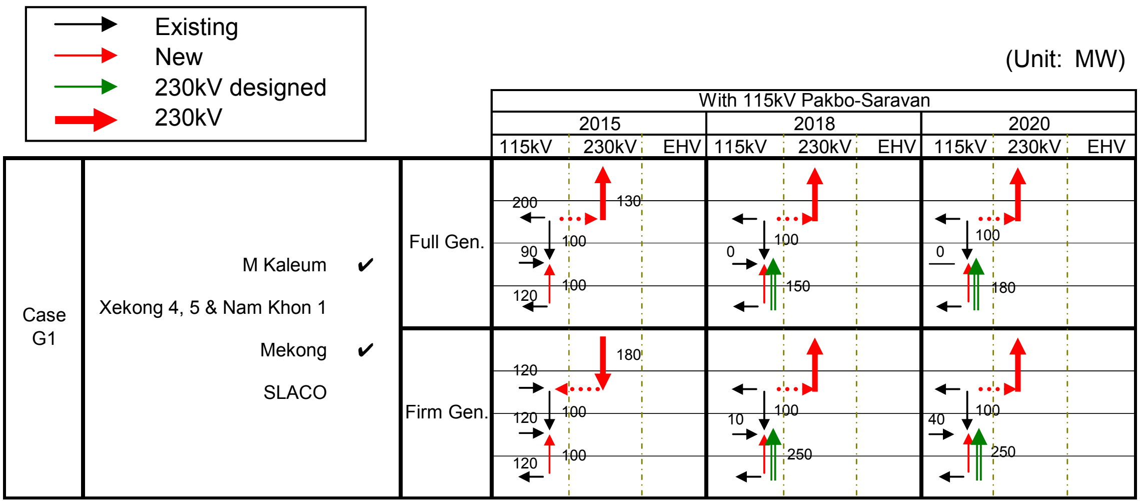



**Figure 8-2 Transmission Lines in Case TA corresponding to Case G1**

### 8.3.2 Application of Case TB to Case G1 (Construction of the 230kV Seno-Saravan Transmission Line Instead of the Construction of the 115 kV Pakbo-Saravan Transmission Line in 2015)

In 2015, the deficit in power in the Target Area will be eliminated via power transmission from the South 2 area by the 230 kV designed Seno-Saravan transmission line operated at 115 kV simultaneously by taking power from the 115 kV EGAT - Thakhek/Pakbo interconnections and the 115 kV Pakxan – Thakhek transmission line. In 2018, the 230/115 kV transformers will be installed at the Seno and Saravan to upgrade the Seno – Saravan transmission line to 230 kV and increase the capacity of the transmission line to correspond with an increase in the power supply from the South 2 area to the Target Area where the deficit in power will be increased. Figure 8-3 illustrates the image of the correspondence by Case TB to Case G1.

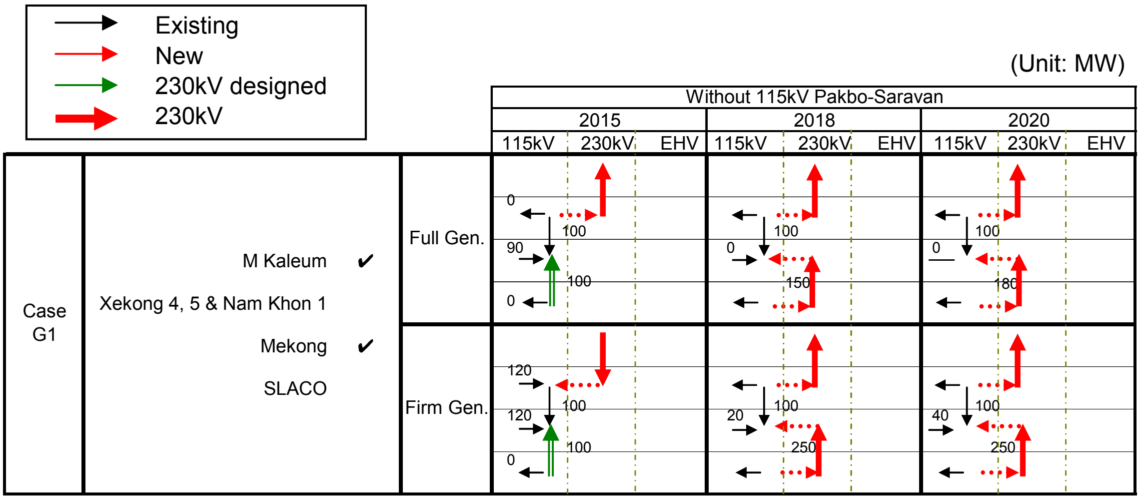



**Figure 8-3 Transmission Lines in Case TB corresponding to Case G1**

### 8.3.3 Application of Case TA (1) to Case G2 (Construction of 115 kV Pakbo-Saravan Transmission Line in 2015) (Deficit in Power in S1 and S2 in 2015 Eliminated by Supplying via the Transmission Line to SLACO)

In Case G2, although with Xekong 4, 5 and Nam Khon 1, the deficit in power occurs in the South 2 area due to a lack of the M Kaleum thermal power station and with SLACO of 900 MW. Thus, SLACO is supplied from other areas via the exclusive 500 kV or DC transmission lines.

**Table 8-4 Regional Surplus Power of Case G2 Including SLACO**

(Unit: MW)

| | | | | | 2015 | 2018 | 2020 |
|---|---|---|---|---|---|---|---|
| Case G2 | M Kaleum | | Full Gen. | China | | | |
| | Xekong 4, 5 & Nam Khon 1 | ✔ | | N&C | 434.8 | 2,089.7 | 2,480.0 |
| | Mekong | ✔ | | Target Area | -288.8 | -245.6 | -270.2 |
| | SLACO | ✔ | | S2(Incl.SLACO) | 174.2 | 1,168.9 | 1,201.3 |
| | | | Firm Gen. | China | | | |
| | | | | N&C | -190.6 | 383.2 | 653.4 |
| | | | | Target Area | -311.3 | -363.8 | -388.4 |
| | | | | S2(Incl.SLACO) | -213.6 | -312.9 | -280.5 |

All the areas will have a deficit in power during the dry season in 2015. In this case, the transmission line for SLACO will be constructed from other areas, the deficit of power is assumed to be eliminated by supplying via the transmission line that also supplies the portion of the deficit in power in the South 1 area and the interconnection between South 1 and South 2 will transmit the power from South 2 to South 1. In 2015, the deficit in power in the Target Area will be eliminated via power transmission from the 115 kV Pakbo-Saravan transmission line from the South 2 area simultaneously by taking power via the 115 kV EGAT-Thakhek/Pakbo interconnections and the 115 kV Pakxan–Thakhek transmission line.

**Table 8-5 Regional Surplus Power in Case G2 Excluding SLACO**

(Unit: MW)

| | | | | 2015 | 2018 | 2020 |
|---|---|---|---|---|---|---|
| Case G2 | M Kaleum<br>Xekong 4, 5 & Nam Khon 1 ✔<br>Mekong ✔<br>SLACO ✔<br>(Note: SLACO is assumed to be supplied directly from China) | Full Gen. | China | | | |
| | | | N&C | 434.8 | 2,089.7 | 2,480.0 |
| | | | Target Area | -288.8 | -245.6 | -270.2 |
| | | | S2(Excl.SLACO) | 174.2 | 1,168.9 | 1,201.3 |
| | | Firm Gen. | China | | | |
| | | | N&C | -190.6 | 383.2 | 653.4 |
| | | | Target Area | -311.3 | -363.8 | -388.4 |
| | | | S2(Excl.SLACO) | -113.6 | 587.2 | 619.6 |

In 2018, the 230 kV designed Seno–Saravan transmission line will be constructed in parallel with the 115 kV Pakbo–Saravan transmission line to correspond with an increase in the power supply from the South 2 area to the Target Area where a deficit in power will be increased. Table 8-5 shows the surplus power in 2015, 2018 and 2020 in each area and Figure 8-4 illustrates the image of the correspondence by Case TA to Case G2.

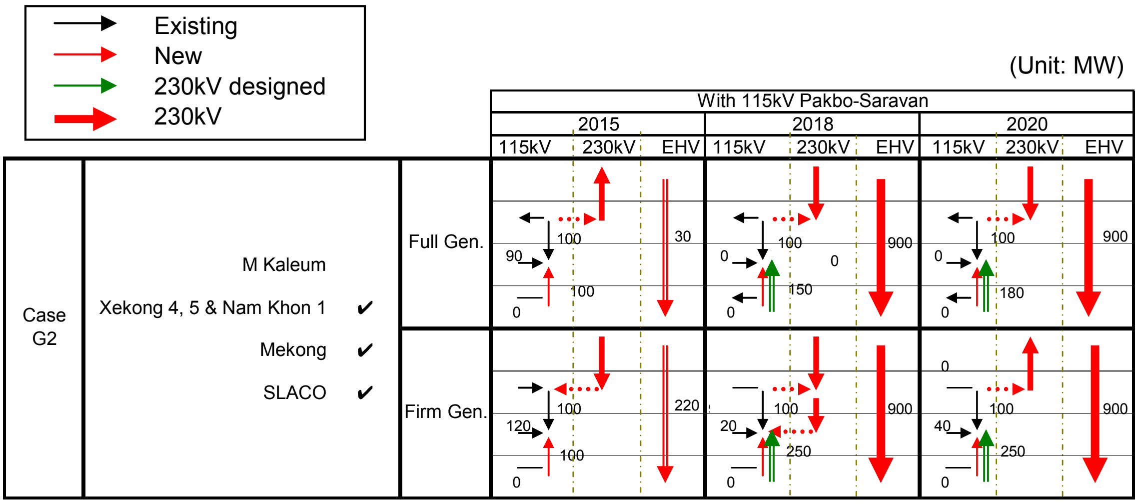



**Figure 8-4 Transmission Lines in Case TA (1) corresponding to Case G2**

### 8.3.4 Application of Case TA (2) to Case G2 (Construction of 115 kV Pakbo-Saravan Transmission Line in 2015) (Deficit in Power in S1 and S2 in 2015 Eliminated by Supplying via the Interconnection from EGAT)

SLACO is supplied from other areas via the exclusive 500 kV or DC transmission lines in the same manner as in the previous case (1). This case assumed that the deficit in power in S1 and S2 in 2015 would be eliminated by supplying through the interconnection from EGAT. The newly expanded interconnections were assumed between EGAT and S1.

The interconnection between South 1 and South 2 will transmit the power from South 1 to South 2 in 2015. In 2018, the deficit in power in Target Area will be eliminated by power transmission by the 115 kV Pakbo-Saravan transmission line from South 2 area.

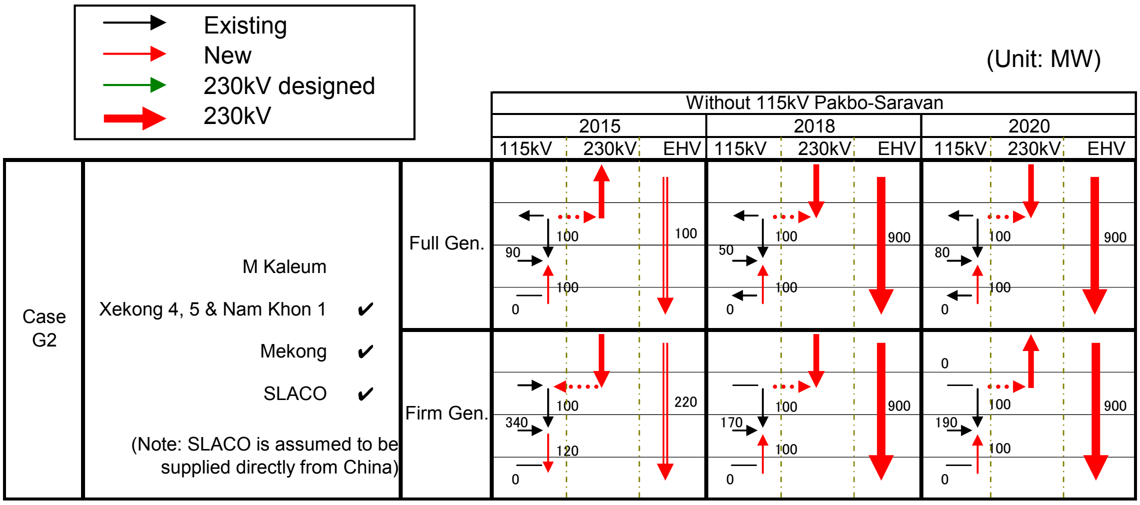



**Figure 8-5 Transmission Lines in Case TA (2) corresponding to Case G2**

### 8.3.5 Application of Case TB (1) to Case G2 (Construction of 230kV Seno-Saravan Transmission Line Instead of Construction of 115 kV Pakbo-Saravan Transmission Line in 2015) (Deficit in Power in S1 and S2 in 2015 Eliminated by Supplying via the Transmission Line to SLACO)

In 2015, South 2 is supplied from other areas via the exclusive 500 kV or DC transmission lines to SLACO, and the deficit in power in the Target Area will be eliminated via power transmission from the South 2 area by the 230 kV designed Seno-Saravan transmission line operated at 115 kV simultaneously by taking power via the 115 kV EGAT - Thakhek/Pakbo interconnections and the 115 kV Pakxan – Thakhek transmission line. In 2018, the 230/115 kV transformers will be installed at Seno and Saravan to upgrade the Seno – Saravan transmission line to 230 kV and increase the capacity of the transmission line to correspond with an increase in the power supply from the South 2 area to the Target Area where the deficit in power will be increased. Figure 8-6 illustrates the image of the correspondence by Case TB to the Case G2.

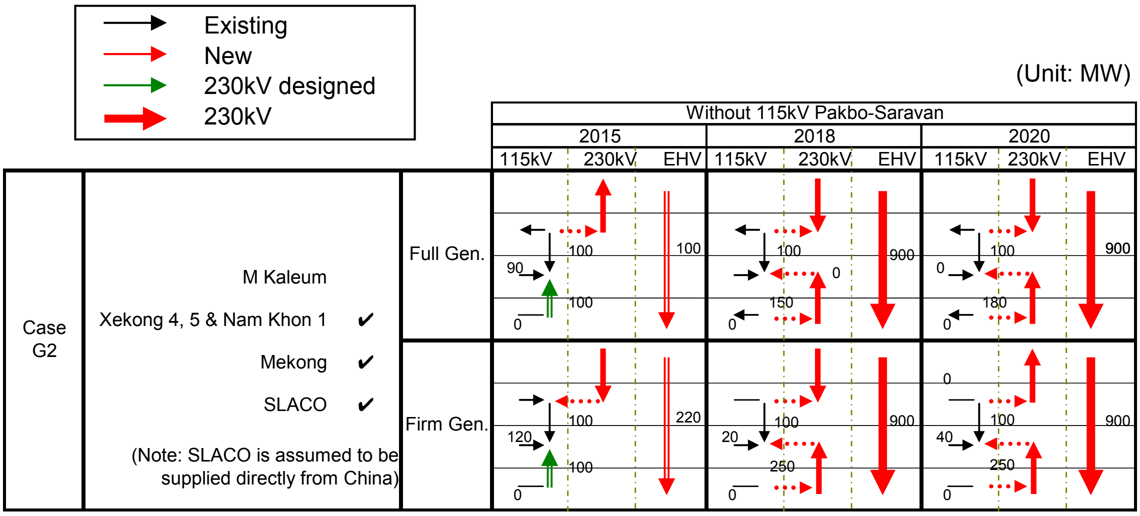



**Figure 8-6 Transmission Lines in Case TB (1) corresponding to Case G2**

### 8.3.6 Application of Case TB (2) to Case G2 (Construction of 230kV Seno-Saravan Transmission Line Instead of Construction of 115 kV Pakbo-Saravan Transmission Line in 2015) (Deficit in Power in S1 and S2 in 2015 Eliminated by Supplying via the Interconnection from EGAT)

This case assumed that the deficit in power in S1 and S2 in 2015 would be eliminated by supplying through the interconnection from EGAT. The newly expanded interconnections were assumed between EGAT and S1.

The interconnection between South 1 and South 2 will transmit the power from South 1 to South 2 in 2015. In 2018, the deficit in power in Target Area will be eliminated by power transmission by the 115 kV Pakbo-Saravan transmission line from South 2 area.

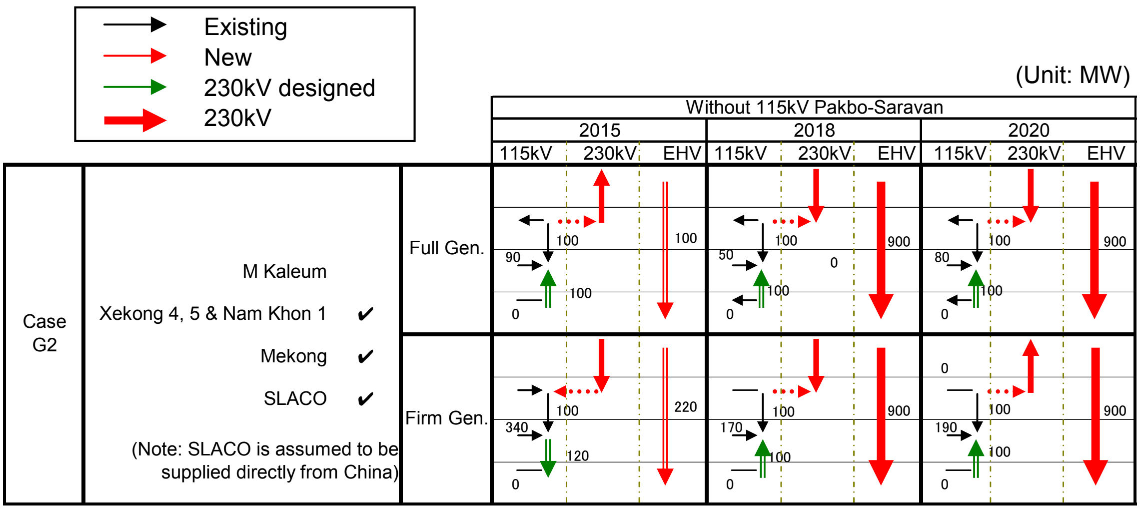



**Figure 8-7 Transmission Lines in Case TB (2) corresponding to Case G2**

The way of correspondence with Case G3 would be similar to Case G1 and Case G2 would be similar to Case G4. Especially in 2015, the deficit in power of S2 in Case G2 and G4 are the same because the commissioning year of Xekong 4&5, Nam Khon1 and Mekong is 2016. The methodologies of the interconnections between South 1 and South 2 up to 2020 become the following in correspondence with Case G1 to Case G4.

- Case TA

2015: 115 k Pakbo-Saravan Transmission Line

2018: 230 kV designed Seno-Saravan Transmission Line operated at 115 kV

- Case TB

2015: 230 kV designed Seno-Saravan Transmission Line operated at 115 kV

2018: Installation of 230/115 kV transformers at Seno and Saravan to upgrade Seno-Saravan transmission line to 230 kV

# Chapter 9 Power System Analysis of Central-South Transmission System Development

## 9.1 Conditions for Analysis

This study carries out a power system analysis by using PSS/E which is used in EDL according to the transmission system development scenario described in Chapter 8

The transmission system development plan of EDL must satisfy the N-1 criteria which does not allow any power outages under the single failure of power equipment such as the transmission line and the transformer. This study adheres to the same criteria and creates a development plan taking into account the loss of high voltage transmission lines in the target area.

The following table shows the allowable voltage ranges under the normal and abnormal conditions in the planning criteria. This study follows the voltage criteria under both conditions. The reactive power compensation equipment (shunt capacitor for voltage rise and shunt reactor for voltage reduction) which controls the system voltage can be installed with relative ease than other major equipment and on a per-need basis. Furthermore, the voltage largely depends on the power flow in the lines. Therefore, this study allows PSS/E to place the shunt capacitors automatically.

**Table 9-1 Voltage Range of Planning Criteria**

| Voltage | Normal Condition | N-1 Contingency |
|---|---|---|
| 230kV | 95 – 105 % | 92 – 108 % |
| 115kV | 95 – 105 % | 92 – 108 % |

The next table describes the fault current limits of each voltage level. The transmission system development plan must satisfy the criteria under the fault conditions. There are two types of fault currents to be calculated. One is the three-phase short circuit fault current and the other is the line to ground fault current. The PSS/E data provided by EDL doesn’t include the zero-phase data which is necessary for the line to ground fault current calculation. Therefore, this study didn’t analyze the line to ground fault current. In general, the line to ground fault current is smaller than the short circuit current, but if the power plants are electrically-closely located around the fault point or the transmission system around the fault pint consists of lots of power cables, the line to the ground fault current can be higher than the short circuit fault current. The target area of this study includes the area of hydro power sources, but it is assumed that the line to ground fault current is less than the criteria according to simulation results shown later.

**Table 9-2 Maximum Fault Current**

| Voltage | Max. Fault Current (kA) |
|---|---|
| 230kV | 40kA / 50kA |
| 115kV | 25kA / 31.5 kA |

As mentioned in Chapter 8, it is assumed that the incoming power flow into the target area in the dry season is higher than that of the rainy season. This increases the line power flow and makes the system severe. Therefore, the study analyzed the system during the dry season.

PSS/E data was provided by EDL and the Consultant gave necessary changes and corrections to this data. The following table shows the newly input line impedances in the target area. It is assumed that the unit impedance of the 115kV Pakbo-Nongdeun-Taothan-Saravan transmission line is the same as that of the 115kV Pakxan-Thakhek transmission line which was financed by Japan. The 2×ACSR 610mm$^2$ line is assumed to be the transmission line of the 230kV Seno-Saravan in consideration of the required transmission capacity.

**Table 9-3 Impedance of Transmission Lines in Target Area**

| Voltage | From | To | Km | R(pu) | X(pu) | Y(pu) | MVA | Note |
|---|---|---|---|---|---|---|---|---|
| 115kV | Pakbo | Nongdeun | 5.0 | 0.0050 | 0.0165 | 0.0021 | 185 | |
| 115kV | Nongdeun | Taothan | 147.0 | 0.1338 | 0.4410 | 0.0559 | 120 | |
| 115kV | Taothan | Saravan | 66.3 | 0.0603 | 0.1989 | 0.0252 | 120 | |
| 115kV | Seno | Nongdeun | 40.0 | 0.0364 | 0.1200 | 0.0152 | 185 | |
| 115kV | Seno | Saravan | 215.0 | 0.0379 | 0.4434 | 0.1183 | 180 | 230kV designed |
| 230kV | Seno | Saravan | 215.0 | 0.0095 | 0.1108 | 0.4732 | 860 | |

The "MVA" in Table 9-3 refers to the thermal capacity of each transmission line. When the transmission line length is short, the maximum transmission capacity is equivalent to the thermal capacity. However, especially for the long-distance transmission line, the transmission capacity constraint determined via the transient stability should be considered, since it will be much lower than that of the thermal capacity. An example is shown later in this chapter.

## 9.2 Power Flow Control

The import/export power flows are controlled by the phase shifter in this study in order to achieve the power flow conditions illustrated in the previous chapter. EDL also discussed the power flow control via the phase shifter in their PDP 2010-2020.

The target area will experience a power shortage. On the other hand, the southern area has lots of potentials of power sources. There is no transmission line available to transmit power from the south to the target area. Hence, it is assumed that the target area imports the power from Thailand if necessary and surplus power is exported to Cambodia.

The power flow of the DC system can be controlled, but it is difficult to control the power flow of the AC system, since the power flow of the AC system obeys Ohm's law. This implies that the large power flow is found in the law impedance areas, whereas the small power flow is found in the high impedance areas, regardless of the thermal capacity of each line.

The system of EDL is connected to EGAT system at some points. According to the aforementioned electricity characteristics, EDL will experience a loop flow, which means the power generated in Laos is supplied to the customer in Laos via the EGAT system. Imported power prices are higher than that of exported power, and this is economically not beneficial for EDL.

The large interconnected system such as the European network and USA network face the same problem and the power flow control is one of the major issues that need to be solved. Recently, the phase shifter or the phase shifting transformer has been installed in the system to control the direction and amount of the power flow by changing the phase angle. This enables EDL to control power imports from Thailand and power exports to Cambodia.

The general phase angle range of the phase shifter is –30 to +30 degree. The angle difference between EDL and the Thailand/Cambodia system should be within a practical range for flexible power flow control (The large angle difference under normal conditions is not preferable.) The careful discussion and study is necessary to connect both systems with the phase shifter.

## 9.3 Power Supply to Taothan Area by 22kV Distribution Line from Saravan S/S

The power demand of the Taothan substation is assumed to be 4.3 MW according to the demand forecast by EDL. Case TB assumes that the 230kV Seno-Saravan transmission line and the power supply of the Taothan area via the 22kV distribution line in consideration of its demand scale and its inexpensive construction costs compared to the 115kV transmission line.

EDL uses the ACSR Wolf 150mm$^2$ conductor as one of the standard distribution lines and the following table shows the study conditions used in the preliminary study to obtain the required circuit number for the cost estimation of the 22kV distribution line from Saravan to Taothan.

**Table 9-4 Study Conditions for Preliminary Study of 22kV Distribution Line**

| Item | | Condition |
|---|---|---|
| 22kV Voltage Criteria | Normal | 95% – 105% (0.95 – 1.05 pu) |
| | N-1 Contingency | 90% – 105% (0.90 – 1.05 pu) |
| 22kV Distribution Line | Conductor | ACSR Wolf (150mm$^2$) |
| | Impedance | R: 0.224Ω/km / X: 0.328Ω/km |
| | Capacity | 12.8MVA/circuit |
| Target Area | Section | Saravan-Taothan |
| | Length | 66.3(km) |
| | Power Factor | 80% at sending end of Saravan 22kV Bus |

As shown in Table 9-4, the 22kV distribution line of the ACSR Wolf has a 12.8MVA capacity per circuit and it can transmit power to the Taothan area via double circuits even under the N-1 condition. However, the voltage at the receiving end (Taothan) can't satisfy the voltage criteria in the case of the 22kV double circuits between Saravan and Taothan since the line length is very long considering the voltage level of the 22kV distribution line.

The voltages at the receiving end are 0.953pu under normal conditions and 0.924pu under the N-1 condition when the distribution line has 4 circuits as shown in Table 9-5. It has been concluded that the 4 circuits of the 22kV distribution line are necessary to supply power to Taothan are from the Saravan substation.

**Table 9-5 Required Number of 22kV Distribution Line for Saravan-Taothan**

| No. of circuit | Capacity (MVA) | Voltage (pu) | | Power (MW) | | Loss | |
|---|---|---|---|---|---|---|---|
| | | Saravan | Taothan | Saravan | Taothan | MW | % |
| 2 | 25.6 | 1.025 | 0.860 | 4.91 | 4.30 | 0.61 | 12.5 |
| 3 | 38.4 | 1.025 | 0.924 | 4.65 | 4.30 | 0.35 | 7.6 |
| 4 | 51.2 | 1.025 | 0.953 | 4.48 | 4.30 | 0.18 | 4.1 |

## 9.4 Power Flow and Voltage Analysis in the Year 2015

The study targets the dry season as the severer assumption as mentioned in section 9.1. This study has developed some scenarios shown in the previous chapter. However, the same power supply-demand balance is assumed in each scenario. Therefore, the following two cases are examined in this study:

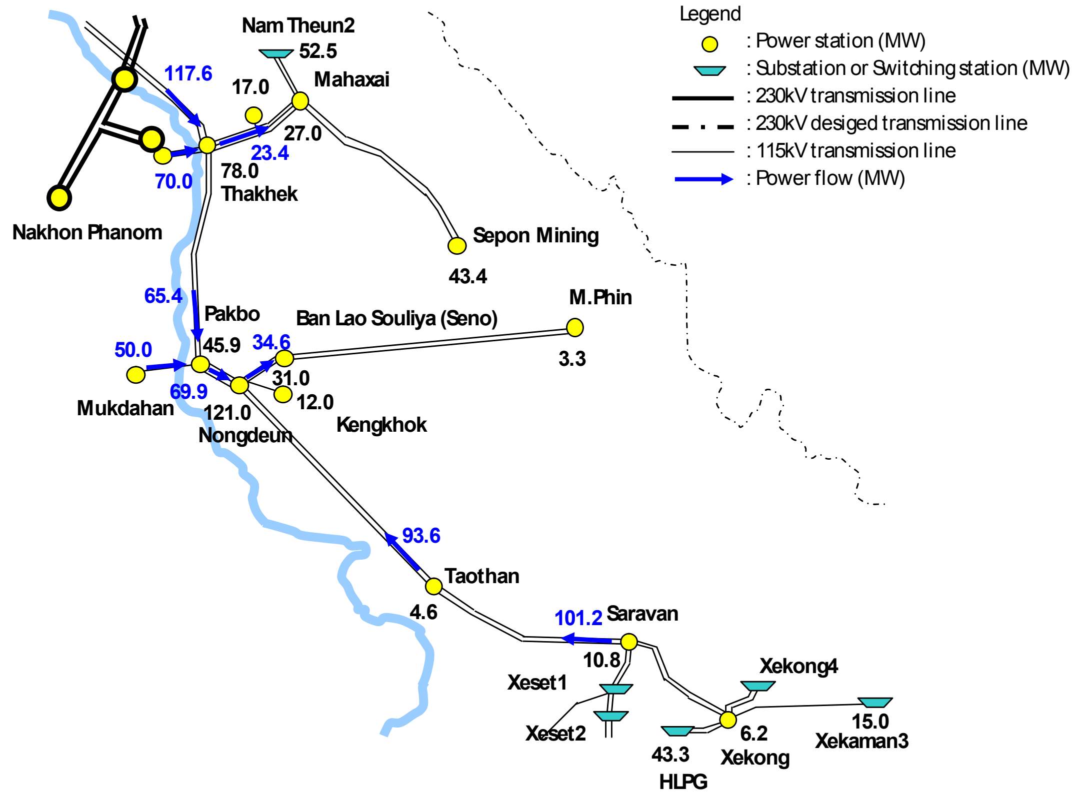
- Case TA: 115kV Pakbo-Nongdeun-Taothan-Saravan 2 circuits
- Case TB: 230kV designed Seno-Saravan 2 circuits operated in 115kV

The simplified power flow and detailed power flow maps are shown in Figure 9-1 to Figure 9-3 . Both Cases satisfy N-1 criteria and voltage criteria.

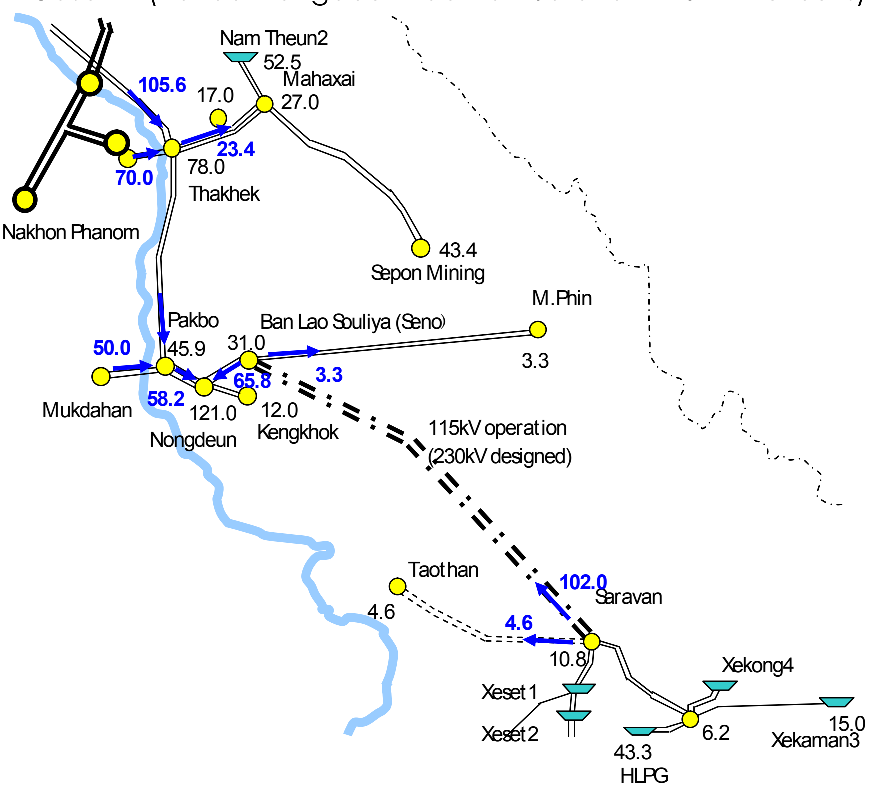
Table 9-6 shows the transmission system losses of the target area in the year 2015. The total system losses of Cases TA and TB are 19.6 MW and 10.4 MW, respectively. Case TA produces more losses than Case TB, because the impedance of the 115kV Pakbo-Saravan line in Case TA is much higher than that of the 230kV Seno-Saravan line in Case TB. The difference of the losses is considered in the cost calculation of the study.

**Table 9-6 Transmission System Losses of Target Area in the Year 2015**

| Case | Substation | | Power flow (MW) | | Loss (MW) | Loss rate (%) |
|---|---|---|---|---|---|---|
| | From | To | From | To | | |
| TA | Saravan | Taothan | 101.2 | 98.2 | 3.0 | 3.0% |
| | Taothan | Nongdeun | 93.6 | 87.8 | 5.8 | 6.2% |
| | Pakbo | Nongdeun | 69.9 | 69.9 | 0.0 | 0.0% |
| | Nongdeun | Seno | 34.6 | 34.4 | 0.2 | 0.6% |
| | Thakhek | Pakbo | 67.2 | 65.4 | 1.8 | 2.7% |
| | Khonsong | Thakhek | 125.8 | 117 | 8.8 | 7.0% |
| | | **Total** | **492.3** | **472.7** | **19.6** | **4.0%** |
| TB | Saravan | Taothan | 4.6 | 4.6 | 0.0 | 0.0% |
| | Saravan | Seno | 102.0 | 100.0 | 2.0 | 2.0% |
| | Seno | Nongdeun | 65.8 | 65.0 | 0.8 | 1.2% |
| | Pakbo | Nongdeun | 58.2 | 58.2 | 0.0 | 0.0% |
| | Thakhek | Pakbo | 55.0 | 53.8 | 1.2 | 2.2% |
| | Khonsong | Thakhek | 112.0 | 105.6 | 6.4 | 5.7% |
| | | **Total** | **397.6** | **387.2** | **10.4** | **2.6%** |




Case TA (Pakbo-Nongdeun-Taothan-Saravan 115kV 2 circuits)




Case TB (Seno- -Saravan 230kV designed 115kV operated 2 circuits)

**Figure 9-1 Simplified Power Flow Map in Dry Season in the Year 2015**

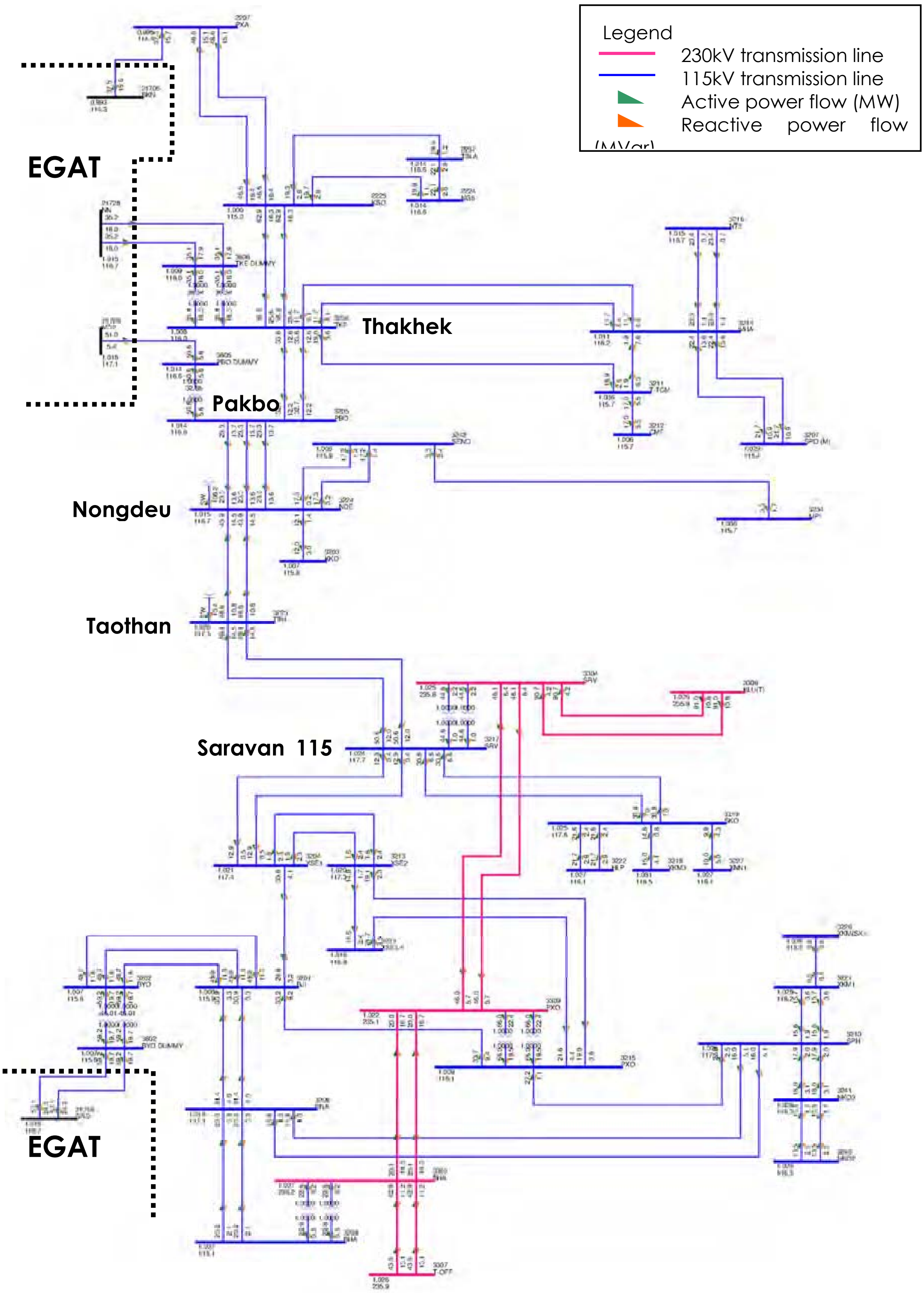



**Figure 9-2 Power Flow Map in Dry Season in the Year 2015 – Case TA**

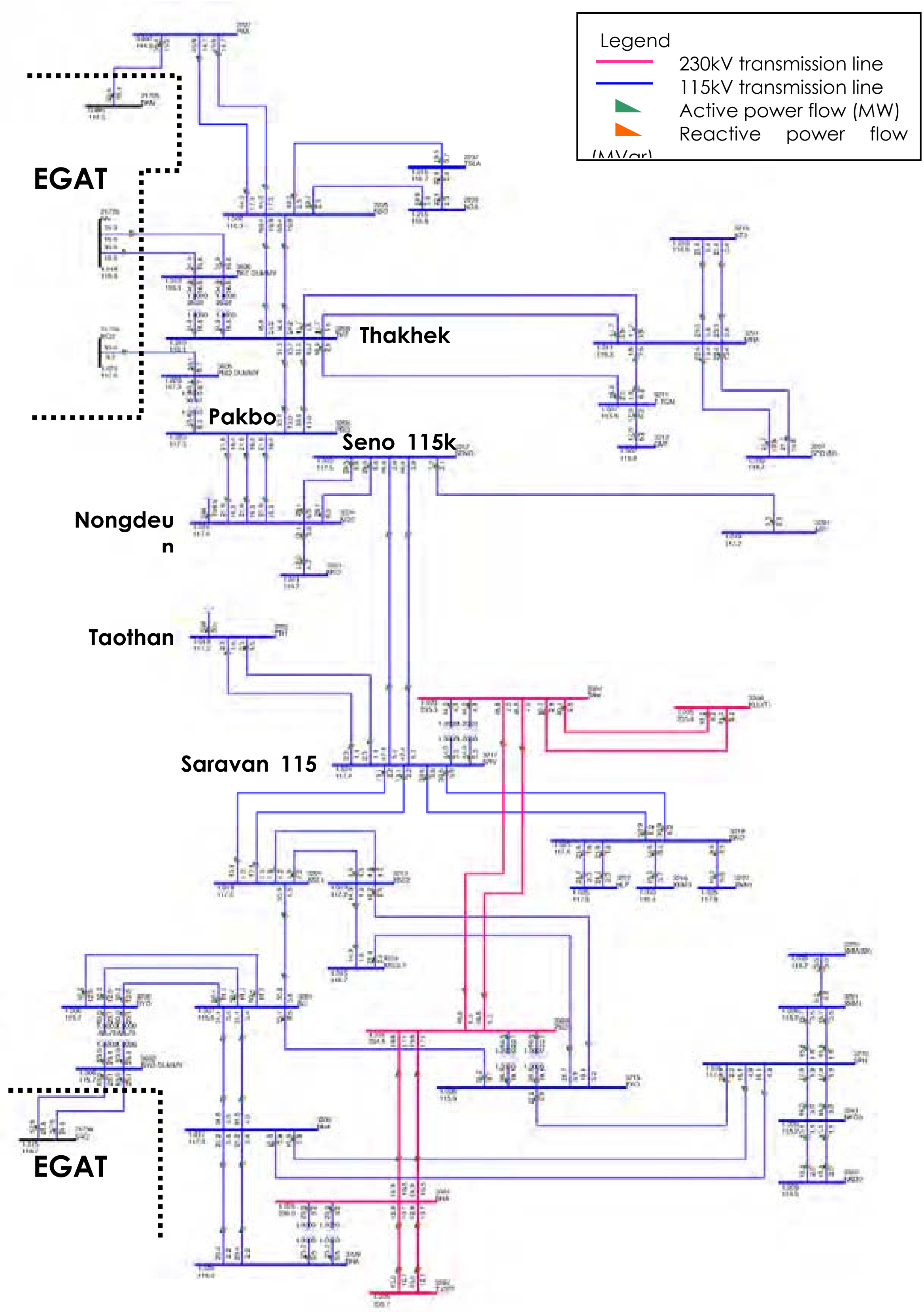



**Figure 9-3 Power Flow Map in Dry Season in the Year 2015 – Case TB**

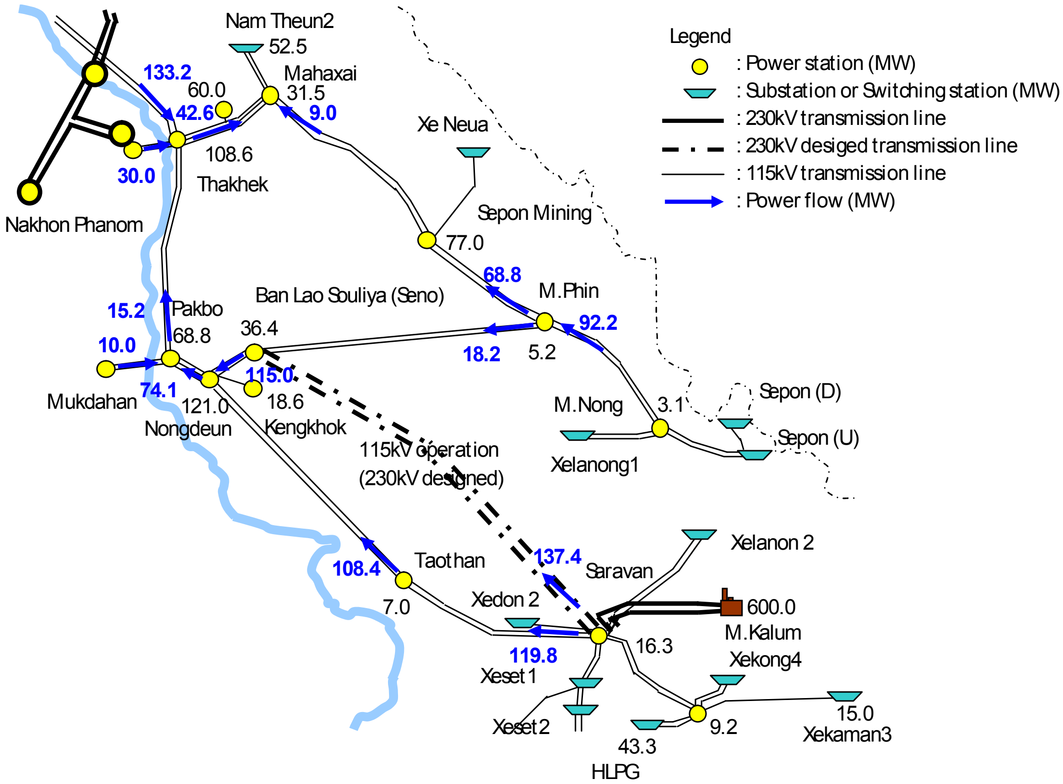
## 9.5 Power Flow and Voltage Analysis in the Year 2020

The study examines the following two cases regardless of the development scenarios illustrated in the previous chapter.

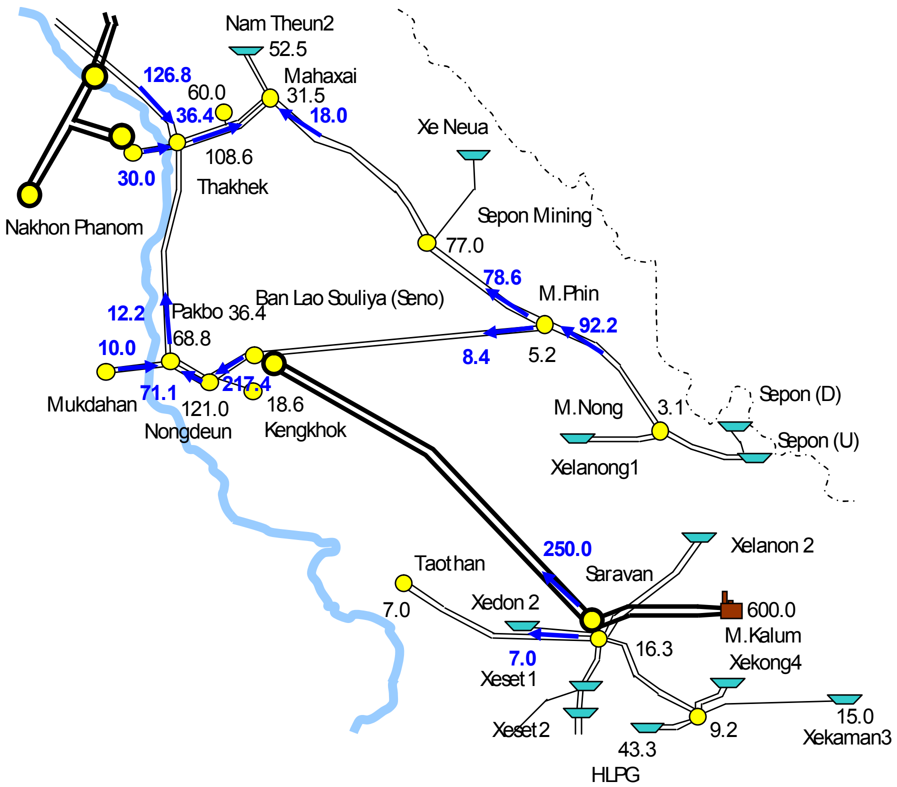
- Case TA: 115kV Pakbo-Nongdeun-Taothan-Saravan 2 circuits
  230kV designed Seno-Saravan 2 circuits operated in 115kV
- Case TB: 230kV Seno-Saravan 2 circuits

The simplified power flow and detailed power flow maps are shown in Figure 9-4 to Figure 9-6. Both Cases satisfy N-1 criteria and voltage criteria.

Figure 9-6 shows the transmission system losses of the target area in the year 2020. Both cases need to transmit 250MW to the target area from Saravan. The total system losses of Case TA and TB are 32.0 MW and 25.0 MW, respectively. Case TA produces more losses than Case TB, because the Seno-Saravan line is operated as the 230kV transmission line and the line impedance is much smaller than that of the 115kV operated line.




Case TA (Pakbo-Nongdeun-Taothan-Saravan 115kV 2 circuits and Seno-Saravan 230kV designed transmission line operated at 115kV 2 circuits)




Case TB (Seno-Saravan 230kV 2 circuits)

**Figure 9-4 Simplified Power Flow Map in Dry Season in the Year 2020**

**Table 9-7 Transmission System Losses of Target Area in the Year 2020**

| Case | Substation | | Power flow (MW) | | Loss (MW) | Loss rate (%) |
|---|---|---|---|---|---|---|
| | From | To | From | To | | |
| TA | Seno | Saravan | 137.4 | 134.0 | 3.4 | 2.5% |
| | Saravan | Taothan | 119.8 | 115.4 | 4.4 | 3.7% |
| | Taothan | Nongdeun | 108.4 | 100.8 | 7.6 | 7.0% |
| | Nongdeun | Pakbo | 74.1 | 74.1 | 0.0 | 0.0% |
| | Seno | Nongdeun | 115.8 | 113.2 | 2.6 | 2.2% |
| | Pakbo | Thakhek | 15.2 | 15.2 | 0.0 | 0.0% |
| | Khonsong | Thakhek | 143.2 | 133.2 | 10.0 | 7.0% |
| | M.Phin | Seno | 18.2 | 18.2 | 0.0 | 0.0% |
| | M.Phin | Sepon M | 68.8 | 65.8 | 3.0 | 4.4% |
| | Sepon M | Mahaxai | 9.0 | 9.0 | 0.0 | 0.0% |
| | Thakhek | Mahaxai | 42.6 | 42.2 | 0.4 | 0.9% |
| | Thakhek | Cement Fact. | 47.1 | 46.6 | 0.5 | 1.1% |
| | Cement Fact. | Mahaxai | 13.5 | 13.4 | 0.1 | 0.7% |
| | | **Total** | **913.1** | **881.1** | **32.0** | **3.5%** |
| TB | Saravan | Taothan | 7.0 | 7.0 | 0.0 | 0.0% |
| | Saravan | Seno | 250.0 | 247.2 | 2.8 | 1.1% |
| | Seno | Nongdeun | 219.1 | 210.9 | 8.2 | 3.7% |
| | Nongdeun | Pakbo | 71.1 | 71.1 | 0.0 | 0.0% |
| | Pakbo | Thakhek | 12.2 | 12.2 | 0.0 | 0.0% |
| | Khonsong | Thakhek | 136.0 | 126.8 | 9.2 | 6.8% |
| | M.Phin | Seno | 8.4 | 8.2 | 0.2 | 2.4% |
| | M.Phin | Sepon M | 78.6 | 75.0 | 3.6 | 4.6% |
| | Sepon M | Mahaxai | 18.2 | 18.0 | 0.2 | 1.1% |
| | Thakhek | Mahaxai | 36.4 | 36.2 | 0.2 | 0.5% |
| | Thakhek | Cement Fact. | 44.1 | 43.6 | 0.5 | 1.1% |
| | Cement Fact. | Mahaxai | 16.5 | 16.4 | 0.1 | 0.6% |
| | | **Total** | **897.6** | **872.6** | **25.0** | **2.8%** |

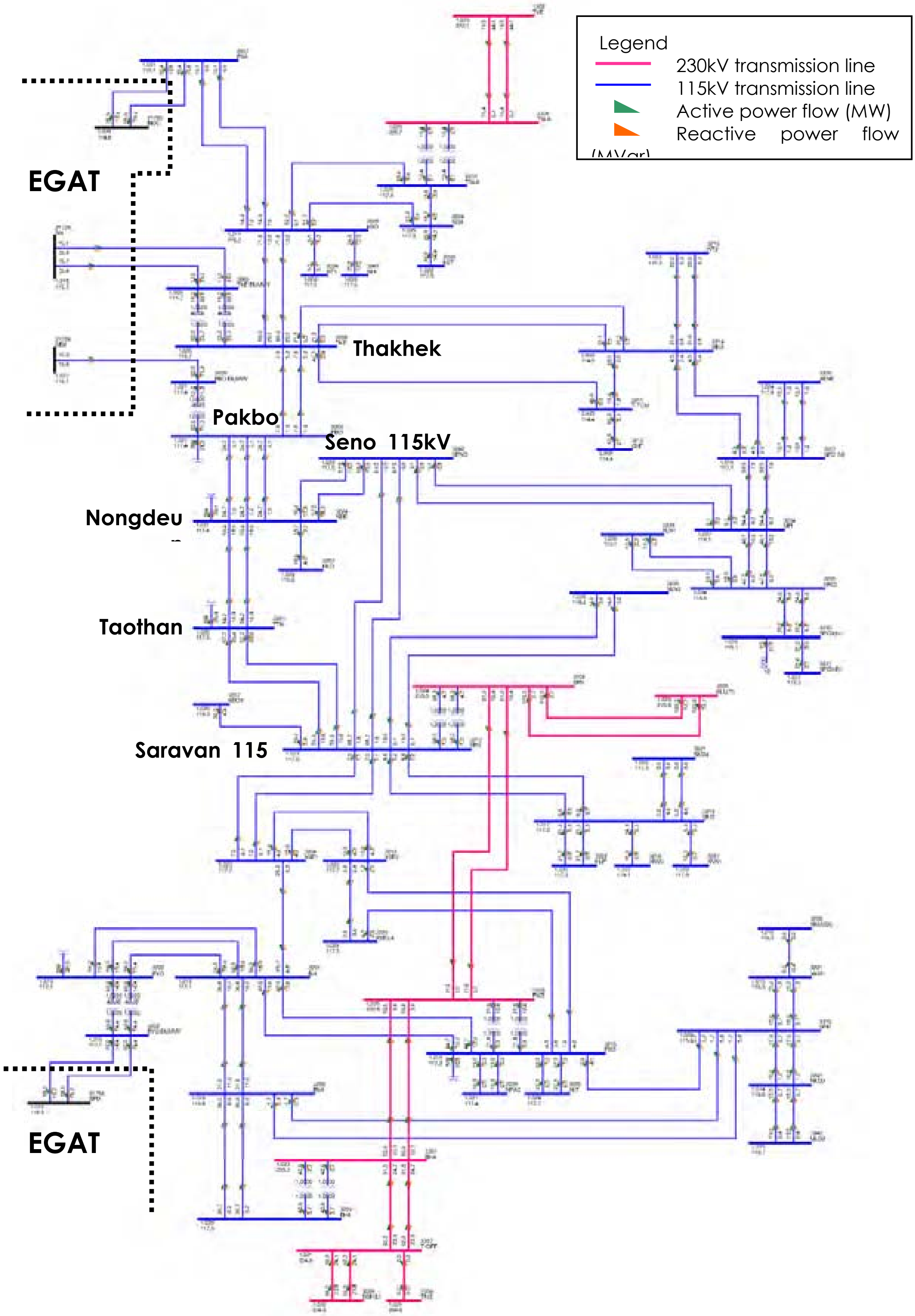



**Figure 9-5 Power Flow Map in Dry Season in the Year 2020 – Case TA**

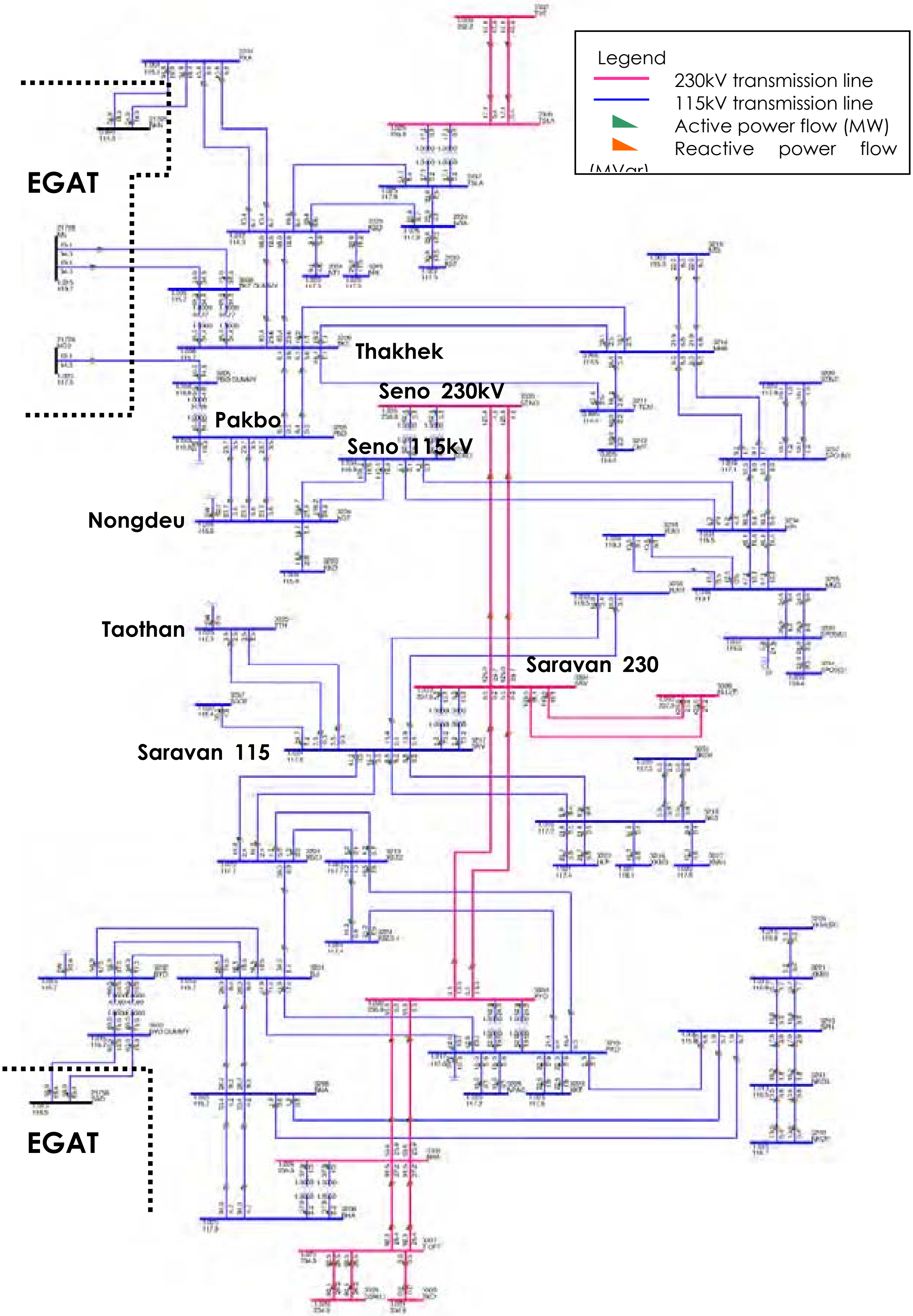



**Figure 9-6 Power Flow Map in Dry Season in the Year 2020 – Case TB**

## 9.6 Fault Current Calculation

As mentioned in section 9.1, the PSS/E data provided by EDL doesn't include the zero sequence impedance which is necessary for the line to ground fault current calculation. Therefore, only the three phase fault is calculated via the PSS/E function of the Automatic Sequence Fault Calculation.

Table 9-8 shows the results of the fault current calculation. As shown in the table, the fault current level of each bus is much less than the maximum fault current limit in both cases in each year.

**Table 9-8 Results of Fault Current Calculation**

(Unit: kA)

| Year | | 2015 | | 2020 | |
|---|---|---|---|---|---|
| Substation | Voltage | Case TA | Case TB | Case TA | Case TB |
| Pakbo | 115kV | 5.6 | 5.7 | 7.2 | 7.3 |
| Nongdeun | 115kV | 5.4 | 5.5 | 7.0 | 7.1 |
| Taothan | 115kV | 3.8 | 2.7 | 4.3 | 3.0 |
| Saravan | 115kV | 5.8 | 5.9 | 8.3 | 7.8 |
| Saravan | 230kV | N/A | N/A | N/A | 4.4 |
| Seno | 115kV | 3.3 | 4.4 | 5.6 | 7.1 |
| Seno | 230kV | N/A | N/A | N/A | 3.5 |

## 9.7 Stability Analysis

The interconnection plans between Savannakhet in South 1 and Saravan in South 2 are as follows:

- 115 kV Pakbo-Saravan transmission line with double circuits of 218.5 km
- 230 kV Seno-Saravan transmission line with double circuits of 215 km

The power flow limitations of those transmission lines with a long length determined by the system stability are smaller than the limitations determined by the thermal capacity of the conductors. In this section, the power flow limitations restricted by the system stability for the aforementioned transmission lines are analyzed by using the simplified model of the system from South 1 to South 2 shown in Figure 9-7 on the PSS/E Software.

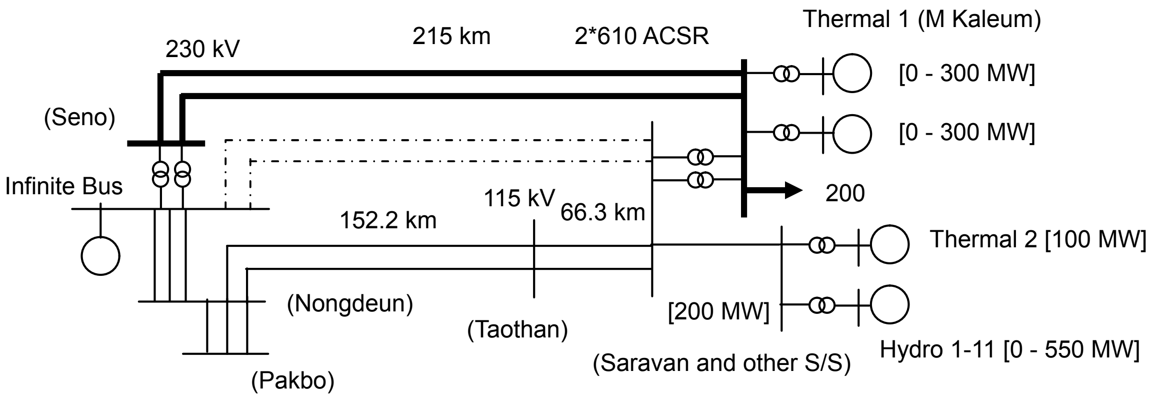



**Figure 9-7 Model for Stability Analysis**

Governors are installed in thermal power plants and the thyristor excitation system is assumed to be at each generator. The capacities of the 230/115 kV substations are adjusted by changing the numbers of the transformers of 200 MVA because of the change in power flow of the transformers for the cases.

System stability was evaluated for the case of a single circuit fault cleared by the circuit breakers 0.1 s after the fault for the 230 kV system or 0.14 s after the fault for 115 kV.

In case of parallel operations of the 115 kV Pakbo-Saravan and the 230 kV Seno-Saravan transmission lines, the system can be kept stable when the total power flow is 250 MW as shown in Figure 9-8. The figure at the left side of Figure 9-9 shows the swing curves of the power outputs of generators illustrating the stable status with damping oscillation going to the nominal power output of the generators, However, when the total amount of power flow becomes 450 MW, as shown in the figure at the right side, the swing curves of the power outputs of the generators doesn't become converged indicating the instability of the system.

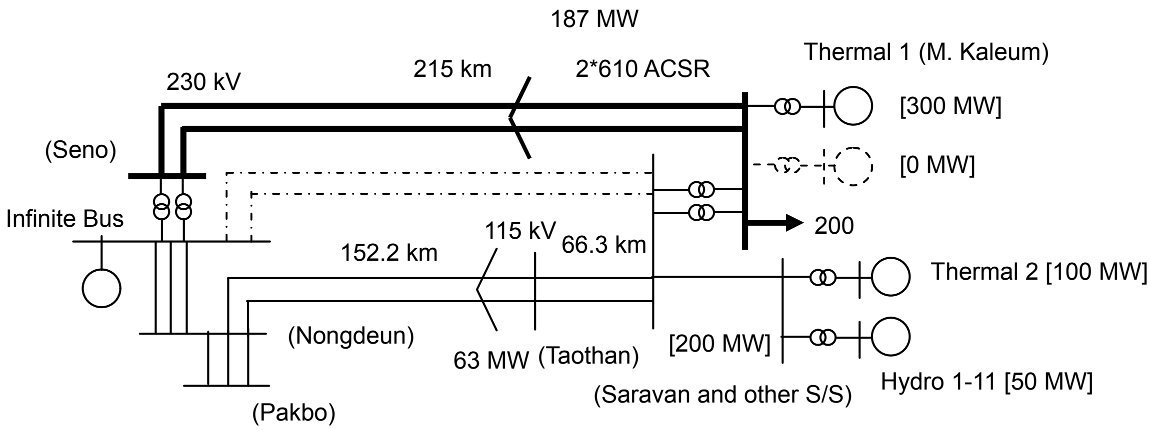



**Figure 9-8 System Model of 230 kV 2 Circuits and 115 kV 2 Circuits with 250 MW Power Transmission**

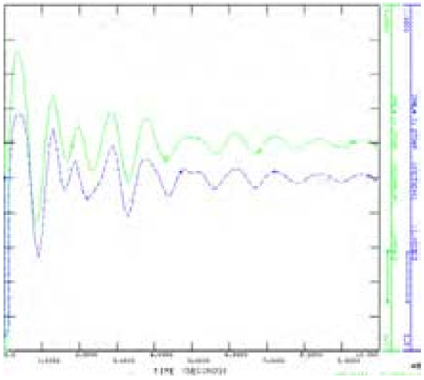


**Figure 9-9 Power Swing Curves in the System of 230 kV 2 Circuits and 115 kV 2 Circuits - Single Circuit Fault on 230 kV Line (250 MW)**

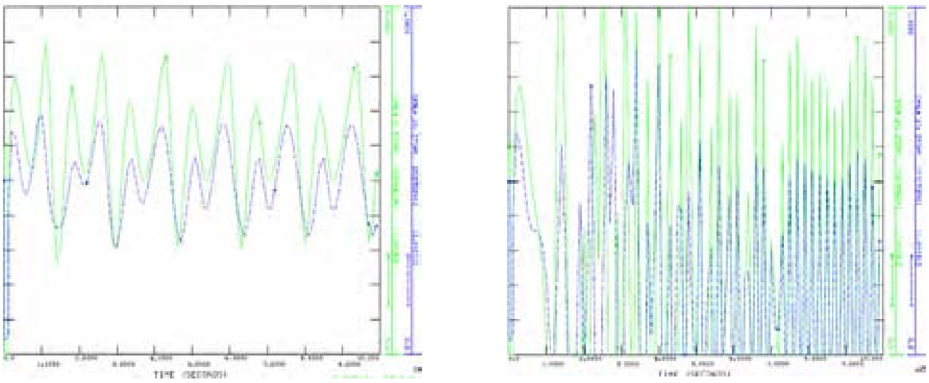


**Figure 9-10 Power Swing Curves in the System of 230 kV 2 Circuits and 115 kV 2 Circuits - Single Circuit Fault on 230 kV (400 MW at left side/450 MW at right side)**

In a similar manner, the system stability for the cases was analyzed. The power flow limitations restricted by the transient stability are summarized in Table 9-9.

**Table 9-9 Power Flow Limitations Restricted by Transient Stability**

| Cases | Power Flow Limitation Restricted by Stability (Total amount of power flow from Saravan to Seno and Pakbo) |
|---|---|
| (1) 115 kV transmission line 2 circuits<br>(2) 230 kV transmission line 2 circuits | 400 MW |
| (1) 115 kV transmission line 2 circuits<br>(2) 230 kV transmission line 2 circuits operated at 115 kV | 250 MW |
| (1) 230 kV transmission line 2 circuits | 250 MW |

# Chapter 10 Candidates of Measures in South 1 Area and Prioritized Project

## 10.1 Candidates of Measures in South 1 Area

Figure 10-1 to Figure 10-4 illustrates the countermeasures against Cases G1 to G4 by Cases TA and TB.

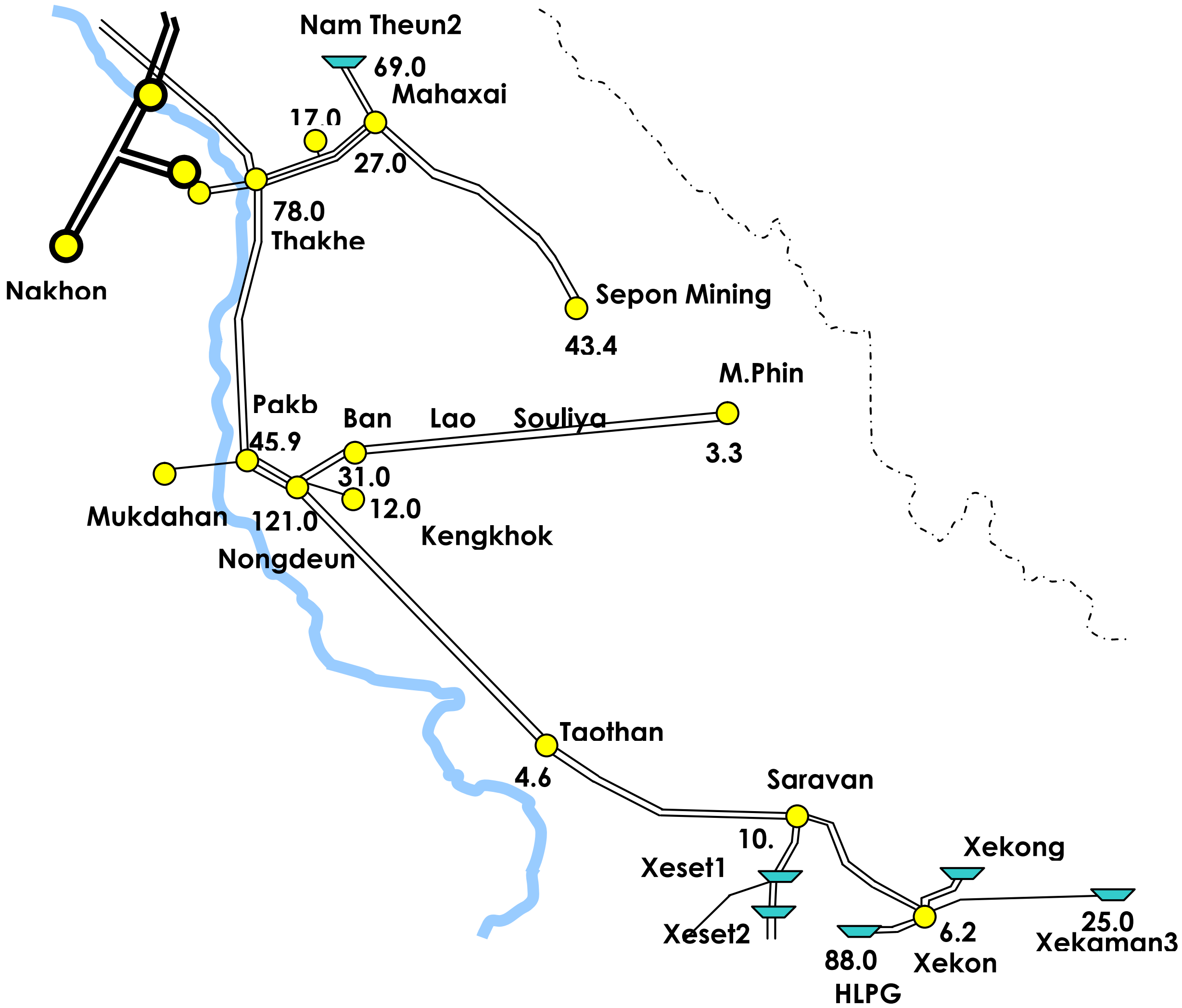



Figure 10-1 Power System of Target Area in Case TA (2015)

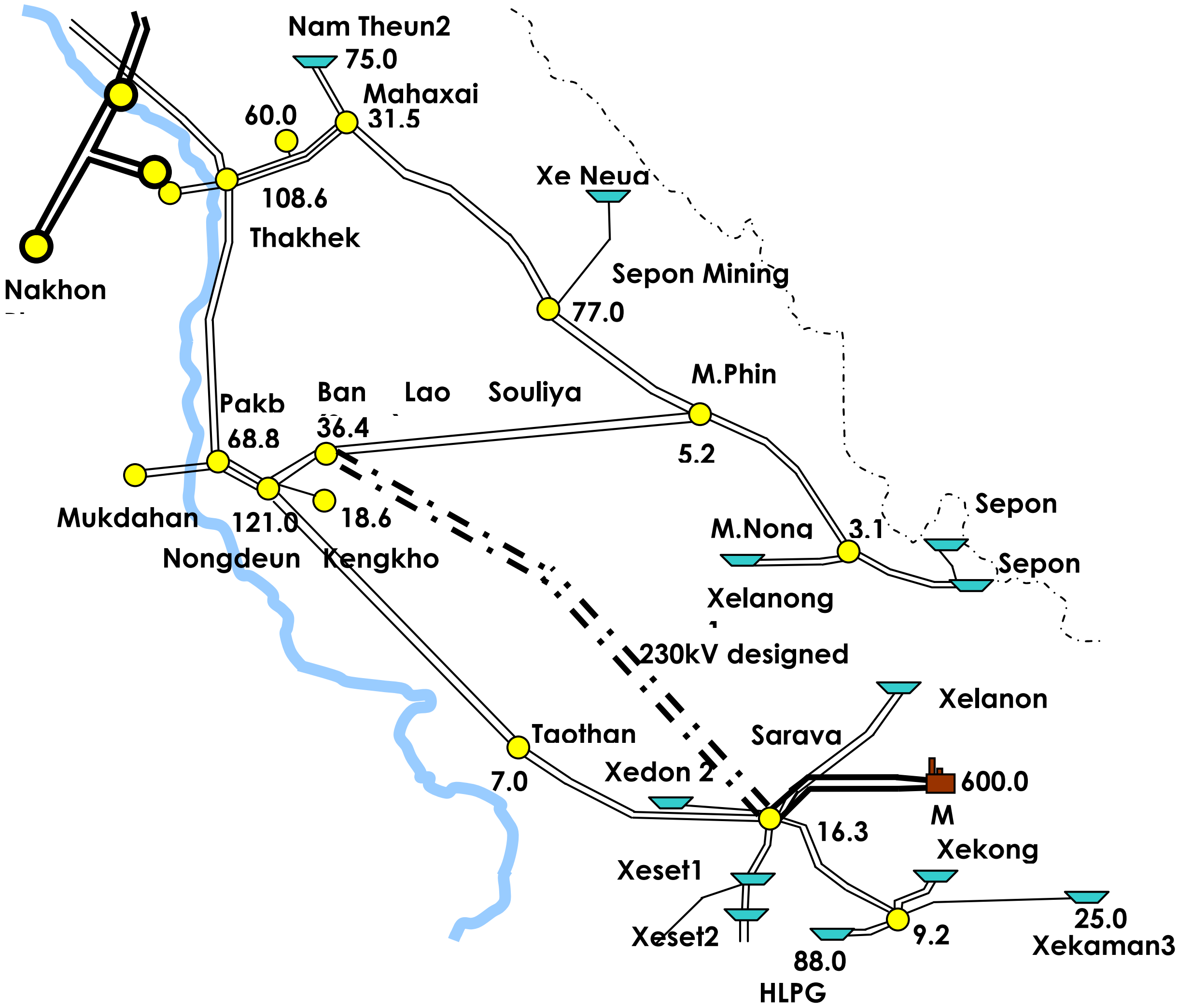



**Figure 10-2 Power System of Target Area in Case TA (2020)**

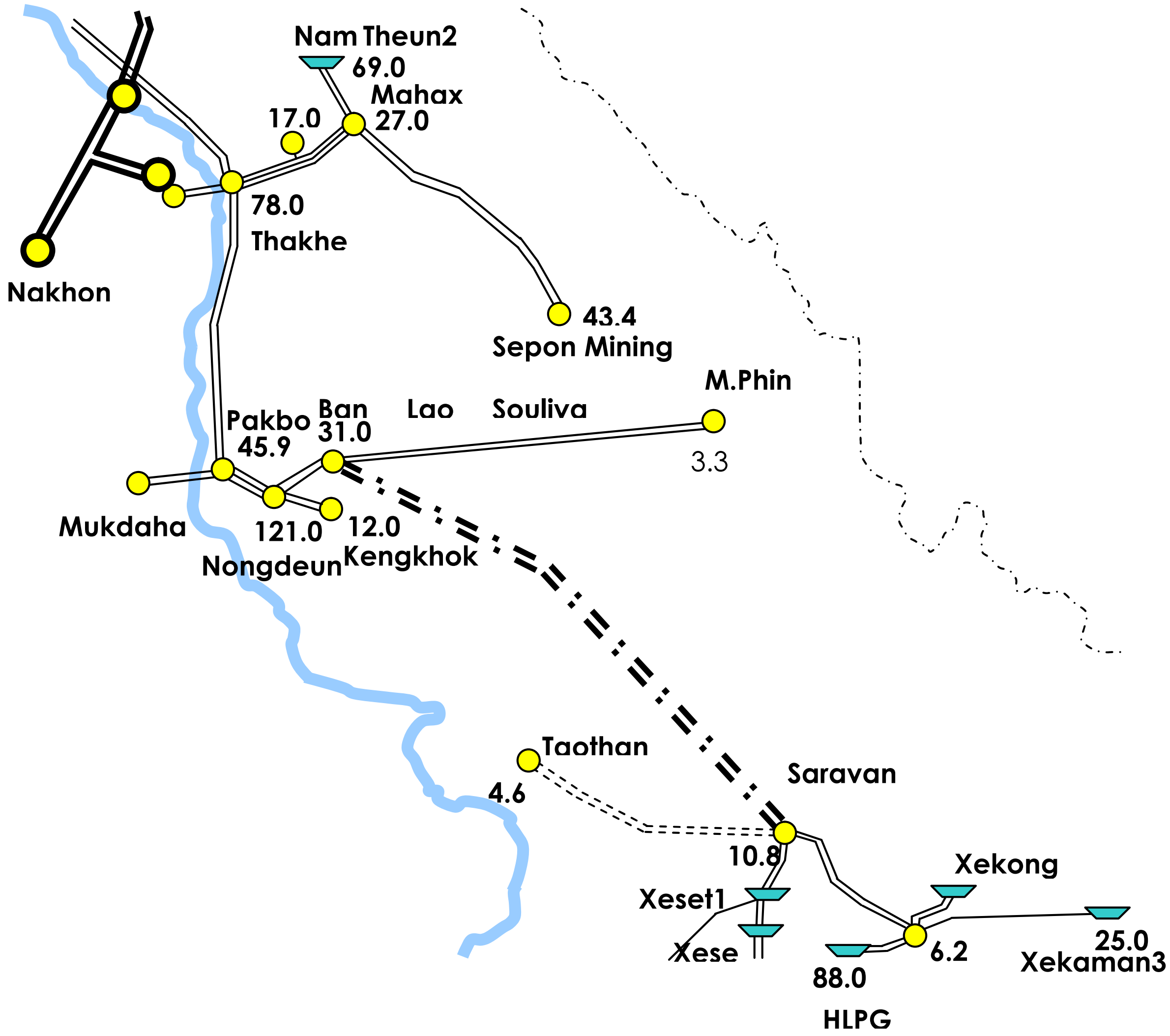



**Figure 10-3 Power System of Target Area in Case TB (2015)**

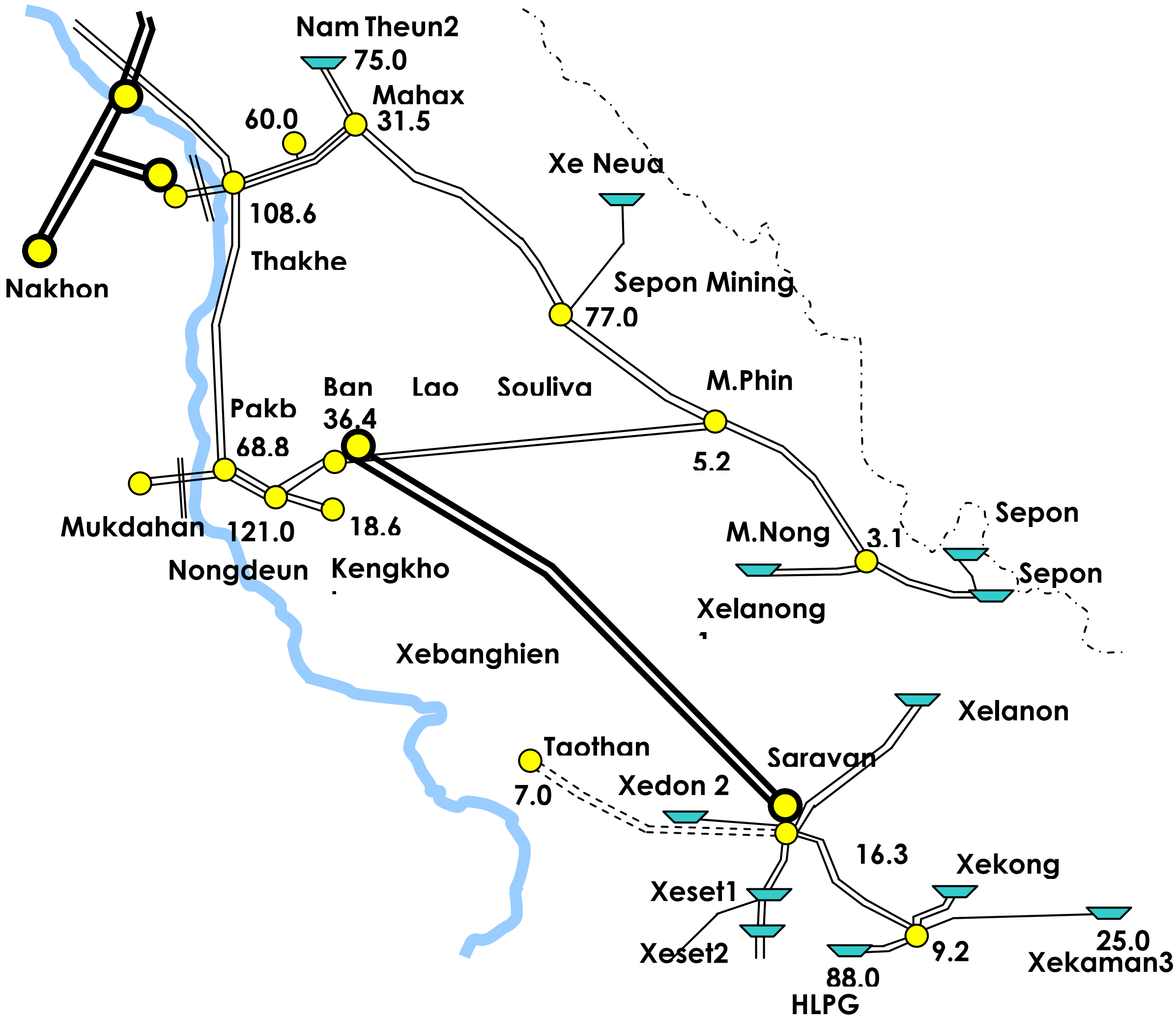



**Figure 10-4 Power System of Target Area in Case TB (2020)**

## 10.2 Power System in Target Area After 2020

After 2020, the power supply required from other regions is considered increased because the power demand in Target Area becomes increased and there are few power stations developed in this area. On the other hand, the stability limitation of the power transmission in the power network system up to 2020 would be around 250 MW both in Case TA and Case TB. Thus, Case TA will require the 230/115 kV Seno and Saravan substations to upgrade the Seno-Saravan transmission line to 230 kV and Case TB will require a new route, for example, the 115 kV Pakbo-Saravan transmission line. As for the results, both Case TA and Case TB are considered to need a transmission system between South 1 and South 2 as shown in Figure 10-5.

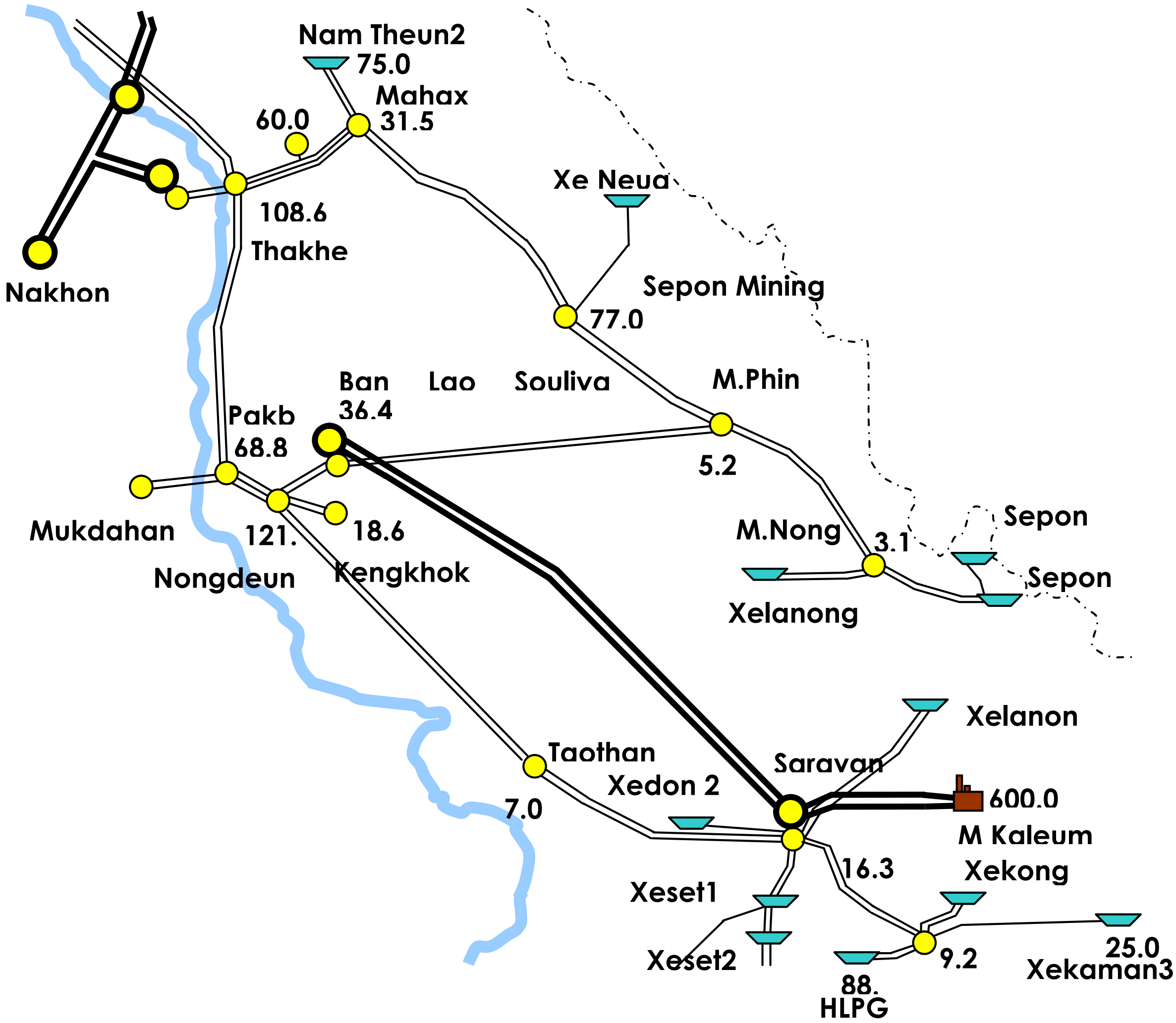



**Figure 10-5 Power System of Target Area in Case TA and TB (after 2020)**

## 10.3 Comparison between Case TA and Case TB

Case TA (Construction of the 115 kV Pakbo-Saravan transmission line in 2015) and Case TB (Construction of the 230kV Seno-Saravan transmission line instead of the construction of the 115 kV Pakbo-Saravan transmission line in 2015) were compared. The difference between Case TA and Case TB is the schedule of its investment and their system losses although both cases will be expected to supply to the same power demand and respond to the same domestic power generation and the final system configurations (after 2020) would become the same.

In this section, a cost comparison was made between Case TA and TB by estimating the cost of facilities and system losses. The amount of the difference of the system losses was estimated from the results of the power flow analysis and the cost of system losses was evaluated via the power import tariffs from EGAT. The year of becoming the same system configuration both of CaseTA and Case TB was assumed in 2025 according to the growth of power demand in the South 1 area. The conditions for cost comparison are shown in Table 10-1.

**Table 10-1 Conditions for Cost Comparison**

| | | | |
|---|---|---|---|
| System Loss (The peak loss of 115 kV transmission lines in the South 1 area) | Case TA | 2015-2017 | 19.6 MW |
| | | 2018-2024 | 32.0 MW |
| | Case TB | 2015-2017 | 10.4 MW |
| | | 2018-2024 | 25.0 MW |
| Loss of 230/115 kV Transformers (Iron loss for 4 x 200 MVA) | | 0.8 MW | |
| Peak distribution Loss for power supply to Taothan | | 2015-2019 | 0.2 MW |
| | | 2020-2024 | 0.4 MW |
| Annual loss factor | | 0.3 | |
| Unit cost of loss (import tariff from EGAT) | | 0.05 USD/kWh | |
| 115kV Pakbo-Saravan Transmission Line Project | | 45,501,540 USD | |
| 230 kV Seno- Saravan Transmission Line Project | | Trans. Line | 105,376,793 USD |
| (Based on the construction cost of the transmission line and substations described in the FS report by the Sino-Hydro in spite of the total costs mentioned as around 162 million USD. Given their uncertain actual costs, only the cost of facilities was included for a conservative evaluation.) | | Substations | 34,247,259 USD |
| 22 kV Saravan-Taothan 65 km 4 circuits | | 6,500,000 USD | |
| Discount rate | | 3% | |

Table 10-2 shows the results of the cost comparison. After 2025, due to the same system configurations, the costs of Case TA and Case TB are the same. Case TB has a larger initial investment than Case TA because it develops the 230 kV system as the first step. The total costs at present value indicate that Case TA is more economical than Case TB.

Thus, the following schedule is recommended in Case TA.

- 2015: 115 kV Pakbo-Saravan Transmission Line
- 2018: 230 kV designed Seno-Saravan transmission line operated at 115 kV
- After 2020: 230/115 kV transformers installed in Seno and Saravan to upgrade the Seno-Saravan Transmission line to 230 kV

From the aforementioned results, in the same manner as in the case of the JICA Study on the Power Network System Plan (MP Study), the 115 kV Pakbo–Saravan transmission line is recommended as the highest prioritized project.

## Table 10-2 Cost Comparison of Both Cases

(Unit: USD)

| Year | Case A | | | | | Case B | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Facilities (USD) | Incremental Cost of System Loss from Case B (USD) | Total Incremental Cost (USD) | Total Incremental Cost at present value (USD) | Scenario | Facilities (USD) | Incremental Cost of System Loss from Case B (USD) | Total Incremental Cost (USD) | Total Incremental Cost at present value (USD) | Scenario |
| 2015 | 45,501,540 | 2,575,440 | 48,076,980 | 45,317,165 | 115kV Pakbo-Saravan T/L | 111,876,793 | 1,392,840 | 113,269,633 | 106,767,493 | 230kV Seno-Saravan T/L<br>22kV Saravan-Taothan D/L |
| 2016 | | 2,575,440 | 2,575,440 | 2,356,892 | | | 1,392,840 | 1,392,840 | 1,274,646 | |
| 2017 | | 2,575,440 | 2,575,440 | 2,288,245 | | | 1,392,840 | 1,392,840 | 1,237,520 | |
| 2018 | 105,376,793 | 4,204,800 | 109,581,593 | 94,526,045 | 230kV Seno-Saravan T/L | 34,247,259 | 3,661,680 | 37,908,939 | 32,700,584 | 230/115kV Seno & SaravanS/S |
| 2019 | | 4,204,800 | 4,204,800 | 3,521,454 | | | 3,661,680 | 3,661,680 | 3,066,599 | |
| 2020 | | 4,204,800 | 4,204,800 | 3,418,887 | | 6,500,000 | 3,687,960 | 10,187,960 | 8,283,744 | 22kV Saravan-Taothan D/L |
| 2021 | | 4,204,800 | 4,204,800 | 3,319,308 | | | 3,687,960 | 3,687,960 | 2,911,310 | |
| 2022 | | 4,204,800 | 4,204,800 | 3,222,629 | | | 3,687,960 | 3,687,960 | 2,826,514 | |
| 2023 | | 4,204,800 | 4,204,800 | 3,128,766 | | | 3,687,960 | 3,687,960 | 2,744,189 | |
| 2024 | | 4,204,800 | 4,204,800 | 3,037,637 | | | 3,687,960 | 3,687,960 | 2,664,261 | |
| 2025 | 34,247,259 | 0 | 34,247,259 | 24,020,338 | 230/115kV Seno & SaravanS/S | 42,428,000 | 0 | 42,428,000 | 29,758,146 | 115kV Pakbo-Saravan T/L<br>22kV Saravan-Taothan D/L |
| 2026 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2027 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2028 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2029 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2030 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2031 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2032 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2033 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2034 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2035 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2036 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2037 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| 2038 | | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| | Total at Present Value | | | 188,157,366 | | Total at Present Value | | | 194,235,005 | |

## 10.4 The Number of Circuits of the 115 kV Pakbo-Saravan Transmission Line and its Conductors

The 115 kV Pakbo-Kengkok transmission line is to be basically constructed with double circuits to secure power supply ability even in case of a fault of a single circuit. EDL is now planning the Nongdeun substation at the land neighbored to or in a proposed industrial zone near Pakbo on the way to the existing 115 kV Pakbo-Kengkok transmission line.

Thus, we confirmed the situations of deriving the transmission lines around the Pakbo substations. Via discussions with EDL and DOE, the area shown in Figure 10-6 was to be set out as the project area of the 115 kV Pakbo-Saravan transmission line with the double circuit.

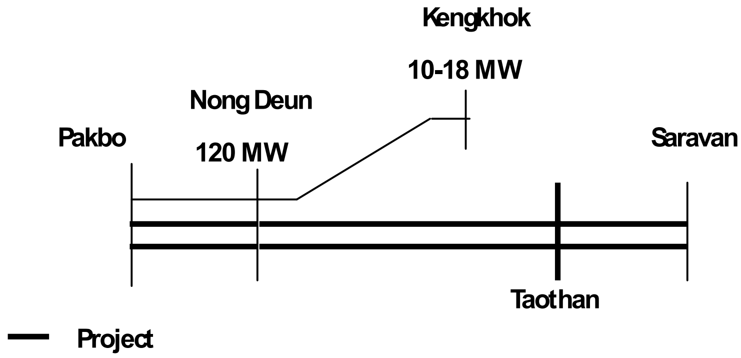



**Figure 10-6 Project of 115 kV Pakbo-Saravan 2 Circuits**

Because the peak load of Nongdeun substation is forecasted to be 120 MW after 2015 and the Kengkok substation is to be around 10 to 18 MW, the power flow from Pakbo to Nongdeun would exceed 100 MW when the direction of the power flow is from Nongdeun to Taothan. Because the capacity of the transmission line between Pakbo and Kengkok is around 100 MW per circuit, three circuits will be required for the interval between Pakbo and Nongdeun if a single circuit fault is considered.

Furthermore, the power flow in the power network system in Laos is varied for the wet and dry seasons because Laos's power generation mainly consists of hydropower stations. For example, when the power generation outputs are relatively small in the South 2 area, it can be considered to transmit around 100 MW from Pakbo or Nongdeun to Taothan or Saravan. In this case, the power flow between Pakbo and Nongdeun exceeds 200 MW and in consideration with a single circuit fault, the remaining two circuits should have more than 200 MW. On the other hand, ACSR 240 mm2 has a capacity of only around 100 MW per circuit, TACSR 240 mm2 whose capacity is 30% to 40% more than the same size conductor, ACSR 240 mm2 needs to be applied.

- There is a possibility of an increase in power flow between Saravan and Taothan where hydropower stations are planned with several 10 MW.
- If the 230 kV Seno-Saravan transmission line is not available in the case of accidents, a portion of the power may be transmitted via this project line.
- There is the possibility of an increase in power flow due to the uncertainty of power development plans in the South area after 2020.

Another consideration may be possible using the upper size conductor, ACSR 410 mm$^2$, however, TACSR 240 mm$^2$ was found to be more economical from the results of the JICA Study on the Power Network System Plan, therefore, TACSR 240 mm$^2$ is recommended for the conductor used in this project.

The 115 KV Taothan substation will be installed on the route of the 115 kV Pakbo-Saravan transmission line following the results of the JICA Study (MP Study).

# Chapter 11 Design Confirmation of the Facilities of the Highest Prioritized Project in Central-South Area

## 11.1 Transmission Line Facilities

### 11.1.1 Present Situation of Transmission Line Route of the Highest Prioritized Project

Since one and a half years have passed since "the Study on Power Network System Plan in Lao People's Democratic Republic" (hereafter "MP study") implemented from October 2008 to January 2010, we conducted a route survey of the transmission line proposed as the highest prioritized project in the MP study (hereafter "MP transmission line") to confirm the present situation of the route.

#### (1) 115kV Pakbo Substation

After the MP study, the 115kV Pakxan-Pakbo transmission line financed by a yen loan was completed in May 2011. The study team confirmed that there is enough space to install the incoming tower of the MP transmission line to Pakbo substation between the 115kV Pakxan-Pakbo transmission line and the existing 115kV Pakbo-Kengkok transmission line (hereafter "existing 115kV transmission line") as shown in the following picture.


**Figure 11-1 Incoming Tower Location of Pakbo Substation**

#### (2) SEZ and Nongdeun Substation

As stated by EDL, there is a plan to construct a new Nongdeun substation along the MP transmission line route, 4 km apart from the Pakbo substation in the SEZ to supply SEZ. The preliminary design and site acquisition for Nongdeun substation has already been finished, and the EPC contract between EDL and a consultant company in Thailand was made in July of 2011.

Then the construction will be completed within 2012. As a result of a discussion with EDL, the study team and EDL agreed that the MP transmission line should connect Pakbo substation and Saravan substation via Nongdeun substation and Taothan substation. Furthermore, the existing 115kV transmission line will also lead to Nongdeun substation.

The MP transmission line route needs to be rerouted in accordance with the incoming Nongdeun substation. We confirmed the present situation around the planned Nongdeun substation site and the SEZ. As shown in the following pictures, the situation of the land preparation in SEZ has not changed so much compared to the situation two years ago and the land leveling of the surrounding area of the planned Nongdeun substation site (Section No. 359-360) near the northwest edge of SEZ has not proceeded at all.


**Figure 11-2 Present Situation in the SEZ**


**Figure 11-3 Existing 115kV Present Situation around Planned Nongdeun Substation Site (left: Pakbo side, right: Kengkok side)**

At the same time, the 115kV transmission line which connects Nongdeun substation and M.Phin substation through the Ban Lao Souliya (Seno) substation is planned to be completed in 2014, and the Nongdeun substation was designed as such a configuration.

### 11.1.2 New Transmission Line Route

Based on the aforementioned circumstances, we studied how to connect the MP transmission line to Nongdeun substation with careful consideration of the following issues.

- ❖ Impacts on the environment and residents
- ❖ Consistency with EDL's facility planning

As a result of the study, the study team proposed the MP transmission line rerouting shown in the following figure and agreed on it with EDL. This new route runs in parallel with the existing 115kV transmission line from Pakbo substation and leads into Nongdeun substation. Then the route goes out line from Nongdeun substation and return to the originally proposed route.

The study team confirmed that no residential area nor nature reserve area exists on the new route through the site survey, so that no impact to the resettlement nor to the environment by rerouting exists. In regard to the incoming Nongdeun substation of the MP transmission line, it matches the bay configuration designed by EDL as well as EDL's facility planning. Via this rerouting, the MP transmission line will not be affected by the design and/or the progress of the 115kV transmission line between Nongdeun and M.Phin via Ban Lao Souliya (Seno) planned to be constructed by China around the same time.

The study team also confirmed that EDL has already finished the site acquision for Nongdeun substation in the SEZ and there is no existing resettlement or environmental impact.

Furthermore, EDL is negociating with SEZ developer if the above mentioned route can pass thourgh the SEZ in parallel with the existing line or not. Therfore, the final route may change to efficient one.

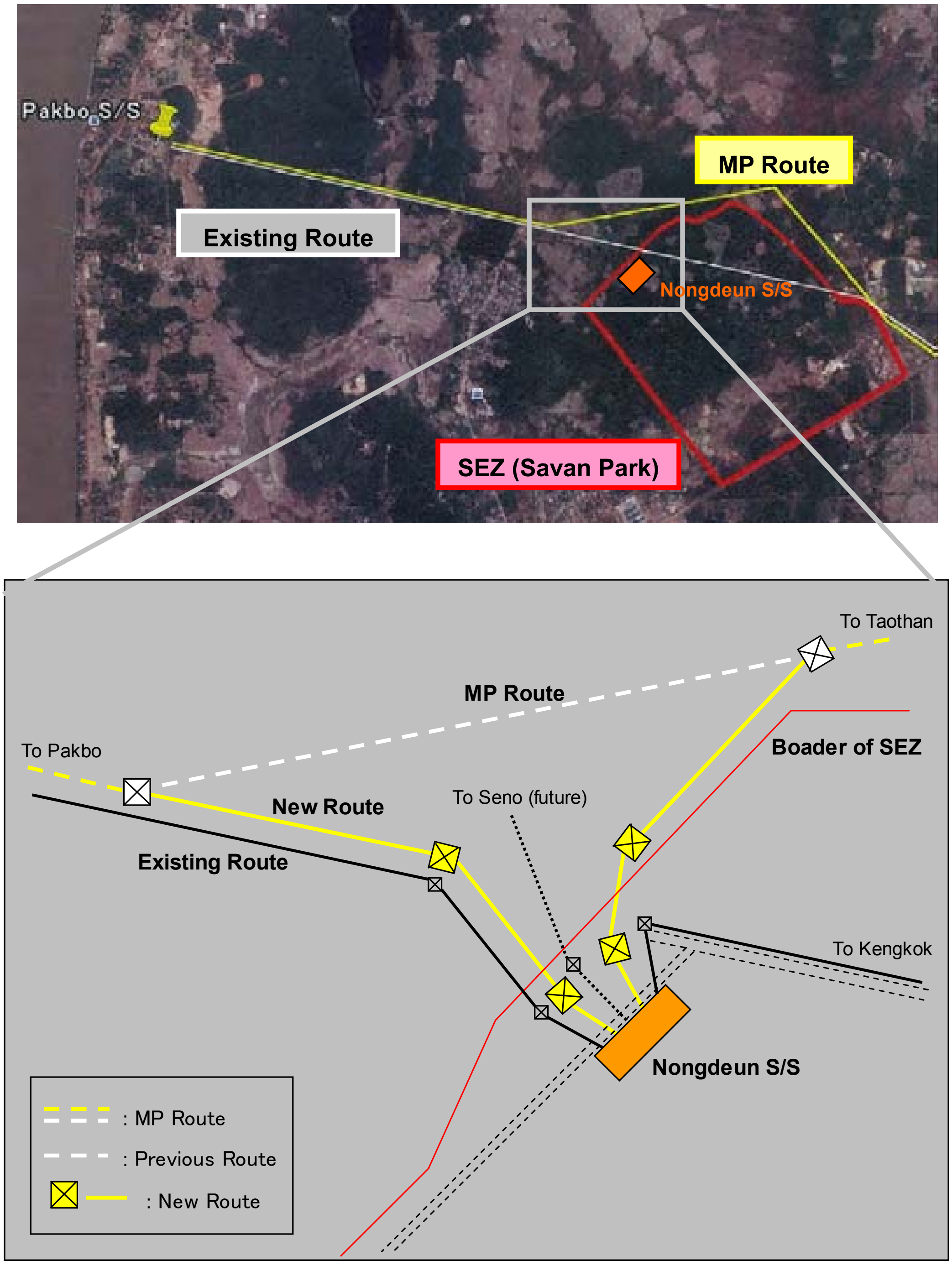



Image of new transmission line route around Nongdeun S/S

**Figure 11-4 Transmission Line Rerouting near Nongdeun Substation**

### 11.1.3 Design of the Transmission Line Facilities

As a result of reviewing the latest power development plan and the demand forecast, the study team confirmed that the design policy of the MP study can be applied as well. Therefore, the study team applied the designs of the MP study such as the tower configuration and the foundation design to the rerouting part in this study.

### 11.1.4 Quantities of Transmission Line Materials

The quantities of transmission line materials in regard to the rerouting such as towers, conductors, ground wires, insulators, insulator assemblies, accessories for the conductor and ground-wire and tower foundations are described in the following tables.

**Table 11-1 Number and Total Weight of Towers**

| Type | Unit Weight [ton] | MP study | | this study | | Increment | |
|---|---|---|---|---|---|---|---|
| | | Tower [Nos] | Total Weight [ton] | Tower [Nos] | Total Weight [ton] | Tower [Nos] | Total Weight [ton] |
| A1 | 6.0 | 466 | 2796.0 | 466 | 2796.0 | - | - |
| A2 | 7.0 | 18 | 126.0 | 18 | 126.0 | - | - |
| B1 | 8.5 | 52 | 442.0 | 52 | 442.0 | - | - |
| B3 | 11.1 | 1 | 11.1 | 1 | 11.1 | - | - |
| C1 | 10.4 | 6 | 62.4 | 6 | 62.4 | - | - |
| D1 | 11.5 | 5 | 57.5 | 5 | 57.5 | - | - |
| D1+6.0 | 15.0 | - | - | 2 | 30.0 | 2 | 30.0 |
| DE | 13.8 | 4 | 55.2 | 6 | 82.8 | 2 | 27.6 |
| Total | | 552 | 3550.2 | 556 | 3607.8 | 4 | 57.6 |

**Table 11-2 Quantities of Conductor and Ground Wire**

| Type | MP study | | | this study | | | Increment | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number [Nos] | Route Length [km] | Quantity [km] | Number [Nos] | Route Length [km] | Quantity [km] | Number [Nos] | Route Length [km] | Quantity [km] |
| TACSR240mm$^2$ | 6 | 218.5 | 1376.6 | 6 | 218.9 | 1379.1 | 6 | 0.4 | 2.5 |
| AC70mm$^2$ | 1 | 218.5 | 229.4 | 1 | 218.9 | 229.8 | 1 | 0.4 | 0.4 |
| OPGW70mm$^2$ | 1 | 218.5 | 229.4 | 1 | 218.9 | 229.8 | 1 | 0.4 | 0.4 |

**Table 11-3 Quantities of Insulators and Insulator Assemblies**

| Tower Type | Items | Unit Q'ty [Pcs] | MP study Tower [Nos] | MP study Sub-total Quantity [Pcs] | this Study Tower [Nos] | this Study Sub-total Quantity [Pcs] | Increment Tower [Nos] | Increment Total Quantity [Pcs] |
|---|---|---|---|---|---|---|---|---|
| Suspension | Insulator | 60 | 459 | 27,540 | 459 | 27,540 | - | - |
| | Single String Set | 6 | | 2,754 | | 2,754 | | - |
| | Insulator | 120 | 26 | 3,120 | 26 | 3,120 | - | - |
| | Double String Set | 6 | | 156 | | 156 | | - |
| Tension | Insulator | 120 | 60 | 7,200 | 63 | 7,560 | 3 | 360 |
| | Single String Set | 12 | | 720 | | 756 | | 36 |
| | Insulator | 240 | 7 | 1,680 | 9 | 2,160 | 2 | 480 |
| | Double String Set | 12 | | 84 | | 108 | | 24 |
| Total | Insulators | | | 39,540 | | 40,380 | | 840 |
| | Insulator Sets | | | 3,714 | | 3,774 | | 60 |

**Table 11-4 Quantities of Fittings of Conductor and Ground Wire**

| Fittings | MP study [Pcs] | this study [Pcs] | Increment [Pcs] |
|---|---|---|---|
| Conductor Dampers | 6,600 | 6,660 | 60 |
| GW Dampers | 1,100 | 1,110 | 10 |
| OPGW Dampers | 1,100 | 1,110 | 10 |
| Conductor Sleeves | 689 | 689 | - |
| GW Sleeves | 115 | 115 | - |
| OPGW Joint Boxes | 42 | 42 | - |
| Suspension GW Fittings | 485 | 485 | - |
| Tension GW Fittings | 67 | 71 | 4 |
| Suspension OPGW Fittings | 485 | 485 | - |
| Tension OPGW Fittings | 67 | 71 | 4 |

**Table 11-5 Quantities of Tower Foundations**

| Soil | Foundation | Concrete Volume /Tower [$m^3$] | MP study Tower [Nos] | MP study Total Concrete Volume [$m^3$] | this study Tower [Nos] | this study Total Concrete Volume [$m^3$] | Increment Tower [Nos] | Increment Total Concrete Volume [$m^3$] |
|---|---|---|---|---|---|---|---|---|
| I | A-I | 7.0 | 480 | 3,360.0 | 480 | 3,360.0 | - | - |
| | B-I | 12.4 | 50 | 620.0 | 50 | 620.0 | - | - |
| | C-I | 16.2 | 8 | 129.6 | 8 | 129.6 | - | - |
| | D-I | 21.8 | 5 | 109.0 | 7 | 152.6 | 2 | 43.6 |
| | DE-I | 31.3 | 4 | 125.2 | 6 | 187.8 | 2 | 62.6 |
| II | A-II | 9.9 | 4 | 39.6 | 4 | 39.6 | - | - |
| III | B-III | 22.8 | 1 | 22.8 | 1 | 22.8 | - | - |
| | | Total | 552 | 4,406.2 | 556 | 4,512.4 | 4 | 106.2 |

## 11.2 Substation Facilities

### 11.2.1 Pakbo Substation

The study team confirmed that there have been no changes compared with the MP study as of Junuary 2010.

### 11.2.2 Taothan Substation

The study team confirmed that there have been no changes compared with the MP study as of January 2010. Furthermore, the site acquisition of the Taothan substation has been completed by EDL and the Sign board for indication of construction site of Taothan substation is installed in the site.


**Figure 11-5 Sign Board in the Planned Construction Site of Taothan S/S by EDL**

### 11.2.3 Saravan Substation

The study team confirmed that there have been no changes compared with the MP study as of January 2010.

### 11.2.4 Nongdeun Substation

#### (1) General

As for Nongdeun SS, EDL has no construction plans as of the MP study, January 2010. However, since the power demand forecast of the special economic zone (SEZ) will be high, power supply from Pakbo substation to SEZ area used by the 22kV line is difficult. It is planned for the SEZ area.

The design of Nongdeun SS was completed already. It will be started in 2011 and per the present timeline will be completed and commissioned in 2012. Therefore, the design for Nongdeun SS under the Project is to be focused on the substation facilities after the EDL project.

The general profile of Nongdeun SS after completion of the EDL Project is as follows:

| | | |
|---|---|---|
| i) | Location | Savannakhet City in Savannakhet Province |
| ii) | Busbar system | Main and transfer busbar system |
| iii) | Main Transformer<br>(as of beginning of operation) | 115/ 22kV 30MVA Transformer: 1 unit |
| iv) | 115 kV switchgear<br>(as of beginning of operation) | transformer bay: 1 bay<br>transmission line bay: 2 bays<br>（1 x Pakbo SS, 1 x Kengkok SS） |
| v) | 22 kV feeders<br>(as of beginning of operation) | Outgoing Feeders:6 feeders<br>Service TR feeder: 1 feeder<br>Capacitor feeder:1 feeder |

### (2) Design and Scope of Works

The installation of two transmission line bays connected to Pakbo SS and two transmission line bays connected to Taothan SS are necessary in Nongdeun SS. Therefore, the result of the discussion with EDL is that the two TL bays of Pakbo SS at #② and #③ are to be installed and the TL bays of Taothan SS at #⑩ and #⑪ are to be installed, respectively.

Since, Nongdeun SS will be planned in anticipation of future expansion at a beginning time, the land expansion works are out of scope for this project.

| ① | ② | ③ | ④ | ⑤ | ⑥ | ⑦ | ⑧ | ⑨ | ⑩ | ⑪ | ⑫ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TL bay<br>Pakbo 1 | TL bay<br>Pakbo 2 | TL bay<br>Pakbo 3 | TL bay<br>Seno 2<br><br>(Future Plan) | TL bay<br>Seno 1<br><br>(Future Plan) | TR bay<br># 2<br><br>(Future Plan) | TR bay<br># 1 | TR bay<br># 3<br><br>(Future Plan) | Bus-tie | TL bay<br>Taothan 1 | TL bay<br>Taothan 2 | TL bay<br>Kengkok |

**Figure 11-6 Nongdeun Substation, 115kV Switchyard Layout Plan**

The scope of works for Nongdeun SS under the Project is as follows:

(a) Extension of gantries and busbars
- Extension of gantries at #②, #③, #⑩ and #⑪ including overhead bus work
- Extension of busbars (main and transfer busbars)

(b) Installation of four TL bays(Pakbo SS at #②, #③ and Taothan SS at #⑩, #⑪)
- Installation of new 115 kV switchgear for Pakbo SS at #②, #③, and installation of new 115 kV switchgear for Taothan SS at #⑩, #⑪.
  (A TL bay consists of 1 set of circuit breakers, 2 sets of disconnecting switches, 1 set of a disconnecting switch with an earthing switch, 1 set of current transformers, 1 set of capacitor voltage transformers, and 1 set of surge arresters.)
- The installation of protection relay and control panels in the substation control building

(c) Civil and erection works
- Foundation work
- Erection work
- Wiring work

- Grounding work including extension of the existing grounding mesh
- Extension of cable trenches, etc.

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

(e) Procurement of spare parts

As a result of the design for Nongdeun SS, the following drawings are attached in Figure 11-8 - Figure 11-10.

- Drawing No. SS_NON_01: Nongdeun Substation, Single Line Diagram
- Drawing No. SS_NON_02: Nongdeun Substation, Layout
- Drawing No. SS_NON_03: Nongdeun Substation, Section

### (3) Specification and Quantity of Major Equipment

(a) General Electrical Requirements

General electrical requirements for 115 kV equipment of the Project are as follows:

| | | |
|---|---|---|
| i) | Nominal system voltage | 115 kV |
| ii) | Rated voltage (r.m.s. value)<br>(Highest voltage for equipment) | 123 kV |
| iii) | Rated frequency | 50 Hz |
| iv) | Insulation level | |
| | Rated short-duration power-frequency withstand voltage (r.m.s. value) | 230 kV |
| | Rated lightning impulse withstand voltage (peak value) | 550 kV |
| | Minimum clearance of phase-to-earth | 1,100 mm |
| | Standard clearance of phase-to-earth | 1,400 mm |
| | Minimum clearance of phase-to-phase | 1,400 mm |
| | Standard clearance of phase-to-phase | 2,300 mm |
| v) | Rated current | 1,250 A |
| vi) | Rated short-duration withstand current (3 sec) | 40 kA |

(b) Specifications of the 115kV Switchgear

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

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

Since Nongdeun SS has been planning construction as of July 2011, the specifications of the 115 kV facilities of Nongdeun SS might be altered, and they should be confirmed during the detailed design stage for the Project, accordingly.

(c) Quantity of Major Equipment

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

**Table 11-6 Quantity of Major Equipment**

| | Major equipment | Nongdeun SS |
|---|---|---|
| 1) | 115 kV switchgear | |
| a) | Circuit breakers (3 phase) | 4 units |
| b) | Disconnecting switches (3 phase) | 8 units |
| c) | DS with earthing switch (3 phase) | 4 units |
| d) | Current transformers | 4 sets |
| e) | Voltage transformers | 4 sets |
| f) | Surge arresters | 4 sets |

(d) 115 kV Transmission Line Protection Relay system

The following protection relay systems are to be applied for the Project:

- Main protection: distance relay phase & earth
- Back-up protection: directional over-current & earth fault relay
- Auto-reclosing relay
- Breaker failure relay
- Synchro-check relay

## 11.3 Implementation Schedule of the Highest Prioritized Project

The period from the appointment of the project consultants to the conclusion of the turn-key contracts for both the transmission line and substations was assumed to be 12 months and the period from the conclusion of the contracts to the taking-over of the facilities was assumed to be 24 months, therefore the total implementation period was assumed to be 36 months after the appointment of the project consultants in the MP study. Even if the incoming addition of Nongdeun substation is considered, the total implementation period is assumed to be 36 months, the same as the conclusion of the MP study.

The following figure shows the assumed implementation schedule.

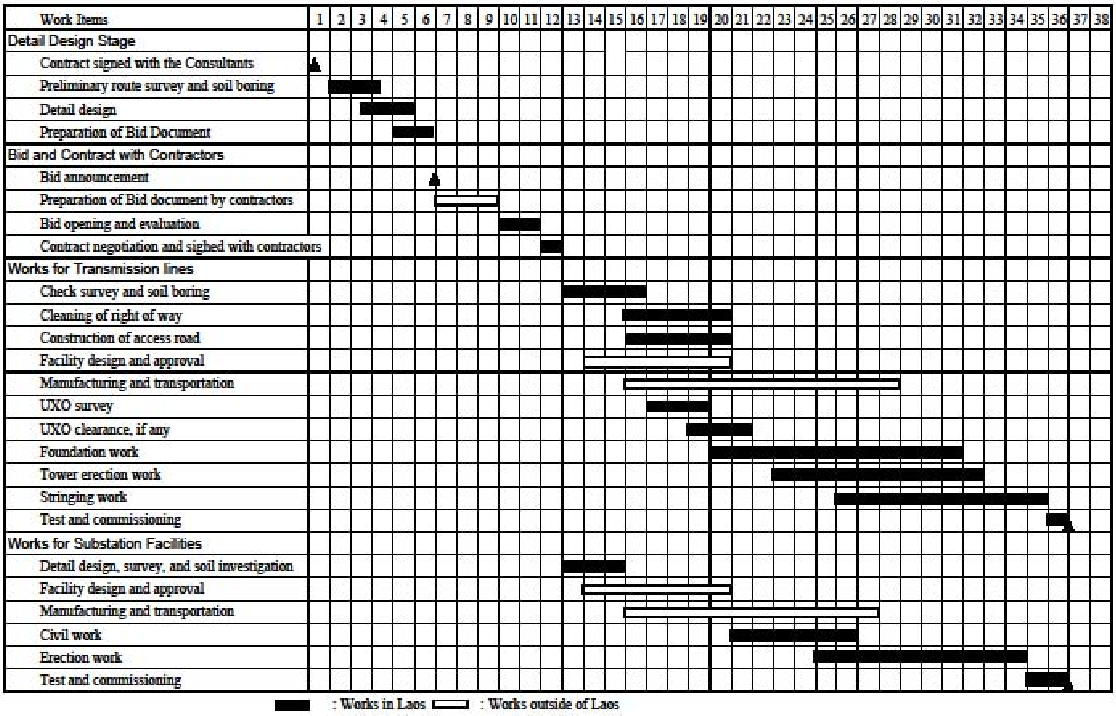



**Figure 11-7 Assumed Implementation Schedule**

## 11.4 Cost of the Highest Prioritized Project

### 11.4.1 Compensation for Lands and Right of Way (ROW), Costs for UXO Investigation and Clearance

In accordance with the incoming Nongdeun substation, four transmission line towers need to be constructed additionally. All the additional lands are not paddy fields and the compensation costs for lands and ROW would be same as the estimation of the MP study.

And the costs for the UXO investigation and clearance would also be the same as the estimation of the MP study because there are no UXO in the rerouting area.

### 11.4.2 Construction Cost of Transmission Line Facilities

As for the construction cost of transmission line facilities for the highest prioritized project, the study team converted the unit prices of equipment and civil & erection works with the adjustment of the exchange rate from 100 JPY/USD as of 2009 to 83 JPY/USD as of now and reviewed the unit prices of some equipment, then estimated by multiplying revised unit prices by those quantities calculated in section 11.1.4.

Table 11-7 and Table 11-9 show the construction costs of the transmission line facilities for the highest prioritized project and its breakdown respectively. In addition, Table 11-8 shows the construction costs of the transmission line facilities estimated in the MP study and the increased amount in this study.

**Table 11-7 Construction Cost of Transmission Line Facilities (1,000USD)**

| Sections | Items | FC | LC | Total |
|---|---|---|---|---|
| Pakbo S/S | Plant & Equipment | 13,330.3 | 0.0 | 13,330.3 |
| - Taothan S/S | Civil & Erection | 1,017.3 | 4,464.6 | 5,481.9 |
| | Sub-total | 14,347.6 | 4,464.6 | 18,812.2 |
| Taothan S/S | Plant & Equipment | 5,722.9 | 0.0 | 5,722.9 |
| - Saravan S/S | Civil & Erection | 436.0 | 1,911.4 | 2347.4 |
| | Sub-total | 6,158.9 | 1,911.4 | 8,070.3 |
| Total | Plant & Equipment | 19,053.2 | 0.0 | 19,053.2 |
| | Civil & Erection | 1,453.3 | 6,376.0 | 7829.3 |
| | **Total** | **20,506.5** | **6,376.0** | **26,882.5** |

**Table 11-8 Construction Cost of Transmission Line Facilities in MP study and Increased Amount in this Study (1,000USD)**

| Sections | Items | Estimation in MP study | | | Increased Amount | | |
|---|---|---|---|---|---|---|---|
| | | FC | LC | Total | FC | LC | Total |
| Pakbo S/S | Plant & Equipment | 11,979.4 | 0.0 | 11,979.4 | 1,350.9 | 0.0 | 1,350.9 |
| -Taothan S/S | Civil & Erection | 999.0 | 4,245.8 | 5,244.8 | 18.3 | 218.8 | 237.1 |
| (152.6 km) | Sub-total | 12,978.4 | 4,245.8 | 17,224.2 | 1,369.2 | 218.8 | 1,588.0 |
| Taothan S/S | Plant & Equipment | 4,839.5 | 0.0 | 4,839.5 | 883.4 | 0.0 | 883.4 |
| - Saravan S/S | Civil & Erection | 417.4 | 1,765.9 | 2,183.3 | 18.6 | 145.5 | 164.1 |
| (66.3 km) | Sub-total | 5,256.9 | 1,765.9 | 7,022.8 | 902.0 | 145.5 | 1,047.5 |
| Total | Plant & Equipment | 16,818.9 | 0.0 | 16,818.9 | 2,234.3 | 0.0 | 2,234.3 |
| (218.9 km) | Civil & Erection | 1,416.4 | 6,011.7 | 7,428.1 | 36.9 | 364.3 | 401.2 |
| | Total | 18,235.3 | 6,011.7 | 24,247.0 | 2,271.2 | 364.3 | 2,635.5 |

# Table 11-9 Breakdown of Construction Cost for Transmission Line Facilities

Assumption:
(1) Foundation Type: 100% of Pad Type Foundations
(2) Soil Conditions: Normal

| Category | No. | Items | 115kV, 2cct, 217.4km, Condutcor : T-Hawk, Single | | | | | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pakbo S/S-Tao Than S/S (152.2 km) | | | | | | Tao Than S/S-Saravan S/S (66.3 km) | | | | | | |
| | | | Unit | Q'ty | Unit Rate (US$) | Amount (US$) | FC (US$) | LC (US$) | Unit | Q'ty | Unit Rate (US$) | Amount (US$) | FC (US$) | LC (US$) | |
| COST, INSURANCE AND FREIGHT | 1 | Tower | ton | 2,531.9 | 1,600 | 4,051,040 | 4,051,040 | 0 | ton | 1,075.9 | 1,600 | 1,721,440 | 1,721,440 | 0 | FC:100% LC:0% |
| | 2 | Conductor | km | 961.4 | 6,145 | 5,907,803 | 5,907,803 | 0 | km | 417.7 | 6,145 | 2,566,767 | 2,566,767 | 0 | |
| | 3 | OPGW 60mm2 | km | 160.2 | 5,900 | 945,180 | 945,180 | 0 | km | 69.6 | 5,900 | 410,640 | 410,640 | 0 | |
| | 4 | OH G.W. | km | 160.2 | 1,200 | 192,240 | 192,240 | 0 | km | 69.6 | 1,200 | 83,520 | 83,520 | 0 | |
| | 5 | Single Suspension Insulator String | set | 1,920 | 440 | 844,800 | 844,800 | 0 | set | 834 | 440 | 366,960 | 366,960 | 0 | |
| | 6 | Single Tension Insulator String | set | 540 | 740 | 399,600 | 399,600 | 0 | set | 216 | 740 | 159,840 | 159,840 | 0 | |
| | 7 | Double Suspension Insulator String | set | 108 | 680 | 73,440 | 73,440 | 0 | set | 48 | 680 | 32,640 | 32,640 | 0 | |
| | 8 | Double Tension Insulator String | set | 84 | 980 | 82,320 | 82,320 | 0 | set | 24 | 980 | 23,520 | 23,520 | 0 | |
| | 9 | Conductor Dumper | unit | 4,668 | 30 | 140,040 | 140,040 | 0 | unit | 1,992 | 30 | 59,760 | 59,760 | 0 | |
| | 10 | OPGW Dumper | unit | 778 | 20 | 15,560 | 15,560 | 0 | unit | 332 | 20 | 6,640 | 6,640 | 0 | |
| | 11 | GW Dumper | unit | 778 | 20 | 15,560 | 15,560 | 0 | unit | 332 | 20 | 6,640 | 6,640 | 0 | |
| | 12 | Conductor Sleeve | unit | 480 | 20 | 9,600 | 9,600 | 0 | unit | 209 | 20 | 4,180 | 4,180 | 0 | |
| | 13 | GW Sleeve | unit | 80 | 15 | 1,200 | 1,200 | 0 | unit | 35 | 15 | 525 | 525 | 0 | |
| | 14 | OPGW Joint Box | unit | 29 | 600 | 17,400 | 17,400 | 0 | unit | 13 | 600 | 7,800 | 7,800 | 0 | |
| | 15 | GW Suspension Unit | unit | 338 | 100 | 33,800 | 33,800 | 0 | unit | 147 | 100 | 14,700 | 14,700 | 0 | |
| | 16 | GW Tenssion Unit | unit | 51 | 200 | 10,200 | 10,200 | 0 | unit | 20 | 200 | 4,000 | 4,000 | 0 | |
| | 17 | OPGW Suspension Unit | unit | 338 | 200 | 67,600 | 67,600 | 0 | unit | 147 | 200 | 29,400 | 29,400 | 0 | |
| | 18 | OPGW Tenssion Unit | unit | 51 | 200 | 10,200 | 10,200 | 0 | unit | 20 | 200 | 4,000 | 4,000 | 0 | |
| | 19 | Others | lot | 1 | 4% | 512,703 | 512,703 | 0 | lot | 1 | 4% | 219,959 | 219,959 | 0 | |
| | | Subtotal | | | | 13,330,286 | 13,330,286 | 0 | | | | 5,722,930 | 5,722,930 | 0 | |
| COST OF LABOUR, INLAND TRANSPORTATION AND EXPENSES | 1 | Survey & S. Investigation | km | 152.6 | 2,000 | 305,200 | 122,080 | 183,120 | km | 66.3 | 2,000 | 132,600 | 53,040 | 79,560 | FC:40%, LC:60% |
| | 2 | Access Construction | km | 305.2 | 1,000 | 305,200 | 91,560 | 213,640 | km | 132.6 | 1,000 | 132,600 | 39,780 | 92,820 | FC:30%, LC:70% |
| | 3 | Land Clearing | km | 152.6 | 1,000 | 152,600 | 30,520 | 122,080 | km | 66.3 | 1,000 | 66,300 | 13,260 | 53,040 | FC:20%, LC:80% |
| | 4 | Foundation (Volume of Concrete) | $m^3$ | 3,169.4 | 500 | 1,584,700 | 316,940 | 1,267,760 | $m^3$ | 1,343.0 | 500 | 671,500 | 134,300 | 537,200 | FC:20%, LC:80% |
| | 5 | Tower Erection | ton | 2,531.9 | 240 | 607,656 | 182,297 | 425,359 | ton | 1,075.9 | 240 | 258,216 | 77,465 | 180,751 | FC:30%, LC:70% |
| | 6 | Stringing | km | 152.6 | 3,000 | 457,800 | 137,340 | 320,460 | km | 66.3 | 3,000 | 198,900 | 59,670 | 139,230 | FC:30%, LC:70% |
| | 7 | Inland Transportion | | | CIF*10% | 1,333,029 | 0 | 1,333,029 | | | CIF*10% | 572,293 | 0 | 572,293 | FC:0%, LC:100% |
| | 8 | Miscellaneous | lot | 1 | 5% | 237,309 | 44,037 | 193,272 | lot | 1 | 5% | 101,620 | 18,876 | 82,745 | |
| | 9 | General Expenses | lot | 1 | 10% | 498,349 | 92,477 | 405,872 | lot | 1 | 10% | 213,403 | 39,639 | 173,764 | |
| | | Subtotal | | | | 5,481,843 | 1,017,251 | 4,464,592 | | | | 2,347,432 | 436,030 | 1,911,403 | |
| | | Total | | | | 18,812,130 | 14,347,537 | 4,464,592 | | | | 8,070,363 | 6,158,960 | 1,911,403 | 26,882,492 |

Estimated Condition ; Aluminum base LME 1550US$/ton, Exchange Rate ; 83Yen/US$, 3.0Yen/THB

| Total [US$] | 26,882,492 |
|---|---|
| (FC) | 20,506,497 |
| (LC) | 6,375,995 |

### 11.4.3 Construction Cost of Substation Facilities

Table 11-10 summarizes the construction costs of the substation facilities for the Project. Since the extension of Nongdeun SS is added, the construction cost of the substation facilities increases compared with the MP study.

**Table 11-10 Construction Cost of Substation Facilities (1,000USD)**

| Substations | Items | FC | LC | Total |
|---|---|---|---|---|
| Pakbo S/S | Plant & Equipment | 681.0 | 65.8 | 746.8 |
| | Civil & Other Works | 32.0 | 315.7 | 347.7 |
| | Sub-total | 713.0 | 381.5 | 1094.5 |
| Nongdeun S/S | Plant & Equipment | 1156.3 | 110.6 | 1266.9 |
| | Civil & Other Works | 14.0 | 233.6 | 247.6 |
| | Sub-total | 1170.3 | 344.2 | 1514.5 |
| Taothan S/S | Plant & Equipment | 4164.7 | 437.9 | 4602.6 |
| | Civil & Other Works | 95.0 | 1,491.9 | 1,586.9 |
| | Sub-total | 4259.7 | 1929.8 | 6189.5 |
| Saravan S/S | Plant & Equipment | 688.6 | 62.9 | 751.5 |
| | Civil & Other Works | 14.0 | 82.0 | 96.0 |
| | Sub-total | 702.6 | 144.9 | 847.5 |
| | Total | 6845.6 | 2800.4 | 9646.0 |

**Table 11-11 Construction Cost of Substation Facilities in MP Study and Increased Amount in This Study (1,000USD)**

| Substations | Items | Estimation in MP study | | | Increased Amount | | |
|---|---|---|---|---|---|---|---|
| | | FC | LC | Total | FC | LC | Total |
| Pakbo S/S | Plant & Equipment | 681.0 | 65.8 | 746.8 | 0.0 | 0.0 | 0.0 |
| | Civil & Other Works | 32.0 | 315.7 | 347.7 | 0.0 | 0.0 | 0.0 |
| | Sub-total | 713.0 | 381.5 | 1,094.5 | 0.0 | 0.0 | 0.0 |
| Nongdeun S/S | Plant & Equipment | - | - | - | 1,156.3 | 110.6 | 1,266.9 |
| | Civil & Other Works | - | - | - | 14.0 | 233.6 | 247.6 |
| | Sub-total | - | - | - | 1,170.3 | 344.2 | 1,514.5 |
| Taothan S/S | Plant & Equipment | 4,069.9 | 427.5 | 4,497.4 | 94.8 | 10.4 | 105.2 |
| | Civil & Other Works | 95.0 | 1,479.9 | 1,574.9 | 0.0 | 12.0 | 12.0 |
| | Sub-total | 4,164.9 | 1,907.4 | 6,072.3 | 94.8 | 22.4 | 117.2 |
| Saravan S/S | Plant & Equipment | 688.6 | 62.9 | 751.5 | 0.0 | 0.0 | 0.0 |
| | Civil & Other Works | 14.0 | 82.0 | 96.0 | 0.0 | 0.0 | 0.0 |
| | Sub-total | 702.6 | 144.9 | 847.5 | 0.0 | 0.0 | 0.0 |
| Total | Plant & Equipment | 5,439.5 | 556.2 | 5,995.7 | 1,251.1 | 121.0 | 1,372.1 |
| | Civil & Other Works | 141.0 | 1,877.6 | 2,018.6 | 14.0 | 245.6 | 259.6 |
| | Total | 5,580.5 | 2,433.8 | 8,014.3 | 1,265.1 | 366.6 | 1,631.7 |

# Table 11-12 Construction Cost of Pakbo Substation

## 1. Plant and equipment

| | Items | unit | Q'ty | FC (US$) CIF | FC (US$) Total FC | LC (US$) Insurance, inland transportation & installation | LC (US$) Total LC |
|---|---|---|---|---|---|---|---|
| **1.1** | **115 kV outdoor switchyard** | | | | | | |
| 1 | Circuit breakers | set | 2 | 50,000.00 | 100,000.00 | 4,800.00 | 9,600.00 |
| 2 | Disconnectors | set | 4 | 6,900.00 | 27,600.00 | 800.00 | 3,200.00 |
| 3 | Disconnectors with earthing switches | set | 2 | 8,100.00 | 16,200.00 | 900.00 | 1,800.00 |
| 4 | Current transformers | pcs | 6 | 7,800.00 | 46,800.00 | 600.00 | 3,600.00 |
| 5 | Capacitor voltage transformers | pcs | 6 | 9,100.00 | 54,600.00 | 500.00 | 3,000.00 |
| 6 | Surge arresters | pcs | 6 | 2,000.00 | 12,000.00 | 200.00 | 1,200.00 |
| 7 | Post insulators | pcs | 8 | 1,100.00 | 8,800.00 | 100.00 | 800.00 |
| 8 | 115 kV busbar with structure | lot | 1 | 8,000.00 | 8,000.00 | 1,500.00 | 1,500.00 |
| 9 | Power coductors | lot | 1 | 2,500.00 | 2,500.00 | 1,000.00 | 1,000.00 |
| 10 | Suspension insulator disks | lot | 1 | 3,000.00 | 3,000.00 | 1,000.00 | 1,000.00 |
| 11 | Steel structures (Gantries), 2 towers & 2 beams | lot | 1 | 36,000.00 | 36,000.00 | 3,600.00 | 3,600.00 |
| 12 | Accessories, connectors, hardware, etc | lot | 1 | 14,000.00 | 14,000.00 | 800.00 | 800.00 |
| **1.2** | **Protection & Control Panels** | | | | | | |
| 1 | 115 kV Line feeder protection | set | 2 | 78,000.00 | 156,000.00 | 3,400.00 | 6,800.00 |
| 2 | 115 kV TL bay control | set | 2 | 25,000.00 | 50,000.00 | 2,800.00 | 5,600.00 |
| **1.3** | **Optical Fiber Communication System** | | | | | | |
| 1 | Optical fiber cable (36 cores) | lot | 1 | 3,200.00 | 3,200.00 | 2,000.00 | 2,000.00 |
| 2 | OPGW joint boxes | lot | 1 | 3,400.00 | 3,400.00 | 500.00 | 500.00 |
| **1.4** | **Power and Control cables** | | | | | | |
| 1 | 1000 V solid dielectric power cables | lot | 1 | 26,400.00 | 26,400.00 | 3,120.00 | 3,120.00 |
| 2 | PVC insulated control cables | lot | 1 | 48,600.00 | 48,600.00 | 7,800.00 | 7,800.00 |
| **1.5** | **Earthing, Lightning Protection and Lighting System** | | | | | | |
| 1 | Earthing system (integration in the existing system) | lot | 1 | 25,300.00 | 25,300.00 | 7,500.00 | 7,500.00 |
| 2 | Lightning protection system | lot | 1 | 1,300.00 | 1,300.00 | 800.00 | 800.00 |
| 3 | Lighting system | lot | 1 | 3,000.00 | 3,000.00 | 600.00 | 600.00 |
| **1.6** | **Spare Parts & Special Tools** | | | | | | |
| 1 | 5% of Total above | lot | 1 | | 32,300.00 | | |
| 2 | Documents | lot | 1 | | 2,000.00 | | |
| | | | | | 681,000.00 | | 65,820.00 |

## 2. Civil & Other Works

| | | unit | Q'ty | FC (US$) FC | FC (US$) Total FC | LC (US$) LC | LC (US$) Total LC |
|---|---|---|---|---|---|---|---|
| **2.1** | **Preliminary Works** | | | | | | |
| 1 | Site survey | lot | 1 | 2,000.00 | 2,000.00 | 2,000.00 | 2,000.00 |
| 2 | Sub-soil investigation | lot | 1 | 2,000.00 | 2,000.00 | 1,000.00 | 1,000.00 |
| 3 | Civil engineering works | lot | 1 | 30,000.00 | 30,000.00 | 0.00 | 0.00 |
| 4 | Temporary works, site office | lot | 1 | | 0.00 | 36,000.00 | 36,000.00 |
| **2.2** | **Site Cleaning & Formation Works** | | | | | | |
| 1 | Cutting and removing trees & shrubs | lot | 1 | | 0.00 | 9,100.00 | 9,100.00 |
| 2 | Demolishing existing structure | lot | 1 | | | 13,500.00 | 13,500.00 |
| 3 | Cutting, filling and compacting earth | lot | 1 | | 0.00 | 42,000.00 | 42,000.00 |
| 4 | Earth retaing structure | lot | 1 | | 0.00 | 23,100.00 | 23,100.00 |
| **2.3** | **Civil Works** | | | | | | |
| 1 | Cable trenches & ducts | lot | 1 | | 0.00 | 32,000.00 | 32,000.00 |
| 2 | Foundations | lot | 1 | | 0.00 | 62,000.00 | 62,000.00 |
| 3 | Water supply and drainage | lot | 1 | | 0.00 | 28,000.00 | 28,000.00 |
| 4 | Servise roads | lot | 1 | | 0.00 | 20,000.00 | 20,000.00 |
| 5 | Chainlink fences | lot | 1 | | 0.00 | 19,200.00 | 19,200.00 |
| 6 | Gravelling | lot | 1 | | 0.00 | 29,800.00 | 29,800.00 |
| | | | | | 32,000.00 | | 315,700.00 |

Total **1,094,520.00**

# Table 11-13 Construction Cost of Nongdeun Substation

## 1. Plant and equipment

| | Items | unit | Q'ty | FC (US$) CIF | FC (US$) Total FC | LC (US$) Insurance, inland transportation & installation | LC (US$) Total LC |
|---|---|---|---|---|---|---|---|
| **1.1** | **115 kV outdoor switchyard** | | | | | | |
| 1 | Circuit breakers | set | 4 | 50,000.00 | 200,000.00 | 4,800.00 | 19,200.00 |
| 2 | Disconnectors | set | 8 | 6,900.00 | 55,200.00 | 800.00 | 6,400.00 |
| 3 | Disconnectors with earthing switches | set | 4 | 8,100.00 | 32,400.00 | 900.00 | 3,600.00 |
| 4 | Current transformers | pcs | 4 | 7,800.00 | 31,200.00 | 600.00 | 2,400.00 |
| 5 | Capacitor voltage transformers | pcs | 4 | 9,100.00 | 36,400.00 | 500.00 | 2,000.00 |
| 6 | Surge arresters | pcs | 4 | 2,000.00 | 8,000.00 | 200.00 | 800.00 |
| 7 | Post insulators | pcs | 32 | 1,100.00 | 35,200.00 | 100.00 | 3,200.00 |
| 8 | Power coductors | lot | 1 | 5,000.00 | 5,000.00 | 2,000.00 | 2,000.00 |
| 9 | Suspension insulator disks | lot | 1 | 6,000.00 | 6,000.00 | 2,000.00 | 2,000.00 |
| 10 | Steel structures (Gantries) | lot | 1 | 72,000.00 | 72,000.00 | 7,200.00 | 7,200.00 |
| 11 | Accessories, connectors, hardware, etc | lot | 1 | 24,000.00 | 24,000.00 | 1,600.00 | 1,600.00 |
| **1.2** | **Protection & Control Panels** | | | | | | |
| 1 | 115 kV Line feeder protection | set | 4 | 78,000.00 | 312,000.00 | 3,400.00 | 13,600.00 |
| 2 | 115 kV TL bay control | set | 4 | 25,000.00 | 100,000.00 | 2,800.00 | 11,200.00 |
| **1.3** | **Optical Fiber Communication System** | | | | | | |
| 1 | Optical fiber cable (36 cores) | lot | 1 | 6,400.00 | 6,400.00 | 4,000.00 | 4,000.00 |
| 2 | OPGW joint boxes | lot | 1 | 6,800.00 | 6,800.00 | 1,000.00 | 1,000.00 |
| **1.4** | **Power and Control cables** | | | | | | |
| 1 | 1000 V solid dielectric power cables | lot | 1 | 39,600.00 | 39,600.00 | 5,400.00 | 5,400.00 |
| 2 | PVC insulated control cables | lot | 1 | 72,900.00 | 72,900.00 | 7,800.00 | 7,800.00 |
| **1.5** | **Earthing, Lightning Protection and Lighting System** | | | | | | |
| 1 | Earthing system (integration in the existing system) | lot | 1 | 50,600.00 | 50,600.00 | 15,000.00 | 15,000.00 |
| 2 | Lightning protection system | lot | 1 | 2,600.00 | 2,600.00 | 1,600.00 | 1,600.00 |
| 3 | Lighting system | lot | 1 | 3,000.00 | 3,000.00 | 600.00 | 600.00 |
| **1.6** | **Spare Parts & Special Tools** | | | | | | |
| 1 | 5% of Total above | lot | 1 | | 55,000.00 | | |
| 2 | Documents | lot | 1 | | 2,000.00 | | |
| | | | | | 1,156,300.00 | | 110,600.00 |

## 2. Civil & Other Works

| | | unit | Q'ty | FC (US$) FC | FC (US$) Total FC | LC (US$) LC | LC (US$) Total LC |
|---|---|---|---|---|---|---|---|
| **2.1** | **Preliminary Works** | | | | | | |
| 1 | Site survey | lot | 1 | 2,000.00 | 2,000.00 | 2,000.00 | 2,000.00 |
| 2 | Sub-soil investigation | lot | 1 | 2,000.00 | 2,000.00 | 1,000.00 | 1,000.00 |
| 3 | Civil engineering works | lot | 1 | 10,000.00 | 10,000.00 | 0.00 | 0.00 |
| 4 | Temporary works, site office | lot | 1 | | 0.00 | 36,000.00 | 36,000.00 |
| **2.3** | **Civil Works** | | | | | | |
| 1 | Cable trenches & ducts | lot | 1 | | 0.00 | 25,000.00 | 25,000.00 |
| 2 | Foundations | lot | 1 | | 0.00 | 110,000.00 | 110,000.00 |
| 3 | Gravelling | lot | 1 | | 0.00 | 59,600.00 | 59,600.00 |
| | | | | | 14,000.00 | | 233,600.00 |

Total **1,514,500.00**

# Table 11-14 Construction Cost of Taothan Substation

**1. Plant and equipment**

| | Items | unit | Q'ty | FC (US$) CIF | FC (US$) Total FC | LC (US$) Insurance, inland transportation & installation | LC (US$) Total LC |
|---|---|---|---|---|---|---|---|
| **1.1** | **Transformers** | | | | | | |
| 1 | 3 phase 115/22 kV transformer, 20 MVA | set | 1 | 550,000.00 | 550,000.00 | 25,000.00 | 25,000.00 |
| 2 | Auxiliary transformer, 22/0.4 kV, 100 kVA | set | 1 | 20,000.00 | 20,000.00 | 3,000.00 | 3,000.00 |
| **1.2** | **115 kV outdoor switchyard** | | | | | | |
| 1 | Circuit breakers for TR bays & bus-tie | set | 2 | 43,000.00 | 86,000.00 | 4,800.00 | 9,600.00 |
| 2 | Circuit breakers for TL bays | set | 4 | 50,000.00 | 200,000.00 | 4,800.00 | 19,200.00 |
| 3 | Disconnectors | set | 12 | 6,900.00 | 82,800.00 | 800.00 | 9,600.00 |
| 4 | Disconnectors with earthing switches | set | 5 | 8,100.00 | 40,500.00 | 900.00 | 4,500.00 |
| 5 | Current transformers for TR bay | pcs | 3 | 8,200.00 | 24,600.00 | 600.00 | 1,800.00 |
| 6 | Current transformers for TL bays | pcs | 12 | 7,800.00 | 93,600.00 | 600.00 | 7,200.00 |
| 7 | Capacitor voltage transformers | pcs | 15 | 9,100.00 | 136,500.00 | 500.00 | 7,500.00 |
| 8 | Surge arresters | pcs | 15 | 2,000.00 | 30,000.00 | 200.00 | 3,000.00 |
| 9 | Post insulators | pcs | 61 | 1,100.00 | 67,100.00 | 100.00 | 6,100.00 |
| 10 | 115 kV busbar with structure | lot | 1 | 28,300.00 | 28,300.00 | 6,200.00 | 6,200.00 |
| 11 | Power coductors | lot | 1 | 22,800.00 | 22,800.00 | 4,800.00 | 4,800.00 |
| 12 | Suspension insulator disks | lot | 1 | 16,300.00 | 16,300.00 | 5,200.00 | 5,200.00 |
| 13 | Steel structures (Gantries), 15 towers & 8 beams | lot | 1 | 154,000.00 | 154,000.00 | 21,300.00 | 21,300.00 |
| 14 | Accessories, connectors, hardware, etc | lot | 1 | 66,000.00 | 66,000.00 | 4,000.00 | 4,000.00 |
| **1.3** | **22 kV outdoor switchgear** | | | | | | |
| 1 | Circuit breakers | set | 7 | 15,100.00 | 105,700.00 | 1,800.00 | 12,600.00 |
| 2 | Disconnectors | set | 7 | 7,100.00 | 49,700.00 | 1,400.00 | 9,800.00 |
| 3 | Disconnectors with earthing switches | set | 5 | 8,200.00 | 41,000.00 | 1,700.00 | 8,500.00 |
| 4 | Current transformers for TR bays | pcs | 3 | 1,800.00 | 5,400.00 | 500.00 | 1,500.00 |
| 5 | Current transformers for feeders | pcs | 12 | 1,800.00 | 21,600.00 | 500.00 | 6,000.00 |
| 6 | Capacitor voltage transformers | pcs | 6 | 1,400.00 | 8,400.00 | 500.00 | 3,000.00 |
| 7 | Surge arresters | pcs | 15 | 900.00 | 13,500.00 | 400.00 | 6,000.00 |
| 8 | Static capacitor bank, 2.5 MVar | set | 1 | 32,500.00 | 32,500.00 | 1,600.00 | 1,600.00 |
| 9 | Static capacitor bank, 5 MVar | set | 1 | 40,000.00 | 40,000.00 | 2,000.00 | 2,000.00 |
| 10 | Switch-Fuse Combinations for Aux. TR | set | 1 | 4,100.00 | 4,100.00 | 1,900.00 | 1,900.00 |
| 11 | 22 kV busbar | lot | 1 | 9,500.00 | 9,500.00 | 3,500.00 | 3,500.00 |
| 12 | Power coductors | lot | 1 | 7,600.00 | 7,600.00 | 2,400.00 | 2,400.00 |
| 13 | 22kV Power Cable(100m) with connection kit | set | 4 | 21,500.00 | 86,000.00 | 2,600.00 | 10,400.00 |
| 14 | Suspension insulator disks | lot | 1 | 5,400.00 | 5,400.00 | 1,800.00 | 1,800.00 |
| 15 | Steel structures (Gantries) | lot | 1 | 36,000.00 | 36,000.00 | 8,800.00 | 8,800.00 |
| 16 | Accessories, connectors, hardware, etc | lot | 1 | 16,000.00 | 16,000.00 | 2,800.00 | 2,800.00 |
| **1.4** | **Protection & Control Panels** | | | | | | |
| 1 | 115/22 kV transformer protection | set | 1 | 82,000.00 | 82,000.00 | 4,000.00 | 4,000.00 |
| 2 | 115 kV Line feeder protection | set | 4 | 78,000.00 | 312,000.00 | 3,400.00 | 13,600.00 |
| 3 | 115 kV busbar protection | set | 1 | 63,000.00 | 63,000.00 | 3,100.00 | 3,100.00 |
| 4 | 115/22 kV transformer control | set | 1 | 32,000.00 | 32,000.00 | 3,000.00 | 3,000.00 |
| 5 | 115 kV TL bay control | set | 4 | 25,000.00 | 100,000.00 | 2,800.00 | 11,200.00 |
| 6 | 115 kV bus-tie control | set | 1 | 16,000.00 | 16,000.00 | 2,500.00 | 2,500.00 |
| 7 | 22 kV feeder protection & control | set | 4 | 47,000.00 | 188,000.00 | 2,400.00 | 9,600.00 |
| 8 | 22 kV static capacitor protection & control | set | 1 | 12,000.00 | 12,000.00 | 2,400.00 | 2,400.00 |
| 9 | Distributed Control System | lot | 1 | 365,000.00 | 365,000.00 | 3,800.00 | 3,800.00 |
| **1.5** | **Optical Fiber Communication System** | | | | | | |
| 1 | SDH, MPX & ODB | lot | 1 | 93,800.00 | 93,800.00 | 50,000.00 | 50,000.00 |
| 2 | Optical fiber cable (36 cores) | lot | 1 | 3,200.00 | 3,200.00 | 5,000.00 | 5,000.00 |
| 3 | OPGW joint boxes | lot | 1 | 3,400.00 | 3,400.00 | 500.00 | 500.00 |
| 4 | Digital PABX | lot | 1 | 21,700.00 | 21,700.00 | 3,000.00 | 3,000.00 |
| 5 | Telephone system | lot | 1 | 15,400.00 | 15,400.00 | 2,500.00 | 2,500.00 |
| 6 | VHF radio telecommunication system | lot | 1 | 28,800.00 | 28,800.00 | 5,300.00 | 5,300.00 |

## Table 11-14 Construction Cost of Taothan Substation (Continued)

| | | unit | Q'ty | FC | Total FC | LC | Total LC |
|---|---|---|---|---|---|---|---|
| **1.6** | **Power and Control cables** | | | | | | |
| 1 | 1000 V solid dielectric power cables | lot | 1 | 52,800.00 | 52,800.00 | 14,400.00 | 14,400.00 |
| 2 | PVC insulated control cables | lot | 1 | 97,200.00 | 97,200.00 | 20,800.00 | 20,800.00 |
| **1.7** | **DC installations** | | | | | | |
| 1 | 110 V battery banks | set | 2 | 16,400.00 | 32,800.00 | 1,400.00 | 2,800.00 |
| 2 | 48 V battrery banks | set | 2 | 14,400.00 | 28,800.00 | 1,300.00 | 2,600.00 |
| 3 | 110 V battery charging system | set | 2 | 11,900.00 | 23,800.00 | 1,100.00 | 2,200.00 |
| 4 | 48 V battery charging system | set | 2 | 8,800.00 | 17,600.00 | 800.00 | 1,600.00 |
| 5 | 110 V DC distribution board | set | 1 | 16,200.00 | 16,200.00 | 1,400.00 | 1,400.00 |
| 6 | 48 V DC distribution board | set | 1 | 16,200.00 | 16,200.00 | 1,400.00 | 1,400.00 |
| **1.8** | **0.4 kV AC installations** | | | | | | |
| 1 | AC distribution board | set | 1 | 32,800.00 | 32,800.00 | 2,900.00 | 2,900.00 |
| **1.9** | **Earthing, Lightning Protection and Lighting System** | | | | | | |
| 1 | Earthing system | lot | 1 | 151,500.00 | 151,500.00 | 37,500.00 | 37,500.00 |
| 2 | Lightning protection system | lot | 1 | 28,000.00 | 28,000.00 | 6,400.00 | 6,400.00 |
| 3 | Lighting system | lot | 1 | 22,000.00 | 22,000.00 | 3,800.00 | 3,800.00 |
| **1.10** | **Spare Parts & Special Tools** | | | | | | |
| 1 | 5% of Total above | lot | 1 | | 197,800.00 | | |
| 2 | Documents | lot | 1 | | 10,000.00 | | |
| | | | | | 4,164,700.00 | | 437,900.00 |

**2. Civil & Other Works**

| | | unit | Q'ty | FC (US$) FC | Total FC | LC (US$) LC | Total LC |
|---|---|---|---|---|---|---|---|
| **2.1** | **Preliminary Works** | | | | | | |
| 1 | Site survey | lot | 1 | 5,000.00 | 5,000.00 | 7,000.00 | 7,000.00 |
| 2 | Sub-soil investigation | lot | 1 | 5,000.00 | 5,000.00 | 12,000.00 | 12,000.00 |
| 3 | Civil engineering works | lot | 1 | 85,000.00 | 85,000.00 | 0.00 | 0.00 |
| 4 | Temporary works, site office | lot | 1 | | 0.00 | 120,000.00 | 120,000.00 |
| **2.2** | **Site Cleaning & Formation Works** | | | | | | |
| 1 | Cutting and removing trees & shrubs | lot | 1 | | 0.00 | 22,600.00 | 22,600.00 |
| 2 | Demolishing existing structure | lot | 1 | | 0.00 | 27,000.00 | 27,000.00 |
| 3 | Cutting, filling and compacting earth | lot | 1 | | 0.00 | 116,500.00 | 116,500.00 |
| 4 | Earth retaing structure | lot | 1 | | 0.00 | 92,400.00 | 92,400.00 |
| **2.3** | **Civil Works** | | | | | | |
| 1 | Cable trenches & ducts | lot | 1 | | 0.00 | 168,000.00 | 168,000.00 |
| 2 | Foundations | lot | 1 | | 0.00 | 278,000.00 | 278,000.00 |
| 3 | Water supply and drainage | lot | 1 | | 0.00 | 84,000.00 | 84,000.00 |
| 4 | Servise roads | lot | 1 | | 0.00 | 60,000.00 | 60,000.00 |
| 5 | Chainlink fences | lot | 1 | | 0.00 | 52,000.00 | 52,000.00 |
| 6 | Gravelling | lot | 1 | | 0.00 | 68,000.00 | 68,000.00 |
| 7 | Oil pit for TR | lot | 1 | | 0.00 | 18,400.00 | 18,400.00 |
| 8 | Sodding | lot | 1 | | 0.00 | 12,000.00 | 12,000.00 |
| **2.4** | **Building Works** | | | | | | |
| 1 | Control building & guard house | lot | 1 | | 0.00 | 354,000.00 | 354,000.00 |
| 2 | Staff house | lot | 1 | | 0.00 | 100,000.00 | 100,000.00 |
| | | | | | 95,000.00 | | 1,491,900.00 |
| | | | | | | Total | **6,189,500.00** |

# Table 11-15 Construction Cost of Saravan Substation

## 1. Plant and equipment

| | Items | unit | Q'ty | FC (US$) CIF | FC (US$) Total FC | LC (US$) Insurance, inland transportation & installation | LC (US$) Total LC |
|---|---|---|---|---|---|---|---|
| **1.1** | **115 kV outdoor switchyard** | | | | | | |
| 1 | Circuit breakers | set | 2 | 50,000.00 | 100,000.00 | 4,800.00 | 9,600.00 |
| 2 | Disconnectors | set | 4 | 8,000.00 | 32,000.00 | 800.00 | 3,200.00 |
| 3 | Disconnectors with earthing switches | set | 2 | 10,000.00 | 20,000.00 | 900.00 | 1,800.00 |
| 4 | Current transformers | pcs | 6 | 8,000.00 | 48,000.00 | 600.00 | 3,600.00 |
| 5 | Capacitor voltage transformers | pcs | 6 | 9,500.00 | 57,000.00 | 500.00 | 3,000.00 |
| 6 | Surge arresters | pcs | 6 | 2,200.00 | 13,200.00 | 200.00 | 1,200.00 |
| 7 | Post insulators | pcs | 28 | 900.00 | 25,200.00 | 100.00 | 2,800.00 |
| 8 | 115 kV busbar with structure | lot | 1 | 8,000.00 | 8,000.00 | 2,000.00 | 2,000.00 |
| 9 | Power coductors | lot | 1 | 2,500.00 | 2,500.00 | 1,000.00 | 1,000.00 |
| 10 | Suspension insulator disks | lot | 1 | 3,000.00 | 3,000.00 | 1,000.00 | 1,000.00 |
| 11 | Steel structures (Gantries), 4 towers & 4 beams | lot | 1 | 36,000.00 | 36,000.00 | 3,600.00 | 3,600.00 |
| 12 | Accessories, connectors, hardware, etc | lot | 1 | 14,000.00 | 14,000.00 | 800.00 | 800.00 |
| **1.2** | **Protection & Control Panels** | | | | | | |
| 1 | 115 kV Line feeder protection | set | 2 | 78,000.00 | 156,000.00 | 3,400.00 | 6,800.00 |
| 2 | 115 kV TL bay control | set | 2 | 25,000.00 | 50,000.00 | 2,800.00 | 5,600.00 |
| **1.3** | **Optical Fiber Communication System** | | | | | | |
| 1 | Optical fiber cable (36 cores) | lot | 1 | 3,200.00 | 3,200.00 | 2,000.00 | 2,000.00 |
| 2 | OPGW joint boxes | lot | 1 | 3,400.00 | 3,400.00 | 500.00 | 500.00 |
| **1.4** | **Power and Control cables** | | | | | | |
| 1 | 1000 V solid dielectric power cables | lot | 1 | 26,400.00 | 26,400.00 | 3,120.00 | 3,120.00 |
| 2 | PVC insulated control cables | lot | 1 | 48,600.00 | 48,600.00 | 7,800.00 | 7,800.00 |
| **1.5** | **Earthing, Lightning Protection and Lighting System** | | | | | | |
| 1 | Earthing system (integration in the existing system) | lot | 1 | 2,000.00 | 2,000.00 | 2,000.00 | 2,000.00 |
| 2 | Lightning protection system | lot | 1 | 2,500.00 | 2,500.00 | 1,500.00 | 1,500.00 |
| **1.6** | **Spare Parts & Special Tools** | | | | | | |
| 1 | 5% of Total above | lot | 1 | | 32,600.00 | | |
| 2 | Documents | lot | 1 | | 5,000.00 | | |
| | | | | | 688,600.00 | | 62,920.00 |

## 2. Civil & Other Works

| | Items | unit | Q'ty | FC (US$) FC | FC (US$) Total FC | LC (US$) LC | LC (US$) Total LC |
|---|---|---|---|---|---|---|---|
| **2.1** | **Preliminary Works** | | | | | | |
| 1 | Site survey | lot | 1 | 2,000.00 | 2,000.00 | 2,000.00 | 2,000.00 |
| 2 | Sub-soil investigation | lot | 1 | 2,000.00 | 2,000.00 | 1,000.00 | 1,000.00 |
| 3 | Civil engineering works | lot | 1 | 10,000.00 | 10,000.00 | | |
| 4 | Temporary works, site office | lot | 1 | | 0.00 | 25,000.00 | 25,000.00 |
| **2.2** | **Civil Works** | | | | | | |
| 1 | Cable trenches & ducts | lot | 1 | | 0.00 | 14,000.00 | 14,000.00 |
| 2 | Foundations | lot | 1 | | 0.00 | 40,000.00 | 40,000.00 |
| | | | | | 14,000.00 | | 82,000.00 |

Total **847,520.00**

### 11.4.4 Total Project Costs

The conditions for the estimation of the total project costs which are the same as the conditions of the MP study are as follows;

a) Physical contingencies for both the FC and the LC portions are estimated at 10% of transmission lines and substation facilities of the total construction costs including Price Contingency.
b) Compensation cost for the lands and ROW, cost for environmental monitoring and cost for UXO investigation and clearance are included in the LC portion of the total costs.
c) Consultant service fee is included in the FC & LC portions and estimated at approximately 7% of the total transmission line and substations' construction cost including Price Contingency.
d) Physical contingencies for both the FC and the LC portions are estimated at 10% of transmission lines and substation facilities of the total construction costs.
e) Price contingencies for the FC are estimated at 2.6% of each portion of the total construction costs and the LC portions are estimated at 8.4% of each portion of the total construction costs.
f) Administration Cost, Tax and Duty and Interest During Construction are estimated based on experiences of 115kV Pakxan-Pakbo transmission line project.

Table 11-16 shows the total costs for the project estimated under the aforementioned conditions. The estimation of the MP study is also written in the table for reference.

**Table 11-16 Total Project Costs (1,000USD)**

| Items | Estimation in MP study | | | Estimation in this study | | |
|---|---|---|---|---|---|---|
| | FC | LC | Total | FC | LC | Total |
| Transmission Lines | 18,235.3 | 6,011.7 | 24,247.0 | 20,506.5 | 6,376.0 | 26,882.5 |
| Substation Facilities | 5,580.5 | 2,433.8 | 8,014.3 | 6,845.6 | 2,800.4 | 9,646.0 |
| Sub-total | 23,815.8 | 8,445.5 | 32,261.3 | 27,352.1 | 9,176.4 | 36,528.5 |
| Compensation | - | 166.8 | 166.8 | - | 166.8 | 166.8 |
| Environment Monitoring | - | 43.1 | 43.1 | - | 43.1 | 43.1 |
| UXO Survey & Clear | - | 271.2 | 271.2 | - | 271.2 | 271.2 |
| Consultant Fee | 2,258.3 | 192.0 | 2,450.3 | 1,914.6 | 642.3 | 2,556.9 |
| Physical Contingency | 1,190.8 | 422.3 | 1,613.1 | 2,811.8 | 994.7 | 3,806.5 |
| Price Contingency | 714.5 | 253.4 | 967.9 | 765.9 | 770.8 | 1,536.7 |
| Administration Cost | - | - | - | - | 1,998.2 | 1,998.2 |
| Tax & Duty | - | - | - | - | 4,230.5 | 4,230.5 |
| Interest During Construction | - | - | - | 526.8 | - | 526.8 |
| Total | **27,979.4** | **9,794.3** | **37,773.7** | **33,371.2** | **18,294.0** | **51,665.2** |

### 11.4.5 Disbursement Schedule of the Costs

The project will be carried out in 36 months as shown in Figure 11-7 in section 11.3. The conditions in preparing the disbursement schedule for the project investment are assumed below:

a) The construction costs for the transmission line facilities and substation facilities for the project will be disbursed in the second and third year equally, after the conclusion of the contracts with the contractors.
b) Compensation cost for the lands and ROW will be disbursed in the first year.
c) Environmental monitoring cost will be disbursed in the second and third year equally.
d) UXO investigation and clearance will be carried out before the excavation work of the foundations for the transmission line towers, and their costs will be disbursed in the second year.
e) 20% of the consultant service fee will be disbursed in the first year and the remaining amount will be disbursed in the second and third year equally.
f) 30% of both the physical and price contingencies will be disbursed in the second year and 70% in the third year.
g) 30% of Administration Cost, Tax and Duty and Interest During Construction will be disbursed in the second year and 70% in the third year

Table 11-17 shows the disbursement schedule for the project costs over three years.

## Table 11-17 Disbursement Schedule (1,000USD)

| Months | Items | MP study | | | This study | | |
|---|---|---|---|---|---|---|---|
| | | FC | LC | Total | FC | LC | Total |
| 1-12 months | T/L facilities | - | - | - | - | - | - |
| | S/S facilities | - | - | - | - | - | - |
| | Compensation | - | 166.8 | 166.8 | - | 166.8 | 166.8 |
| | Monitoring | - | - | - | - | - | - |
| | UXO | - | - | - | - | - | - |
| | Consultant | 451.7 | 38.4 | 490.1 | 382.9 | 128.5 | 511.4 |
| | Contingencies | - | - | - | - | - | - |
| | Administration | - | - | - | - | - | - |
| | Tax & Duty | - | - | - | - | - | - |
| | Interest | - | - | - | - | - | - |
| | subtotal | **451.7** | **205.2** | **656.9** | **382.9** | **295.3** | **678.2** |
| 13-24 months | T/L facilities | 9,117.7 | 3,005.9 | 12,123.6 | 10,253.3 | 3,188.0 | 13,441.3 |
| | S/S facilities | 1,674.2 | 730.1 | 2,404.3 | 3,422.8 | 1,400.2 | 4,823.0 |
| | Compensation | - | - | - | - | - | - |
| | Monitoring | - | 21.5 | 21.5 | - | 21.6 | 21.6 |
| | UXO | - | 271.2 | 271.2 | - | 271.2 | 271.2 |
| | Consultant | 903.3 | 76.8 | 980.1 | 765.8 | 256.9 | 1,022.7 |
| | Contingencies | 571.6 | 202.7 | 774.3 | 1,073.3 | 529.7 | 1,603.0 |
| | Administration | - | - | - | - | 599.5 | 599.5 |
| | Tax & Duty | - | - | - | - | 1,269.2 | 1,269.2 |
| | Interest | - | - | - | 158.0 | - | 158.0 |
| | subtotal | **12,266.7** | **4,308.2** | **16,574.9** | **15,673.2** | **7,536.3** | **23,209.5** |
| 25-36 months | T/L facilities | 9,117.7 | 3,005.8 | 12,123.5 | 10,253.2 | 3,188.0 | 13,441.2 |
| | S/S facilities | 3,906.4 | 1,703.7 | 5,610.1 | 3,422.8 | 1,400.2 | 4,823.0 |
| | Compensation | - | - | - | - | - | - |
| | Monitoring | - | 21.5 | 21.5 | - | 21.5 | 21.5 |
| | UXO | - | - | - | - | - | - |
| | Consultant | 903.3 | 76.8 | 980.1 | 765.8 | 256.9 | 1,022.7 |
| | Contingencies | 1,333.7 | 473.0 | 1,806.7 | 2,504.4 | 1,235.9 | 3,740.3 |
| | Administration | - | - | - | - | 1,398.7 | 1,398.7 |
| | Tax & Duty | - | - | - | - | 2,961.4 | 2,961.4 |
| | Interest | - | - | - | 368.8 | - | 368.8 |
| | subtotal | **15,261.0** | **5,280.9** | **20,541.9** | **17,315.0** | **10,462.6** | **27,777.6** |
| | Total | **27,979.4** | **9,794.3** | **37,773.7** | **33,371.1** | **18,294.2** | **51,665.3** |

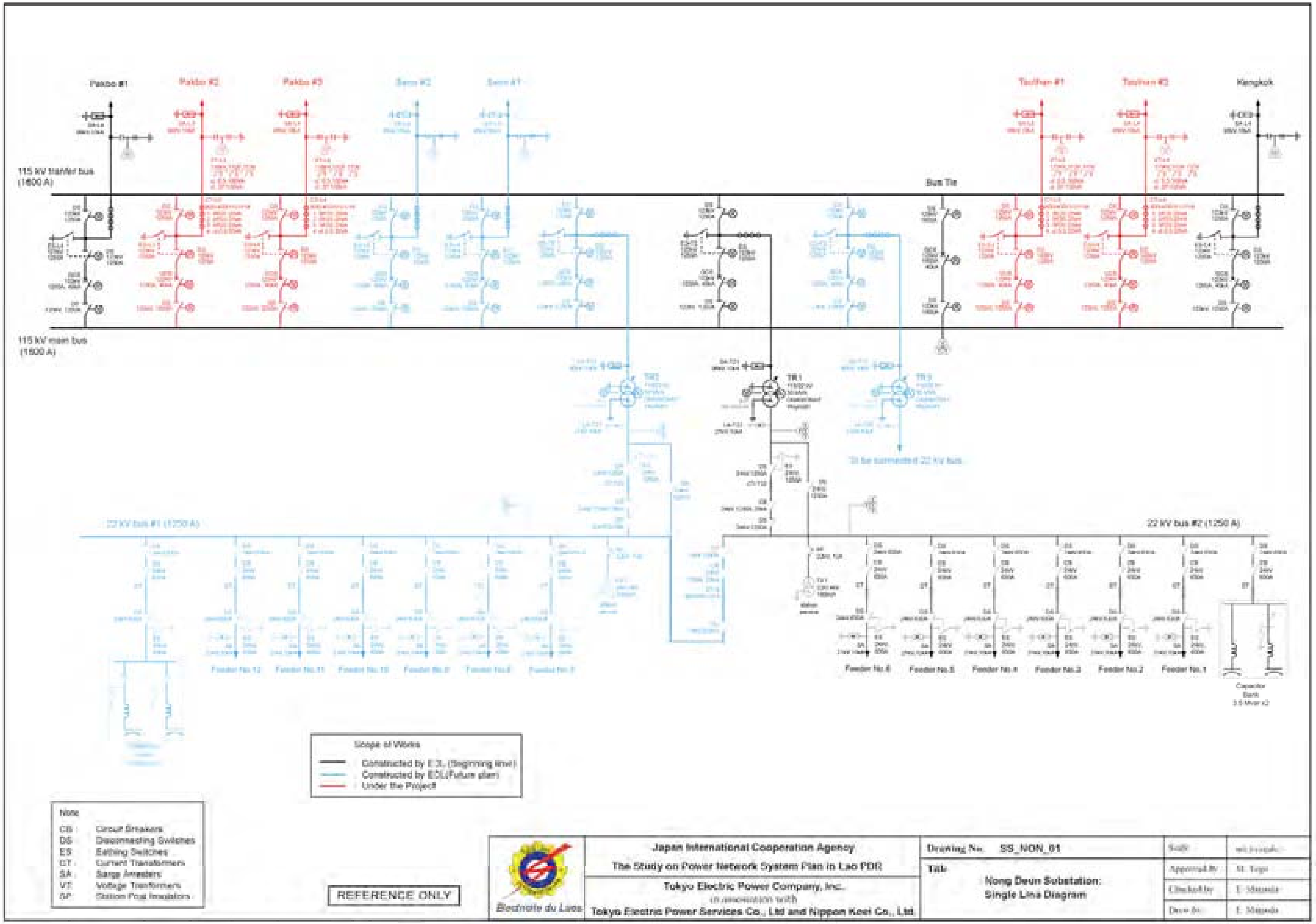



**Figure 11-8 Drawing No. SS_NON_01: Nongdeun Substation – Single Line Diagram**

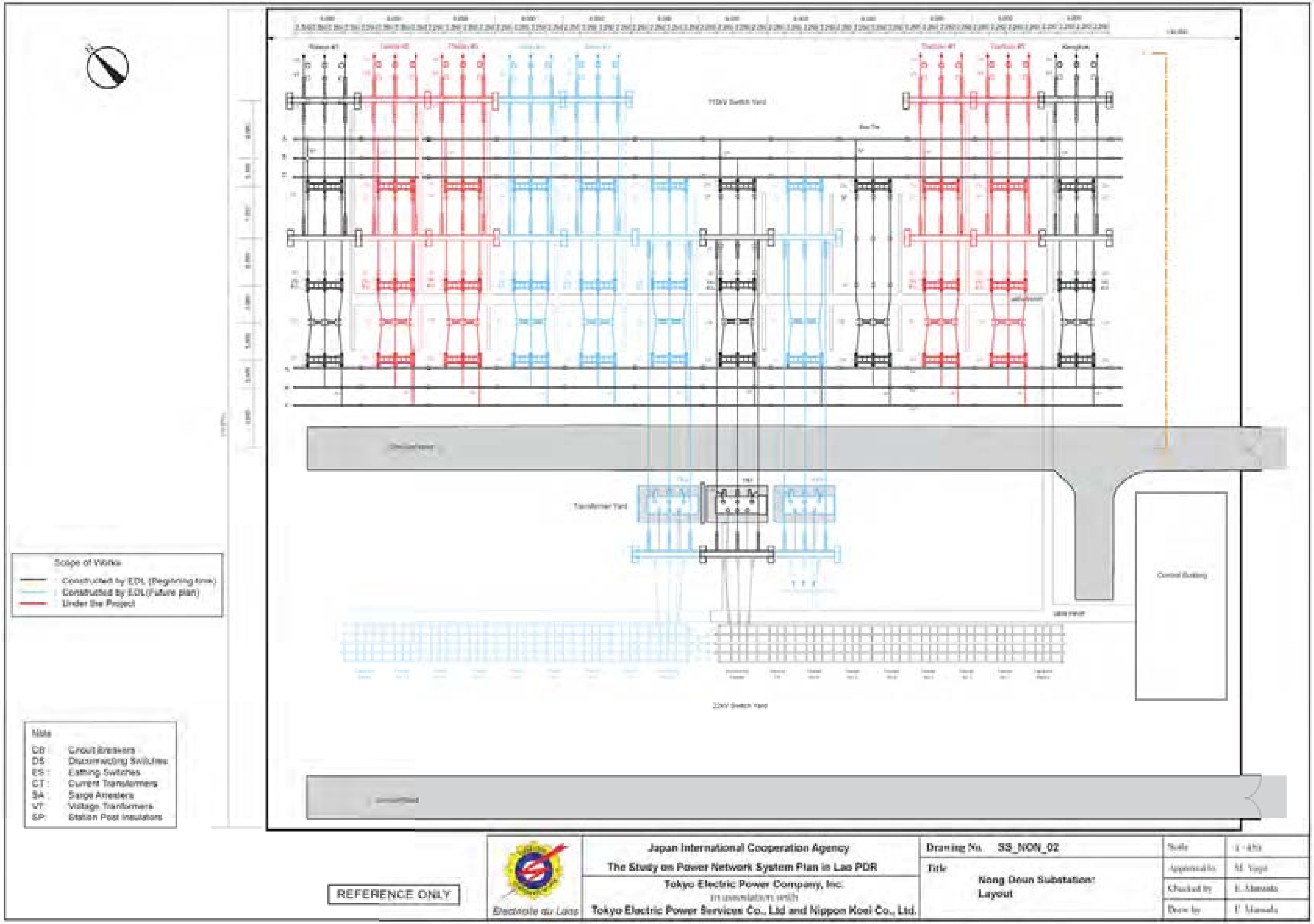



Figure 11-9 Drawing No. SS_NON_02: Nongdeun Substation – Layout

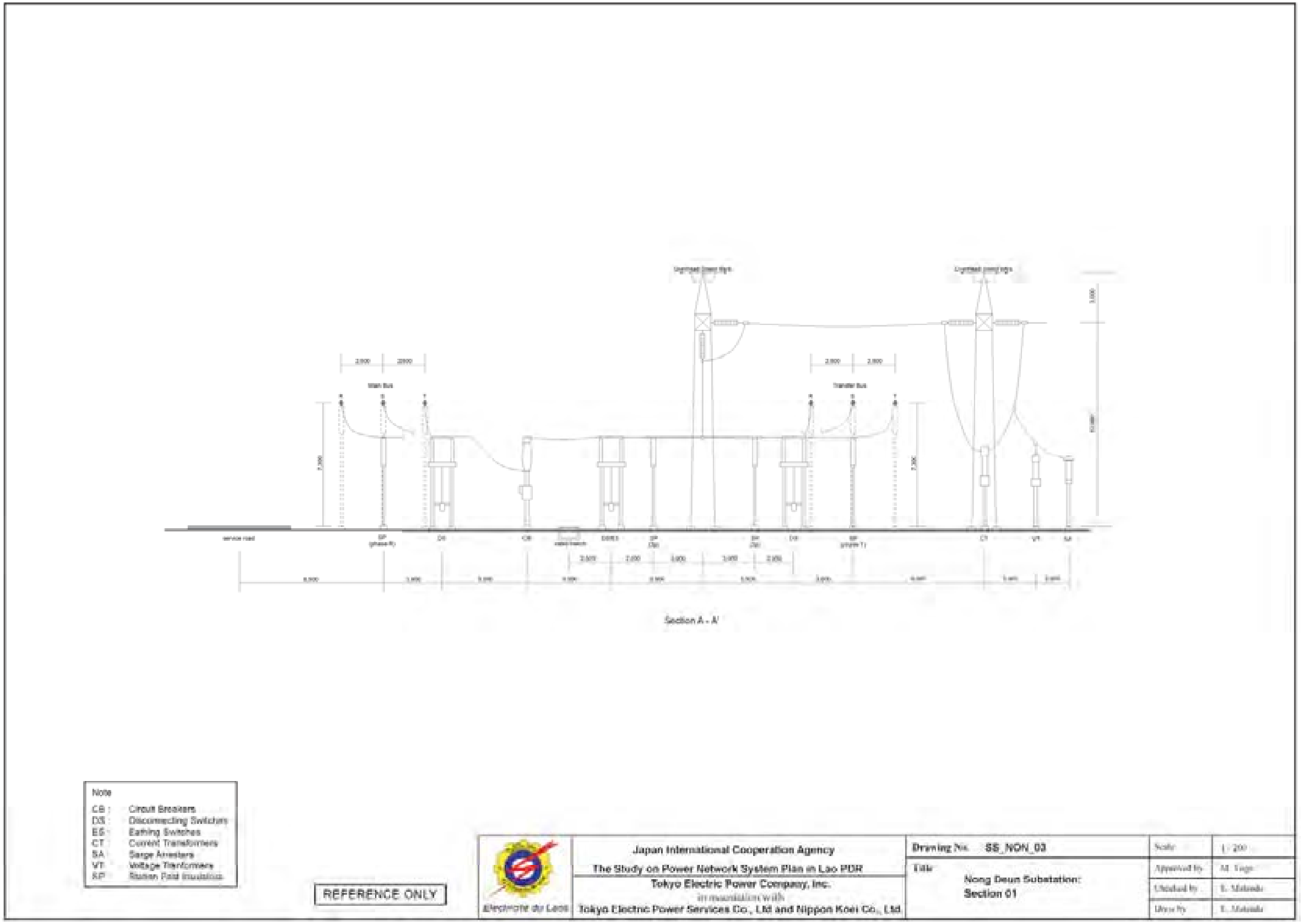



Figure 11-10 Drawing No. SS_NON_03: Nongdeun Substation – Section

# Chapter 12 Economic Evaluation of the First Priority Project of the Central-South System

## 12.1 Benefit of First Priority Project

The project of 115 kV Pakbo-Saravan transmission line in the central southern areas was evaluated from the viewpoint of the below benefits as:

(1) Avoidance of power outage in the two southern areas
(2) Reduction of exported and imported energy
(3) Avoidance of investment of long distance 22 kV distribution line between Saravan-Taothan
(4) Increased power supply capacity to Nongdeun Substation

(1) and (2) is based on the estimated values from the “Benefits of 115 kV Transmission Line” in section 6.4.

The amount of energy equivalent to avoid a power outage is 1 GWh every year from 2015 to 2018. The benefits of avoiding outages is estimated to be 0.2 USD/kWh, assuming that alternative dispersion power sources such as emergency diesel generators are operated for power outages.

Avoiding the spilled water of hydropower plants was evaluated by the difference of the unit price of imported and exported energy. The difference of the unit price of imported and exported energy was set as 0.19 BHT/kWh (0.0057 USD) based on the current contract between EGAT and EDL (1 BHT=0.03 USD).

The costs and system losses of the distribution line between Saravan-Taothan in Section 10.3 were used in this chapter.

Although the transmission lines supplied to Nongdeun substation consist of three lines from Pakbo and two lines from the 230 kV Seno substation, transmission lines, this study include two lines between Pakbo- Nongdeun substations. Two alternate lines between the Seno-Nongdeun substations are necessary if this project does not include the transmission lines. Thus, we assumed that this project can avoid investment for the transmission lines.

The financial benefits of this project is calculated based on the revenue obtained from increased demand due to the energy consumption of final customers, which is expected to be supplied by this transmission project. Transported energy was estimated based on a power flow calculation, and 488 GWh of energy per year is estimated to flow through the transmission lines of this project.

## 12.2 Economical and Financial Analyses of Highest Prioritized Project

### (1) Economical Analysis of the Project

The study team confirmed the economical validity of this transmission-transformation project based on a comparison of the Economic Internal Rate of Return (EIRR) and the Opportunity Cost of Capital (OCC). It is noted that 12 % is used as the OCC value of Laos based on the project of the "Power Network System Plan".

- The total project costs of this study have been obtained from Table 11-16 and Table 11-17.
- Annual operation and maintenance costs of this transmission-transformation project are assumed to be 1.5 % (transmission facilities) and 2.0 % (substation facilities) of the total investment cost for the facilities.
- Depreciation, payment of interests, and other payments of tax and customs are excluded from the economical costs.
- The local currency portion was converted into an economical price using the Standard Conversion Factor (SCF, 0.9).

The total project and economical costs are listed in Table 12-1. The calculated EIRR is shown in Table 12-2. The project is evaluated to be economically appropriate since 15 % of EIRR is greater than 12 % of the Opportunity Cost of Capital (OCC).

## Table 12-1 Total Cost and Economical Cost of the Project

(Unit: 1,000USD)

| Months | Items | Total Project Cost | | | Economic Project Cost | | | O&M |
|---|---|---|---|---|---|---|---|---|
| | | FC | LC | Total | FC | LC | Total | |
| From 1st to 12th months | T/L facilities | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | S/S facilities | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Compensation | 0.0 | 166.8 | 166.8 | 0.0 | 150.1 | 150.1 | |
| | Monitoring | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | UXO | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Consultant | 382.9 | 128.5 | 511.4 | 382.9 | 115.7 | 498.6 | |
| | Contingencies | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Administration | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Tax & Duty | 0.0 | 0.0 | 0.0 | - | - | - | |
| | Interest | 0.0 | 0.0 | 0.0 | - | - | - | |
| | **subtotal** | **382.9** | **295.3** | **678.2** | **382.9** | **265.8** | **648.7** | |
| From 13th to 24th months | T/L facilities | 10,253.3 | 3,188.0 | 13,441.3 | 10,253.3 | 2,869.2 | 13,122.5 | |
| | S/S facilities | 3,422.8 | 1,400.2 | 4,823.0 | 3,422.8 | 1,260.2 | 4,683.0 | |
| | Compensation | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Monitoring | 0.0 | 21.6 | 21.6 | 0.0 | 19.4 | 19.4 | |
| | UXO | 0.0 | 271.2 | 271.2 | 0.0 | 244.1 | 244.1 | |
| | Consultant | 765.8 | 256.9 | 1,022.7 | 765.8 | 231.2 | 997.0 | |
| | Contingencies | 1,073.3 | 529.7 | 1,603.0 | 1,073.3 | 476.7 | 1,550.0 | |
| | Administration | 0.0 | 599.5 | 599.5 | 0.0 | 539.6 | 539.6 | |
| | Tax & Duty | 0.0 | 1,269.2 | 1,269.2 | - | - | - | |
| | Interest | 158.0 | 0.0 | 158.0 | - | - | - | |
| | **subtotal** | **15,673.2** | **7,536.3** | **23,209.5** | **15,515.2** | **5,640.4** | **21,155.6** | |
| From 25th to 36th months | T/L facilities | 10,253.2 | 3,188.0 | 13,441.2 | 10,253.2 | 2,869.2 | 13,122.4 | |
| | S/S facilities | 3,422.8 | 1,400.2 | 4,823.0 | 3,422.8 | 1,260.2 | 4,683.0 | |
| | Compensation | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Monitoring | 0.0 | 21.5 | 21.5 | 0.0 | 19.4 | 19.4 | |
| | UXO | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Consultant | 765.8 | 256.9 | 1,022.7 | 765.8 | 231.2 | 997.0 | |
| | Contingencies | 2,504.4 | 1,235.9 | 3,740.3 | 2,504.4 | 1,112.3 | 3,616.7 | |
| | Administration | 0.0 | 1,398.7 | 1,398.7 | 0.0 | 1,258.8 | 1,258.8 | |
| | Tax & Duty | 0.0 | 2,961.4 | 2,961.4 | - | - | - | |
| | Interest | 368.8 | 0.0 | 368.8 | - | - | - | |
| | **subtotal** | **17,315.0** | **10,462.6** | **27,777.6** | **16,946.2** | **6,751.1** | **23,697.3** | |
| **Total** | | **33,371.1** | **18,294.2** | **51,665.3** | **32,844.3** | **12,657.2** | **45,501.5** | **596.2** |

## Table 12-2 Calculated EIRR

(Unit: USD)

| Year | Cost | | | Benefit | | | | |
|---|---|---|---|---|---|---|---|---|
| | Facilities | O&M | Total Cost | Power Supply Interruption | Import/Export | Avoiding Taothan D/L | Avoiding Seno Nongdeun T/L | Total Benefit |
| 2015 | 648,670 | 0 | 648,670 | 200,000 | 5,643,000 | 6,526,280 | 0 | 12,369,280 |
| 2016 | 21,155,590 | 0 | 21,155,590 | 200,000 | 5,643,000 | 26,280 | 0 | 5,869,280 |
| 2017 | 23,697,280 | 0 | 23,697,280 | 200,000 | 5,643,000 | 26,280 | 0 | 5,869,280 |
| 2018 | 0 | 596 | 596 | 200,000 | 2,143,200 | 26,280 | 4,800,000 | 7,169,480 |
| 2019 | 0 | 596 | 596 | 0 | 2,143,200 | 26,280 | 4,800,000 | 6,969,480 |
| 2020 | 0 | 596 | 596 | 0 | 1,647,300 | 6,552,560 | 4,800,000 | 12,999,860 |
| 2021 | 0 | 596 | 596 | 0 | 1,647,300 | 52,560 | 4,800,000 | 6,499,860 |
| 2022 | 0 | 596 | 596 | 0 | 1,647,300 | 52,560 | 4,800,000 | 6,499,860 |
| 2023 | 0 | 596 | 596 | 0 | 1,647,300 | 52,560 | 4,800,000 | 6,499,860 |
| 2024 | 0 | 596 | 596 | 0 | 1,647,300 | 52,560 | 4,800,000 | 6,499,860 |
| 2025 | 0 | 596 | 596 | 0 | 1,647,300 | 6,578,840 | 4,800,000 | 13,026,140 |
| 2026 | 0 | 596 | 596 | 0 | 1,647,300 | 78,840 | 4,800,000 | 6,526,140 |
| 2027 | 0 | 596 | 596 | 0 | 1,647,300 | 78,840 | 4,800,000 | 6,526,140 |
| 2028 | 0 | 596 | 596 | 0 | 1,647,300 | 78,840 | 4,800,000 | 6,526,140 |
| 2029 | 0 | 596 | 596 | 0 | 1,647,300 | 78,840 | 4,800,000 | 6,526,140 |
| 2030 | 0 | 596 | 596 | 0 | 1,647,300 | 6,605,120 | 4,800,000 | 13,052,420 |
| 2031 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| 2032 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| 2033 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| 2034 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| 2035 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| 2036 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| 2037 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| 2038 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| 2039 | 0 | 596 | 596 | 0 | 1,647,300 | 105,120 | 4,800,000 | 6,552,420 |
| | | | | | | | EIRR | 15% |

### (2) Financial Evaluation of Project

Financial validation is studied based on a comparison between the Economic Internal Rate of Return (EIRR) and the Weighted Average Cost of Capital (WACC). It is noted that 2.7 % is used as the WACC value based on the project of the "Power Network System Plan".

- The total project cost of this study has been obtained from Table 11-16.
- Annual operation and maintenance costs of this transmission-transformation project are also assumed to be 1.5 % (transmission facilities) and 2.0 % (transformation facilities) of the total investment cost for facilities.
- Depreciation and payment of interests are excluded from the costs.
- A 2 % increase is expected in 2016, up to 18 % by 2016.
- According to discussions with EDL, the study team assumed that the unit financial worth of benefits will increase by 6 % every year up to 2016, using current electricity tariffs (average retail rate of 663 (Kip) in 2011). After 2016, the averaged tariff was assumed constant at 887 kip/kWh.
- According to the latest tariff survey (Tariff Study 2009), investment costs for the transformation system is estimated to be 14 % of the total investment cost of the electric power system including generation plants. Thus, the revenue of the project based on the FIRR was set at 14 %. The financial worth is calculated by multiplying the aforementioned retail rate and 14 % (transmission-transformation system).

The calculated FIRR is shown in Table 12-3. The project is evaluated to be financially appropriate since 6 % of FIRR is greater than 2.7 % of the Weighted Average Cost of Capital (WACC).

## Table 12-3 Calculated FIRR

(Unit: USD)

| Year | Cost | | | Benefit |
|---|---|---|---|---|
| | Facilities | O&M | Total Cost | Revenue |
| 2015 | 678,200 | 0 | 678,200 | 4,529,616 |
| 2016 | 23,209,500 | 0 | 23,209,500 | 4,802,896 |
| 2017 | 27,777,600 | 0 | 27,777,600 | 5,089,840 |
| 2018 | 0 | 596 | 596 | 5,397,280 |
| 2019 | 0 | 596 | 596 | 5,718,384 |
| 2020 | 0 | 596 | 596 | 6,059,984 |
| 2021 | 0 | 596 | 596 | 6,059,984 |
| 2022 | 0 | 596 | 596 | 6,059,984 |
| 2023 | 0 | 596 | 596 | 6,059,984 |
| 2024 | 0 | 596 | 596 | 6,059,984 |
| 2025 | 0 | 596 | 596 | 6,059,984 |
| 2026 | 0 | 596 | 596 | 6,059,984 |
| 2027 | 0 | 596 | 596 | 6,059,984 |
| 2028 | 0 | 596 | 596 | 6,059,984 |
| 2029 | 0 | 596 | 596 | 6,059,984 |
| 2030 | 0 | 596 | 596 | 6,059,984 |
| 2031 | 0 | 596 | 596 | 6,059,984 |
| 2032 | 0 | 596 | 596 | 6,059,984 |
| 2033 | 0 | 596 | 596 | 6,059,984 |
| 2034 | 0 | 596 | 596 | 6,059,984 |
| 2035 | 0 | 596 | 596 | 6,059,984 |
| 2036 | 0 | 596 | 596 | 6,059,984 |
| 2037 | 0 | 596 | 596 | 6,059,984 |
| 2038 | 0 | 596 | 596 | 6,059,984 |
| 2039 | 0 | 596 | 596 | 6,059,984 |
| | | | FIRR | 6% |

# Chapter 13 Recommendations

## 13.1 The Transmission Line from Other Areas to Target Area in South Area

The power demand in Khammouane and Savannakhet of the South Area of Laos is expected to increase, especially in Industry and Mining. On the other hand, this area does not have so many locations for the installation of power plants and the capacity limitation of power flow from other areas exists. Thus, more power from other areas is needed.

Based on the results of this study, the transmission line connected to the Target Area is needed in 2015 from the South 2 area where surplus power is expected. An efficient construction schedule was found by first constructing the 115 kV Pakbo-Saravan transmission line in 2015 and second the 230 kV Seno-Saravan transmission line. Thus, the 115 kV Pakbo-Saravan transmission line should be implemented as the first prioritized project as follows.

- Pakbo-Nongdeun-Thaotan-Saravan 115 kV with 2 circuits
- Bay for 2 circuits at Pakbo substation
- Bay for 4 circuits at Nongdeun substation
- Bay for 2 circuits at Saravan substation
- Installation of Taothan substation

Even if the 230 kV Seno-Saravan transmission line is constructed ahead, the 115 kV Pakbo-Saravan transmission line will be necessary.

This project will contribute to eliminating power supply interruptions in the South 1 area, reducing power imports to the South 1 area and power supply to Taothan substation in Saravan province and Nongdeun substation in Savannakhet province.

## 13.2 Interconnections between Target Area and the Neighboring Country

The interconnection between Thakhek in Kammouan and EGAT uses the 115 kV double circuit transmission line with different conductors from each other circuit. The power flow is restricted by the smaller size conductor. The interconnection between Pakbo in Savannakhet and EGAT uses the double circuit transmission line with a single circuit but cannot sufficiently utilize the capacity of its conductor because the power from EGAT to Thakhek tends to flow more than between EGAT and Pakbo.

The study and the planning of the re-conductoring of the 115 kV transmission lines between EGAT and Thakhek, adding a circuit to the 115 kV transmission line between EGAT and Pakbo and installing the phase shifters to control the power flow of EGAT-Thakhek/Pakbo should proceed in cooperation with EGAT, because the increase in power imports from EGAT by modifying the interconnections such as those measures may be considered more economical than the construction of large power transmission lines such as 230 kV from far places.

## 13.3 Interconnections between Laos and Neighboring Countries and Plan of Thermal Power Station

The power generation of Laos mainly consists of hydropower stations. Thus, the power output capacity of the generators largely varies between the wet and dry seasons. On the other hand, power demand in Laos is not so much different between the wet and dry seasons. Thus, the difference in the ability of the power outputs of the generators should be adjusted based on the amount of imported or exported power from the neighboring countries via the interconnections or the thermal power plants installed in Laos.

Because at present, the difference in the power outputs of the generators are considered at most to be 200-300 MW even in total of all the generators in Laos, its adjustment can be done utilizing the existing capacity of the interconnections to EGAT.

However, if most of the generators planned for domestic power supply in Laos becomes composed of hydropower stations, the difference in power outputs in Laos between the wet and dry seasons becomes large. According to the present Draft PDP, surplus power during the wet seasons would be more than 2,000 MW in 2020. Thus, it is considered that the following list of facilities is required in the future to adjust such a huge amount of surplus power and the study of them is needed.

- Large power interconnections to neighboring countries
- Replacement of planned hydropower stations to thermal power plants

## 13.4 Recommendation of Power Demand Forecast

### (1) Large-Scale Demand via the Mining Development of the Southern Area

The power demand of the aluminum refining plants located in the Attapeu area in southern Laos is planning 900 MW. This demand is 150% of all of Laos's demand in 2010 and 30% of all of Laos's demand in 2020. Moreover, the load factor is 85%, which means that it is always necessary to supply 900 MW. Thus, it is difficult to cover the construction costs for the power supply facilities of the plans based on the electricity bill from the consumer because this demand is double of the whole demand of Laos. For this reason, it is necessary to cover the construction costs for the power supply facilities such as the transmission line and substation with this project budget.

### (2) Reorganization of Power Demand Forecast

The power demand forecast is the base of the power facilities investment. For this reason, it is necessary to be consistent with the national policy of industrial promotion of energy and of the electricity bill. Thus, a reorganization of the power demand forecast is needed. This organization member should be the cabinet ministers concerned and the chief should be the prime minister.

Regarding Laos's present organization, there is concern about overinvestment into electric power facilities because unknown large-scale development is included in the power development plan without understanding the status of the government agreement and licensing. A sufficient degree of feasibility should be secured before forming an investment program because in case projects such as SLACO, whose demand is double of Laos's demand, is not realized, investment in power facilities could be unrecoverable. When it falls into a financial deficit, trouble will arise in the electric power supply and have a tremendous impact to the national economy.

### (3) Policy of Energy Efficiency Improvement

It should be reorganized towards energy-efficient policy-making. This organization should have the ability to guide private enterprises through regulations concerning the introduction of efficient facilities for mining or the improvement of operational methods.

### (4) Peak Load Decision Method

Raising the assumption accuracy of the peak load is required. Regarding the method of Peak load assumption, it is necessary to analyze the difference in electricity usage via the characteristics of the load according to industry and labor conditions based on a track record, and being reflected in the assumption of a load factor.