No. 57

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ELECTRICITY GENERATING AUTHORITY OF THAILAND (EGAT)
THE KINGDOM OF THAILAND

# FEASIBILITY STUDY
# ON
# BULK POWER SUPPLY PROJECT
# FOR
# THE GREATER BANGKOK AREA

## FINAL REPORT

## SUMMARY

AUGUST 1993

ELECTRIC POWER DEVELOPMENT CO., LTD.

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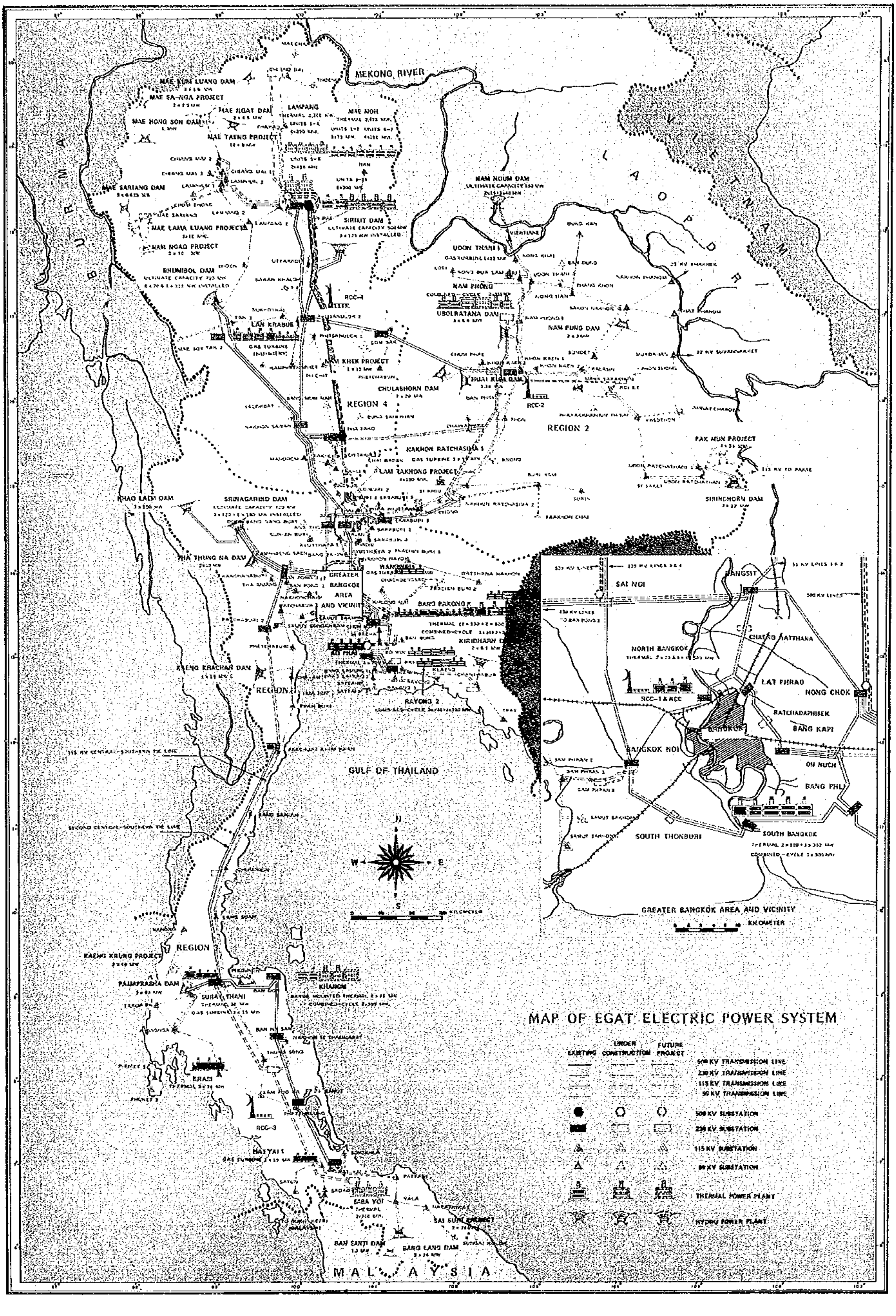
MAP OF EGAT ELECTRIC POWER SYSTEM
MEKONG RIVER
LAOPDR
VIETNAM
BURMA
MALAYSIA
GULF OF THAILAND
REGION 2
REGION 3
REGION 4
GREATER BANGKOK AREA AND VICINITY
SIRIKIT DAM
BHUMIBOL DAM
NAM NGUM DAM
UBOLRATANA DAM
NAM PHONG
CHULABHORN DAM
NAKHON RATCHASIMA 1
LAM TAKHONG PROJECT
SRINAGARIND DAM
KHAO LAEM DAM
THA THUNG NA DAM
SIRINDHORN DAM
PAK MUN PROJECT
NAM PUNG DAM
KAENG KRACHAN DAM
BANG PAKONG
RAYONG 2
SURAT THANI
KHANOM
KRABI
HAT YAI 1
RCC-2
RCC-3
RCC-4
SAI NOI
BANGSIT
NORTH BANGKOK
CHAENG WATTHANA
LAT PHRAO
NONG CHOK
RATCHADAPHISEK
BANG KAPI
BANGKOK NOI
ON NUCH
BANG PHLI
SOUTH BANGKOK
SOUTH THONBURI
RCC-1 & NCC
EXISTING
UNDER CONSTRUCTION
FUTURE PROJECT
500 KV TRANSMISSION LINE
230 KV TRANSMISSION LINE
115 KV TRANSMISSION LINE
69 KV TRANSMISSION LINE
500 KV SUBSTATION
230 KV SUBSTATION
115 KV SUBSTATION
69 KV SUBSTATION
THERMAL POWER PLANT
HYDRO POWER PLANT
KILOMETER

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## CONCLUSIONS

### 1. Power Demand in Greater Bangkok Area

In Thailand, the power generation is done by Electricity Generating Authority of Thailand (EGAT) and the maximum power generation and annual energy production in 1992 were recorded at 8,877 MW and 56,021 GWh, respectively. The power supply to the customers in the greater Bangkok area is made by Metropolitan Electricity Authority (MEA) and the maximum demands in the future are as follows:

| Year | Max. Demand |
|---|---|
| 1992 | 3,890 MW |
| 1997 | 6,089 MW |
| 2001 | 7,952 MW |
| 2006 | 10,264 MW |
| 2011 | 13,569 MW |

### 2. Present Situations and Problems of Power Supply Facilities

In the Greater Bangkok area, there are two thermal power plants, say North Bangkok Thermal Power Plant (237.5 MW) and South Bangkok Thermal Power Plant (1,339 MW). The power supply to the demand in the Greater Bangkok Area is from the above two power plants and from power plants outside the area by 500 kV and/or 230 kV transmission lines from north, west and southeast.

The power supply facilities such as transmission lines and substations are expanded according to the demand increasing. However, it is difficult to expand the necessary power facilities following to the demand by EGAT itself since the power demand increase is extraordinary high pitch due to rapid development of the city areas and arising the many problems such as land acquisition for substations and transmission lines as well as environmental issues for installing new power facilities.

Under these circumstances, EGAT has realized the needs of the feasibility study on the power supply project for the Greater Bangkok Area based on the long range vision and requested the study to the Japanese government through Thai government, and the study has been done by this Japan International Cooperation Agency (JICA) Study Team.

### 3. Basic Assumptions of the Feasibility Study

This feasibility study has been made based on the following assumptions:

(1) Economy

Growing up steady as same as that at the present.

(2) Power Demand

The power is to be supplied without load control.

(3) Budget for the Project

The planning of the Project is based on the technical requirement, say there is no power supply interruption after clearing fault when a transmission line or a transformer damaged. Therefore, the planning has not been reduced in the scale due to any budgetary restriction.

(4) Right of Way of Transmission Line

The present right of way is available in the future.

(5) Environmental Issues

Only predicted issues are considered within the present environmental restricts.

(6) Power System Design

In principle, the planning is based on the single contingency criteria used by EGAT.

(7) Implementation of the Project

The planning of transmission lines is mainly by overhead transmission lines taking economy into consideration, only the route where overhead transmission line could not be built by physical restrictions or by aviation regulations.

The planning is without considerable power supply interruption during implementation of the Project.

(8) Level of Technology

The planning is made by using the proven technology. (Unproven new technology was not considered.)

## 4. Major Features of Bulk Power Supply Project

(1) Outline

- 500 kV Overhead Transmission Line (new) : 226 circuit-km
- 230 kV Overhead Transmission Line (new) : 146 circuit-km
- 230 kV Overhead Transmission Line (Renov.) : 472 circuit-km
- 230 kV Underground Transmission Line (new) : 242 circuit-km

- 500 kV Substations : 6 substations (5 new, 1 expansion)

- 230 kV Substations : 18 substations (10 new, 8 expansion)

(2) Project Cost (including both of EGAT's and MEA's portions and estimated in 1992 price level)

| | | |
|---|---|---|
| - Stage 1 (to be completed by 1997) | : | US$696,285,000.- |
| - Stage 2 (to be completed by 2001) | : | US$470,739,000.- |
| - Stage 3 (to be completed by 2006) | : | US$365,768,000.- |
| - Stage 4 (to be completed by 2011) | : | US$421,288,000.- |
| Total | : | US$1,954,080,000.- |

Note: The cost of foundation of the transmission lines is different by the foundation soil, the most of the transmission lines tower foundation is constructed at the poor soil area. The above cost is based on the assumption that all the foundations are in the poor soil.

## 5. Economic Justification

In the study, the cost of the Project was estimated for the poor soil tower foundation case. In the study of the economic evaluation of the Project, the Project is considered economically to be justified.

## 6. Financial Analysis

In the financial analysis of the Project, the flow of cost and flow of the benefit are considered as follows:

(1) Cost flow consists of the construction cost and the operation and maintenance cost of the power facilities, and:

(2) Benefit flow consists of increased electricity sales due to the Project.

As the result of the financial analysis, the Project is considered also financially to be sound.

## RECOMMENDATIONS

(1) This study is made globally taking long range view of bulk power supply for the Greater Bangkok Area into consideration. Therefore, in advance to the actual implementation of the Project, it is necessary to study the Project further in detail. During the study, when the better alternatives be found, the revision of the plan will be preferable taking the long range view into consideration.

(2) In the study, the 500 kV transmission lines to supply the power to the Greater Bangkok Area Project has been designed based on the present Power Development Plan (PDP) by EGAT. Therefore, if there is any change in the 500 kV transmission line system, the transmission system has to be reviewed accordingly.

(3) Since the preparation of the required budget, the field survey, the detailed design and negotiation of the land acquisition will take for long time, the preparatory works should be started few years before the construction work start.

(4) This is the first feasibility study on the Bulk Power Supply for the Greater Bangkok Area, therefore, the basic drawing for the Project is in the report taking the present situation of the power supply for the area into consideration. The study of the Project has to be reviewed time to time when the circumstances be changed.

(5) Consequence to this study, the feasibility study on the expansion and renovation of the transmission line and distribution network system with the voltages 230 kV and below in the Greater Bangkok Area is necessary.

# CHAPTER 1 INRTRODUCTION

## 1.1 Background of the Project

In Thailand, due to increase of population and vivid commercial and industrial activities as well as grading-up of living standard, the electric energy consumption is heavily increasing in these years. In Greater Bangkok area which electricity is supplied by Metropolitan Electricity Authority (MEA), the average annual growth rate of power demand in these five years is 12.35%. It is noted that this growth rate is tremendously high comparing to 6.3% in Japan. The maximum power demand of the Greater Bangkok area in 1992 was recorded at 3,890 MW, and according to the Working Group for Load Forecast which members compose of staff of Electricity Generating Authority of Thailand (EGAT) and MEA, the expected maximum power demand will be:

| | |
|---|---|
| 6,089 MW | in 1997 |
| 7,952 MW | in 2001 |
| 10,264 MW | in 2006 |

To meet the power demand of MEA, EGAT has expanded power facilities in accordance with the short and long term plans. However, due to rapid development in the Greater Bangkok area, it is very difficult to obtain spaces for substations and new right of ways for transmission lines. In long term view, it is jeopardized to expand the power facilities in accordance with the long term plan if the demand is increased steadily.

To solve these problems, EGAT took up "Bulk Power Supply Project for the Greater Bangkok Area" as an emergency issue, which is a long term power facilities expansion plan in the Greater Bangkok Area up to the year of 2011 including 500kV and 230kV transmission lines and substations.

The Government of Thailand therefore requested technical assistant for "the feasibility study on Bulk Power Supply Project for the Greater Bangkok Area" to the Government of Japan in May 1991.

In response to this request, the Government of Japan had the Japan International Cooperation Agency (JICA) dispatched the Preliminary Study Mission to Thailand in November 1991, and the Mission surveyed the background of the request, performed site surveys, collected information and data, and made a preliminary study in the future policies and other relevant matters.

On November 8, 1991, the Preliminary Study Team of JICA and EGAT reached an agreement on "the Scope of Work for Feasibility Study on Bulk Power Supply Project for the Greater Bangkok Area".

Based on the Agreement, the Government of Japan decided to conduct a feasibility Study on the Project, and assigned this work to JICA.

## 1.2 Objective and Scope of the Study

### 1.2.1 Objective of the Study

The objrective of this study is;

- To estimate the power demand growth in the Greater Bangkok Area of the Kingdom of Thailand, and
- To formulate the optimal transmission line and substation facility expansion plan which is designated to meet this power demand growth up to the year of 2011.

In formulating this plan,

- all factors affecting the future electric power supply potentials, including the current status of power supply facilities as identified by available data,
- constraints on power supplies including site problems and technical problems,
- as well as environmental issues that may affect social reactions,

shall be thoroughly addressed and evaluated.

### 1.2.2 Scope of the Study

This study is a feasibility study, the objective area of which consists of the Greater Bangkok Area and the Central Area which are respectively defined as below.

| Greater Bangkok Area |
|---|

The 230 kV transmission lines and 500 kV transmission lines, plus substations related to these transmission lines (including the 230 kV facilities of MEA)

| Central Area |
|---|

500 kV transmission lines and substations related to these transmission lines

### 1.2.3 Study Items

Study items in this feasibility study consists of;

a) Collection and evaluation of existing data and information

b) Field investigation

c) Power survey

d) Environmental studies

e) Optimal power system plan

f) Basic Design

g) Economic and financial Analyses

h) Cost estimation and construction scheduling

## 1.3 Activities of the Team in Thailand

During the period from July 1992 to August 1993, the JICA study team performed following activities in Thailand.

1st: July 1 to 30, 1992

Presentation of the methodology and the schedule of the study based on the Inception Report(Draft), the field survey for the related areas, collection of the study data and discussion on the Inception Report(Draft).

2nd: October 7 to 21, 1992

Presentation of the progress and achievement of the study. Discussion on updated EGAT PDP, progress of environmental survey and basic approach to economic analysis.

3rd: February 16 to March 2, 1993

Presentation of the Interim Report. Discussion on power system planning, power system analysis and change of transmission line route by proposed new airport area. Site survey to proposed new substation.

4th: June 20 to July 4, 1993

Presentation of the Draft Final Report by personnel each other. Discussion on economic evaluation financial analyses, construction schedule and future study.

Meeting of training schedule and item of technical transfer.

## 1.4 Member of JICA Study Team

| | |
|---|---|
| Mr. Takuya Takaoka | Team Leader |
| Mr. Mitsuru Omori | Power System Planning |
| Mr. Masao Koike | Transmission Line Planning |
| Mr. Shigekatsu Soejima | Substation Planning |
| Mr. Vichien Virapanish | Environmental Study |
| Mr. Hiroto Inabe | Power System Analysis |

| | |
|---|---|
| Mr. Takashi Masuo | Economic Analysis |
| Mr. Hideaki Morishita | Secretary |

## 1.5 Provision of Equipment

To promote the power system analyses using computer in this study, the following equipment was provided by JICA to EGAT.

| Item | Q'ty | Unit | Type |
|---|---|---|---|
| Computer | 1 | set | ACER Frame 1000,1750 |
| Laser Printer | 1 | set | HP Laser Jet III |
| X-Y Plotter | 1 | set | Roland DXY-1300 |
| Power Stabilizer | 1 | set | |

## 1.6 Technology Transfer to the Counterparts

The technology transfer to the counterparts from EGAT was performed in Japan during this study period as follows:

(1) Transmission Line and Substation Design

a) Counterpart : Mr. Kijja Snipatthamgkura

b) Schedule : November 29 to December 23, 1992 (25 days)

(2) Power System Analysis

a) Counterpart : Mr. Kittipon Chuanagaroon

b) Schedule : July 13 to August 7, 1993 (26 days)

# CHAPTER 2 ELECTRIC POWER DEMAND FORECAST

## 2.1 Current Status of Electric Power Demand in the Kingdom of Thailand

The electric power demand in Thailand has been increasing substantially due to her recent favorable economic growth and incoming rush of enterprises and factories.

Transition of power and energy generated in Thailand for the past ten years is shown in Table 2-1. Yearly average growth rates of power and energy generation during the last ten years are 12.07% and 12.74% respectively. The annual load factor at generating end, which once showed a tendency to decrease at a rate of about 0.4% per year from about 70% in 1981 reaching the lowest 66.77% in 1989, has begun to increase and recovered to the level of about 70%.

Transition of power and energy requirement from EGAT's customers, i.e. the Metropolitan Electricity Authority (MEA), the Provincial Electricity Authority (PEA) and other direct customers, is shown in Table 2-2.

MEA is an organization to distribute electric energy in the Greater Bangkok Area, Nonthaburi and Samut Prakan Provinces, whereas PEA is one to distribute in all the provinces except the MEA's area.

The actual result of 1992 shows ratios of the three parties' energy consumption as MEA 45.2% PEA 51.5%, and the other direct customers 3.3%.

In respect of the maximum power demand, ratios of the three parties were as MEA 43.2%, PEA 53.6% and the other direct customers 3.2%.

Most part of the PEA demand comes from local cities, towns, and fishing and agrarian villages, and the demand is particularly high at the lighting peak time.

The load factor of PEA demand is about 0.57 ~ 0.60, which is considerably low in comparison with MEA's 0.68 or so.

## 2.2 Power Demand Forecast Made by JICA Team

Fig. 2-1 shows the method of predicting future power and energy demand.

Power demand of Thailand in future forecasted by the JICA Team is shown in Table 2-2 and 2-3, and Fig. 2-2, 2-3, 2-4 and 2-5.

Table 2-1 ENERGY AND POWER GENERATION IN THAILAND ( 1981 -1992 )

| Fiscal Year | Energy | | | Power | | | Load Factor |
|---|---|---|---|---|---|---|---|
| | Generation | Growth | | Generation | Growth | | |
| | (GWh) | (GWh) | (%) | (MW) | (MW) | (%) | (%) |
| 1981 | 15,960 | 1,206 | 8.2 | 2,589 | 171 | 7.1 | 70.4 |
| 1982 | 16,882 | 922 | 5.8 | 2,838 | 249 | 9.6 | 67.9 |
| 1983 | 19,066 | 2,184 | 12.9 | 3,204 | 366 | 12.9 | 67.9 |
| 1984 | 21,066 | 2,000 | 10.5 | 3,547 | 343 | 10.7 | 67.8 |
| 1985 | 23,357 | 2,290 | 10.9 | 3,878 | 331 | 9.3 | 68.8 |
| 1986 | 24,780 | 1,423 | 6.1 | 4,181 | 303 | 7.8 | 67.7 |
| 1987 | 28,193 | 3,414 | 13.8 | 4,734 | 553 | 13.2 | 68.0 |
| 1988 | 31,997 | 3,804 | 13.5 | 5,444 | 710 | 15.0 | 67.1 |
| 1989 | 36,457 | 4,460 | 13.9 | 6,233 | 789 | 14.5 | 66.8 |
| 1990 | 43,189 | 6,732 | 18.5 | 7,094 | 861 | 13.8 | 69.5 |
| 1991 | 49,225 | 6,036 | 14.0 | 8,045 | 951 | 13.4 | 69.8 |
| 1992 | 56,006 | 6,781 | 13.8 | 8,877 | 832 | 10.3 | 72.0 |
| Average Growth | | | | | | | |
| 1982 - 1986 | - | 1,764 | 9.2 | - | 318 | 10.1 | - |
| 1987 - 1992 | - | 5,205 | 14.6 | - | 783 | 13.4 | - |

Table 2-2 REQUIREMENT OF POWER AND ENERGY FROM EGAT BY UTILITIES

| Fiscal Year | Power & Energy Generated by EGAT | | | Requirement by MEA | | | Requirement by PEA | | | Requirement by Direct Customers | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Power (MW) | Energy (GWh) | Load Factor (%) | Power (MW) | Energy (GWh) | Load Factor (%) | Power (MW) | Energy (GWh) | Load Factor (%) | Power (MW) | Energy (GWh) | Load Factor (%) |
| 1981 | 2,589 | 15,960 | 70.4 | 1,388 | 8,496 | 69.9 | 1,115 | 5,569 | 57.0 | 100 | 505 | 57.6 |
| 1982 | 2,838 | 16,882 | 67.9 | 1,499 | 8,719 | 66.4 | 1,264 | 6,190 | 55.9 | 102 | 494 | 55.3 |
| 1983 | 3,204 | 19,066 | 67.9 | 1,631 | 9,666 | 67.7 | 1,493 | 7,287 | 55.7 | 125 | 637 | 58.2 |
| 1984 | 3,547 | 21,066 | 67.8 | 1,776 | 10,498 | 67.5 | 1,675 | 8,174 | 55.7 | 129 | 710 | 62.8 |
| 1985 | 3,878 | 23,357 | 68.7 | 1,823 | 10,910 | 68.3 | 1,918 | 9,391 | 55.9 | 162 | 963 | 67.9 |
| 1986 | 4,181 | 24,780 | 67.7 | 1,983 | 11,391 | 65.6 | 2,078 | 10,190 | 56.0 | 170 | 1,037 | 69.6 |
| 1987 | 4,734 | 28,193 | 68.0 | 2,178 | 12,930 | 67.8 | 2,375 | 11,792 | 56.7 | 167 | 1,123 | 76.8 |
| 1988 | 5,444 | 31,997 | 67.1 | 2,432 | 14,564 | 68.4 | 2,745 | 13,737 | 57.1 | 175 | 1,192 | 77.8 |
| 1989 | 6,233 | 36,457 | 66.8 | 2,715 | 16,144 | 67.9 | 3,239 | 16,130 | 56.8 | 206 | 1,337 | 74.1 |
| 1990 | 7,094 | 43,189 | 69.5 | 3,124 | 18,623 | 68.1 | 3,737 | 19,318 | 59.0 | 214 | 1,428 | 76.2 |
| 1991 | 8,045 | 49,225 | 69.8 | 3,519 | 20,777 | 67.4 | 4,252 | 22,493 | 60.4 | 229 | 1,504 | 74.9 |
| 1992 | 8,877 | 56,006 | 72.0 | 3,993 | 22,946 | 65.6 | 4,956 | 26,132 | 60.2 | 295 | 1,693 | 65.6 |
| Average Annual Growth Rate (%) (1983 - 1992) | 12.1 | 12.7 | - | 10.3 | 10.2 | - | 14.7 | 15.5 | - | 11.2 | 13.1 | - |

Table 2-3 POWER DEMAND FORECAST IN TAILAND (1/2)

| Year | Generating End | | | | | | | Sending End | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Generated Energy (GWh) | kWh Station Losses (GWh) | kWh Station Losses (%) | Maximum Power (MW) | kW Station Losses (MW) | kW Station Losses (%) | Load Factor (%) | Energy (GWh) | Maximum Power (MW) | Load Factor (%) |
| 1980 | 14,753.73 | 590.45 | 4.00 | 2,417.40 | 87 | 3.60 | 69.7 | 14163.28 | 2,330.37 | 69.38 |
| 1981 | 15,959.97 | 612.29 | 3.84 | 2,588.70 | 89 | 3.45 | 70.4 | 15,347.68 | 2,499 | 70.1 |
| 1982 | 16,881.95 | 602.49 | 3.57 | 2,838.00 | 91 | 3.21 | 67.9 | 16,279.46 | 2,747 | 67.7 |
| 1983 | 19,066.30 | 658.00 | 3.45 | 3,204.30 | 100 | 3.11 | 67.9 | 18,408.30 | 3,105 | 67.7 |
| 1984 | 21,066.44 | 830.10 | 3.94 | 3,547.30 | 126 | 3.55 | 67.8 | 20,236.34 | 3,422 | 67.5 |
| 1985 | 23,356.57 | 1,022.81 | 4.38 | 3,878.40 | 153 | 3.94 | 68.7 | 22,333.76 | 3,726 | 68.4 |
| 1986 | 24,779.53 | 1,013.63 | 4.09 | 4,180.90 | 154 | 3.68 | 67.7 | 23,765.90 | 4,027 | 67.4 |
| 1987 | 28,193.16 | 1,189.30 | 4.22 | 4,733.90 | 180 | 3.80 | 68.0 | 27,003.86 | 4,554 | 67.7 |
| 1988 | 31,996.94 | 1,406.49 | 4.40 | 5,444.00 | 215 | 3.96 | 67.1 | 30,590.45 | 5,229 | 66.8 |
| 1989 | 36,457.09 | 1,532.25 | 4.20 | 6,232.70 | 236 | 3.78 | 66.8 | 34,924.84 | 5,997 | 66.5 |
| 1990 | 43,188.79 | 2,139.00 | 4.95 | 7,093.70 | 316 | 4.46 | 69.5 | 41,049.79 | 6,778 | 69.1 |
| 1991 | 49,225.03 | 2,379.92 | 4.83 | 8,045.00 | 350 | 4.35 | 69.8 | 46,845.11 | 7,695 | 69.5 |
| 1992 | 56,006.44 | 2,721.00 | 4.86 | 8,876.90 | 388 | 4.37 | 72.0 | 53,285.44 | 8,489 | 71.7 |
| 1993 | 61,919 | 3,045 | 4.92 | 10,103 | 447 | 4.43 | 70.0 | 58,874 | 9,656 | 69.6 |
| 1994 | 68,744 | 3,415 | 4.97 | 11,217 | 501 | 4.47 | 70.0 | 65,329 | 10,715 | 69.6 |
| 1995 | 75,860 | 3,793 | 5.00 | 12,359 | 556 | 4.50 | 70.1 | 72,067 | 11,803 | 69.7 |
| 1996 | 83,576 | 4,179 | 5.00 | 13,616 | 613 | 4.50 | 70.1 | 79,397 | 13,004 | 69.7 |
| 1997 | 91,271 | 4,564 | 5.00 | 14,849 | 668 | 4.50 | 70.2 | 86,707 | 14,181 | 69.8 |
| 1998 | 99,333 | 4,967 | 5.00 | 16,160 | 727 | 4.50 | 70.2 | 94,366 | 15,433 | 69.8 |
| 1999 | 108,047 | 5,402 | 5.00 | 17,553 | 790 | 4.50 | 70.3 | 102,645 | 16,763 | 69.9 |
| 2000 | 117,093 | 5,855 | 5.00 | 18,995 | 855 | 4.50 | 70.4 | 111,238 | 18,141 | 70.0 |
| 2001 | 126,883 | 6,344 | 5.00 | 20,584 | 926 | 4.50 | 70.4 | 120,539 | 19,657 | 70.0 |
| 2002 | 135,895 | 6,795 | 5.00 | 22,046 | 992 | 4.50 | 70.4 | 129,100 | 21,053 | 70.0 |
| 2003 | 145,508 | 7,275 | 5.00 | 23,605 | 1062 | 4.50 | 70.4 | 138,232 | 22,543 | 70.0 |
| 2004 | 155,302 | 7,765 | 5.00 | 25,194 | 1134 | 4.50 | 70.4 | 147,537 | 24,060 | 70.0 |
| 2005 | 165,292 | 8,265 | 5.00 | 26,815 | 1207 | 4.50 | 70.4 | 157,028 | 25,608 | 70.0 |
| 2006 | 175,755 | 8,788 | 5.00 | 28,512 | 1283 | 4.50 | 70.4 | 166,967 | 27,229 | 70.0 |
| 2007 | 186,437 | 9,322 | 5.00 | 30,245 | 1361 | 4.50 | 70.4 | 177,115 | 28,884 | 70.0 |
| 2008 | 196,738 | 9,837 | 5.00 | 31,916 | 1436 | 4.50 | 70.4 | 186,901 | 30,480 | 70.0 |
| 2009 | 206,872 | 10,344 | 5.00 | 33,560 | 1510 | 4.50 | 70.4 | 196,528 | 32,050 | 70.0 |
| 2010 | 216,868 | 10,843 | 5.00 | 35,181 | 1583 | 4.50 | 70.4 | 206,025 | 33,598 | 70.0 |
| 2011 | 226,672 | 11,334 | 5.00 | 36,772 | 1655 | 4.50 | 70.4 | 215,339 | 35,117 | 70.0 |

Table 2-3 POWER DEMAND FORECAST IN TAILAND (2/2)

| Transmission & Distribution Losses (GWh) | (%) | Energy Consumption (GWh) | Growth (%) | GDP in 1972 price (M Baht) | Growth (%) | Elasticity of GWh per GDP | Energy Consumption per GDP (Wh/Baht) | Population (Thousand) | kWh per Capita (kWh) | Growth (%) | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,156.31 | 8.16 | 13006.97 | | 299,472 | | | 43.43 | 46,961 | 277 | | 1980 |
| 1,978.23 | 12.9 | 13,369.45 | 2.8 | 318,440 | 6.3 | 0.44 | 41.98 | 47,875 | 279 | 0.82 | 1981 |
| 1,461.30 | 9.0 | 14,818.16 | 10.8 | 331,379 | 4.1 | 2.67 | 44.72 | 48,847 | 303 | 8.63 | 1982 |
| 2,355.61 | 12.8 | 16,052.69 | 8.3 | 355,411 | 7.3 | 1.15 | 45.17 | 49,515 | 324 | 6.87 | 1983 |
| 2,633.92 | 13.0 | 17,602.42 | 9.7 | 380,739 | 7.1 | 1.35 | 46.23 | 50,583 | 348 | 7.34 | 1984 |
| 2,674.14 | 12.0 | 19,659.62 | 11.7 | 394,113 | 3.5 | 3.33 | 49.88 | 51,796 | 380 | 9.07 | 1985 |
| 2,710.65 | 11.4 | 21,055.25 | 7.1 | 411,813 | 4.5 | 1.58 | 51.13 | 52,969 | 398 | 4.73 | 1986 |
| 2,768.53 | 10.3 | 24,235.33 | 15.1 | 446,361 | 8.4 | 1.80 | 54.30 | 53,973 | 449 | 12.96 | 1987 |
| 3,025.65 | 9.9 | 27,564.80 | 13.7 | 495,378 | 11.0 | 1.25 | 55.64 | 54,961 | 502 | 11.69 | 1988 |
| 3,410.53 | 9.8 | 31,514.31 | 14.3 | 574,355 | 15.9 | 0.90 | 54.87 | 55,448 | 568 | 13.32 | 1989 |
| 3,964.75 | 9.7 | 37,085.03 | 17.7 | 633,395 | 10.3 | 1.72 | 58.55 | 56,340 | 658 | 15.81 | 1990 |
| 4,820.04 | 10.3 | 42,559.03 | 14.8 | 693,559 | 9.5 | 1.55 | 61.36 | 57,199 | 744 | 13.04 | 1991 |
| 5,681 | 10.7 | 47,604 | 11.9 | 756,806 | 9.1 | 1.30 | 62.9 | 58,041 | 820 | 10.2 | 1992 |
| 5,812 | 9.9 | 53,062 | 11.5 | 823,547 | 8.8 | 1.30 | 64.4 | 58,876 | 901 | 9.9 | 1993 |
| 6,385 | 9.8 | 58,945 | 11.1 | 893,781 | 8.5 | 1.30 | 65.9 | 59,693 | 987 | 9.6 | 1994 |
| 6,973 | 9.7 | 65,095 | 10.4 | 968,380 | 8.3 | 1.25 | 67.2 | 60,508 | 1076 | 8.9 | 1995 |
| 7,605 | 9.6 | 71,792 | 10.3 | 1,048,089 | 8.2 | 1.25 | 68.5 | 61,311 | 1171 | 8.8 | 1996 |
| 8,222 | 9.5 | 78,485 | 9.3 | 1,129,518 | 7.8 | 1.20 | 69.5 | 62,100 | 1264 | 7.9 | 1997 |
| 8,859 | 9.4 | 85,508 | 8.9 | 1,213,735 | 7.5 | 1.20 | 70.4 | 62,879 | 1360 | 7.6 | 1998 |
| 9,540 | 9.3 | 93,105 | 8.9 | 1,303,605 | 7.4 | 1.20 | 71.4 | 63,640 | 1463 | 7.6 | 1999 |
| 10,235 | 9.2 | 101,003 | 8.5 | 1,399,768 | 7.4 | 1.15 | 72.2 | 64,390 | 1569 | 7.2 | 2000 |
| 10,980 | 9.1 | 109,559 | 8.5 | 1,502,868 | 7.4 | 1.15 | 72.9 | 65,182 | 1681 | 7.2 | 2001 |
| 11,642 | 9.0 | 117,458 | 7.2 | 1,601,374 | 6.6 | 1.10 | 73.3 | 66,012 | 1779 | 5.9 | 2002 |
| 12,341 | 8.9 | 125,891 | 7.2 | 1,705,899 | 6.5 | 1.10 | 73.8 | 66,803 | 1885 | 5.9 | 2003 |
| 13,040 | 8.8 | 134,497 | 6.8 | 1,811,911 | 6.2 | 1.10 | 74.2 | 67,594 | 1990 | 5.6 | 2004 |
| 13,740 | 8.7 | 143,288 | 6.5 | 1,921,565 | 6.1 | 1.08 | 74.6 | 68,385 | 2095 | 5.3 | 2005 |
| 14,464 | 8.7 | 152,504 | 6.4 | 2,036,000 | 6.0 | 1.08 | 74.9 | 69,176 | 2205 | 5.2 | 2006 |
| 15,189 | 8.6 | 161,926 | 6.2 | | | | | | | | 2007 |
| 15,868 | 8.5 | 171,033 | 5.6 | | | | | | | | 2008 |
| 16,519 | 8.4 | 180,009 | 5.2 | | | | | | | | 2009 |
| 17,144 | 8.3 | 188,881 | 4.9 | | | | | | | | 2010 |
| 17,739 | 8.2 | 197,599 | 4.6 | | | | | | | | 2011 |

Table 2-4 POWER DEMAND FORECAST FOR MEA, PEA & EGAT'S DIRECT CUSTOMERS

| Year | EGAT | | | MEA | | | PEA | | | EGAT's Direct Customers | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Generated Energy (GWh) | Maximum Power (MW) | Load Factor (%) | Received Energy (GWh) | Maximum Power (MW) | Load Factor (%) | Received Energy (GWh) | Maximum Power (MW) | Load Factor (%) | Received Energy (GWh) | Maximum Power (MW) |
| 1980 | 14,754 | 2,417 | 69.7 | 8,286 | 1,392 | 68.0 | 4,966 | 974 | 58.2 | 446 | 86 |
| 1981 | 15,960 | 2,589 | 70.4 | 8,496 | 1,388 | 69.9 | 5,569 | 1,115 | 57.0 | 505 | 100 |
| 1982 | 16,882 | 2,838 | 67.9 | 8,719 | 1,499 | 66.4 | 6,190 | 1,264 | 55.9 | 494 | 102 |
| 1983 | 19,066 | 3,204 | 67.9 | 9,666 | 1,631 | 67.7 | 7,287 | 1,493 | 55.7 | 637 | 125 |
| 1984 | 21,066 | 3,547 | 67.8 | 10,498 | 1,776 | 67.5 | 8,174 | 1,675 | 55.7 | 710 | 129 |
| 1985 | 23,357 | 3,878 | 68.7 | 10,910 | 1,823 | 68.3 | 9,391 | 1,918 | 55.9 | 963 | 162 |
| 1986 | 24,780 | 4,181 | 67.7 | 11,391 | 1,983 | 65.6 | 10,190 | 2,078 | 56.0 | 1,037 | 170 |
| 1987 | 28,193 | 4,734 | 68.0 | 12,930 | 2,178 | 67.8 | 11,792 | 2,375 | 56.7 | 1,123 | 167 |
| 1988 | 31,997 | 5,444 | 67.1 | 14,564 | 2,432 | 68.4 | 13,737 | 2,745 | 57.1 | 1,192 | 175 |
| 1989 | 36,457 | 6,233 | 66.8 | 16,144 | 2,715 | 67.9 | 16,130 | 3,239 | 56.8 | 1,337 | 206 |
| 1990 | 43,189 | 7,094 | 69.5 | 18,623 | 3,124 | 68.1 | 19,318 | 3,737 | 59.0 | 1,428 | 214 |
| 1991 | 49,225 | 8,045 | 69.8 | 20,777 | 3,519 | 67.4 | 22,493 | 4,252 | 60.4 | 1,504 | 229 |
| 1992 | 56,006 | 8,877 | 72.0 | 22,946 | 3,993 | 65.6 | 26,132 | 4,956 | 60.2 | 1,693 | 295 |
| 1993 | 61,919 | 10,103 | 70.0 | 26,230 | 4,403 | 68.0 | 29,201 | 5,377 | 62.0 | 1,717 | 280 |
| 1994 | 68,744 | 11,217 | 70.0 | 28,849 | 4,843 | 68.0 | 32,820 | 5,854 | 64.0 | 1,820 | 297 |
| 1995 | 75,860 | 12,359 | 70.1 | 31,549 | 5,296 | 68.0 | 36,653 | 6,538 | 64.0 | 1,929 | 315 |
| 1996 | 83,576 | 13,616 | 70.1 | 34,460 | 5,785 | 68.0 | 40,872 | 7,290 | 64.0 | 2,045 | 333 |
| 1997 | 91,271 | 14,849 | 70.2 | 37,292 | 6,260 | 68.0 | 45,142 | 8,052 | 64.0 | 2,147 | 350 |
| 1998 | 99,333 | 16,160 | 70.2 | 40,214 | 6,751 | 68.0 | 49,661 | 8,858 | 64.0 | 2,254 | 368 |
| 1999 | 108,047 | 17,553 | 70.3 | 43,345 | 7,277 | 68.0 | 54,594 | 9,738 | 64.0 | 2,367 | 386 |
| 2000 | 117,093 | 18,995 | 70.4 | 46,560 | 7,816 | 68.0 | 59,789 | 10,500 | 65.0 | 2,485 | 405 |
| 2001 | 126,883 | 20,584 | 70.4 | 50,003 | 8,394 | 68.0 | 65,451 | 11,495 | 65.0 | 2,610 | 426 |
| 2002 | 135,895 | 22,046 | 70.4 | 53,041 | 8,904 | 68.0 | 70,746 | 12,425 | 65.0 | 2,714 | 443 |
| 2003 | 145,508 | 23,605 | 70.4 | 56,261 | 9,445 | 68.0 | 76,452 | 13,427 | 65.0 | 2,823 | 460 |
| 2004 | 155,302 | 25,194 | 70.4 | 59,484 | 9,986 | 68.0 | 82,328 | 14,459 | 65.0 | 2,936 | 479 |
| 2005 | 165,292 | 26,815 | 70.4 | 62,713 | 10,528 | 68.0 | 88,380 | 15,522 | 65.0 | 3,053 | 498 |
| 2006 | 175,755 | 28,512 | 70.4 | 66,051 | 11,088 | 68.0 | 94,765 | 16,643 | 65.0 | 3,175 | 518 |
| 2007 | 186,437 | 30,245 | 70.4 | 69,304 | 11,634 | 68.0 | 101,471 | 17,821 | 65.0 | 3,270 | 533 |
| 2008 | 196,738 | 31,916 | 70.4 | 72,396 | 12,153 | 68.0 | 107,975 | 18,963 | 65.0 | 3,368 | 549 |
| 2009 | 205,872 | 33,560 | 70.4 | 75,345 | 12,648 | 68.0 | 114,461 | 20,102 | 65.0 | 3,469 | 566 |
| 2010 | 216,868 | 35,181 | 70.4 | 78,161 | 13,121 | 68.0 | 120,942 | 21,240 | 65.0 | 3,574 | 583 |
| 2011 | 226,672 | 36,772 | 70.4 | 80,825 | 13,569 | 68.0 | 127,385 | 22,372 | 65.0 | 3,681 | 600 |

Fig. 2-1 Method of Predicting Future Power and Energy Demand

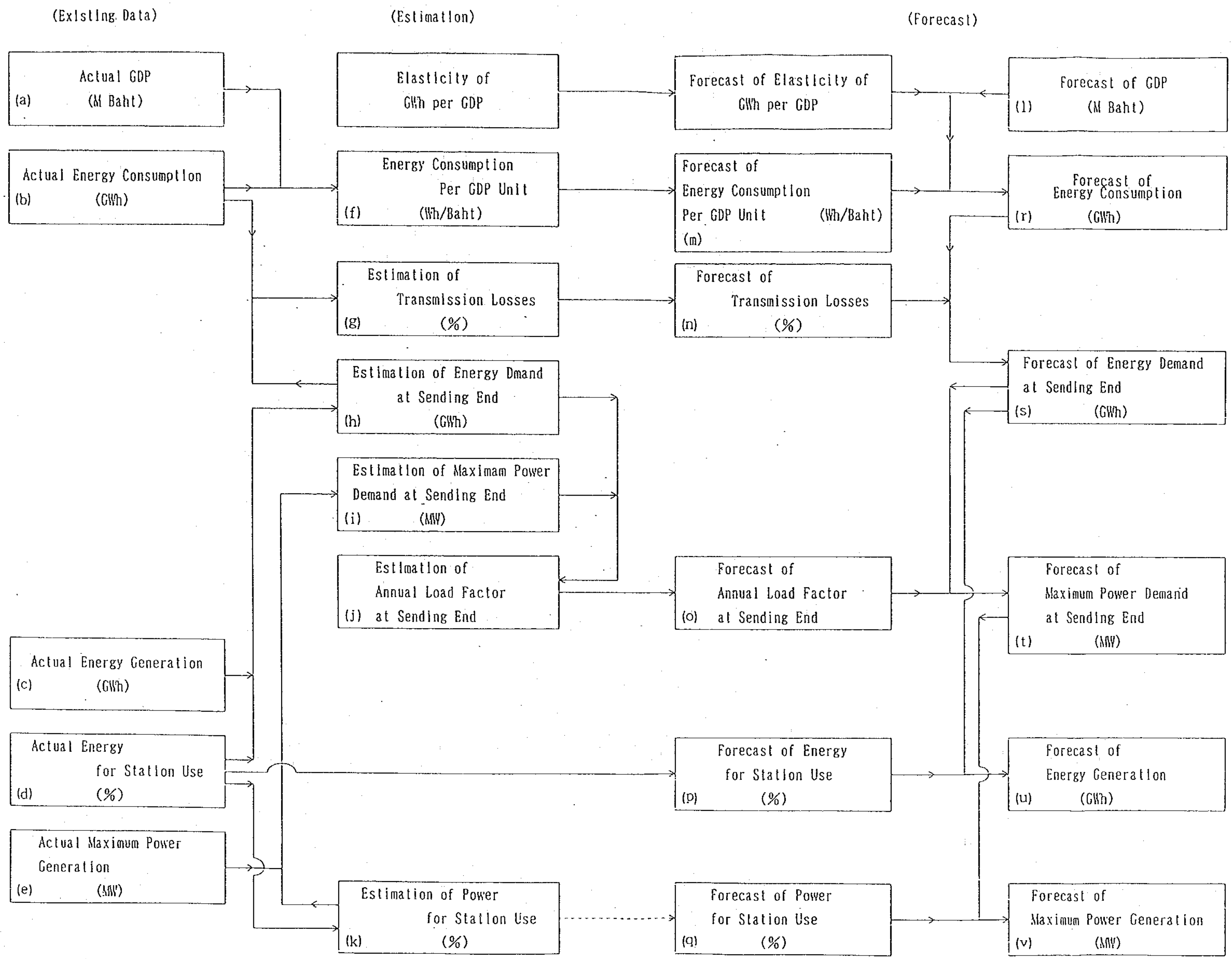


Fig. 2-2 Energy Demand at Generating End

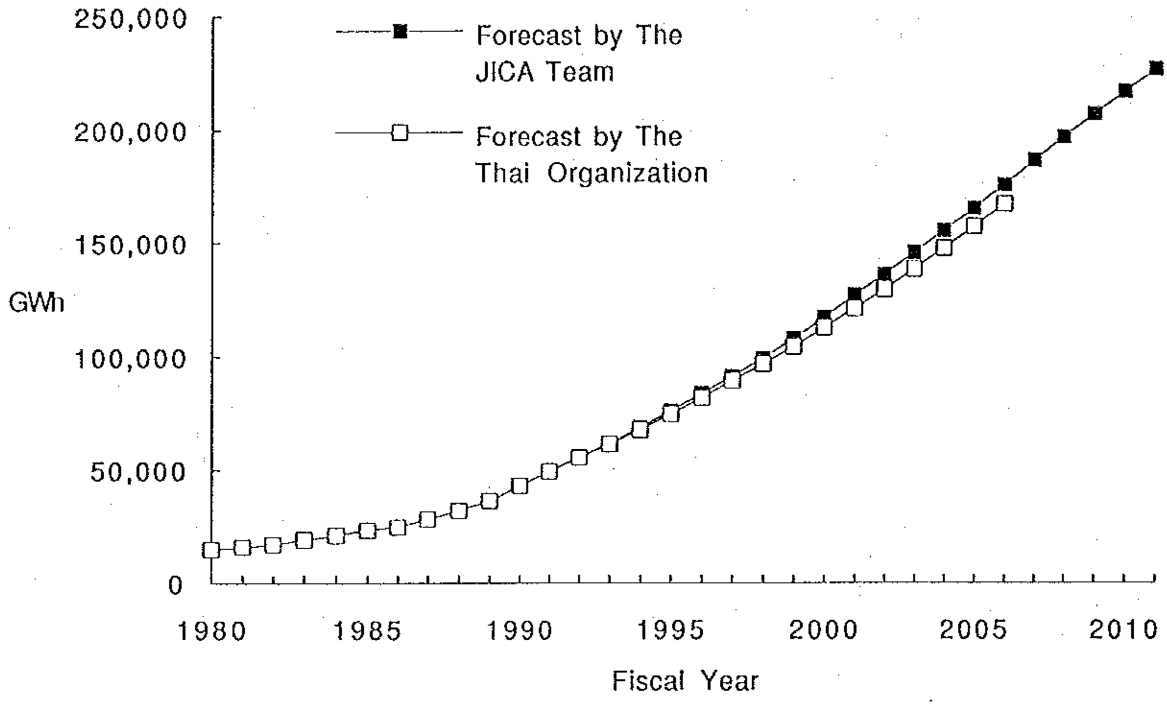



Fig. 2-3 Maximum Power Demand at Generating End

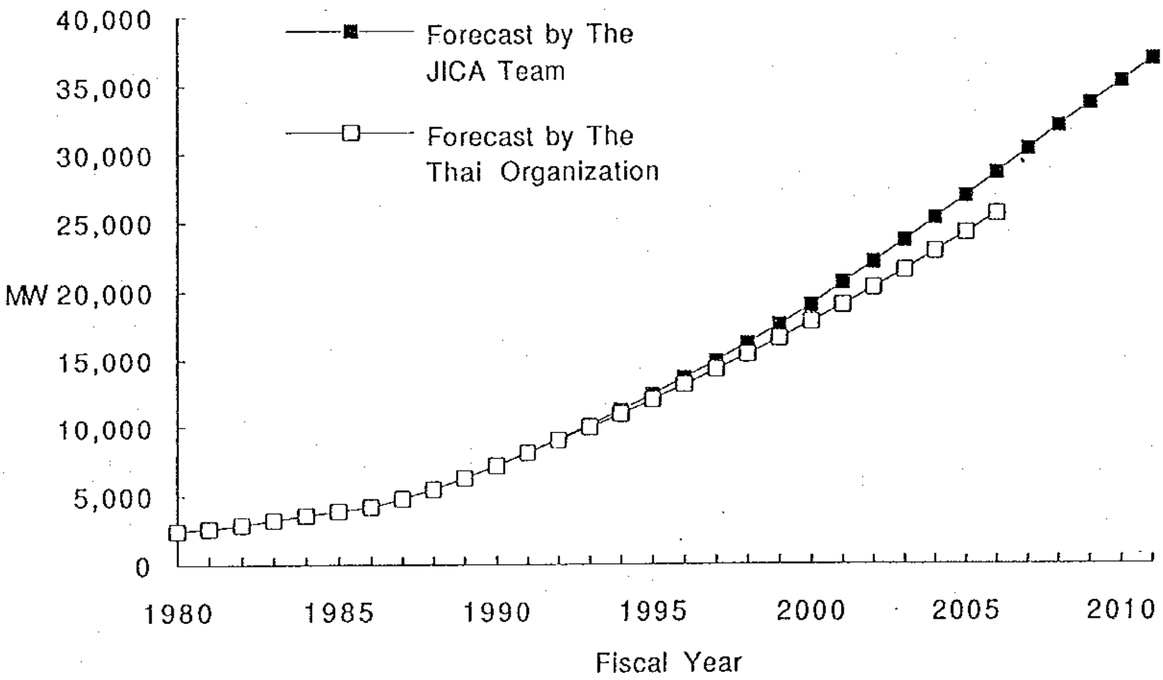


Fig. 2-4 Energy Demand by MEA

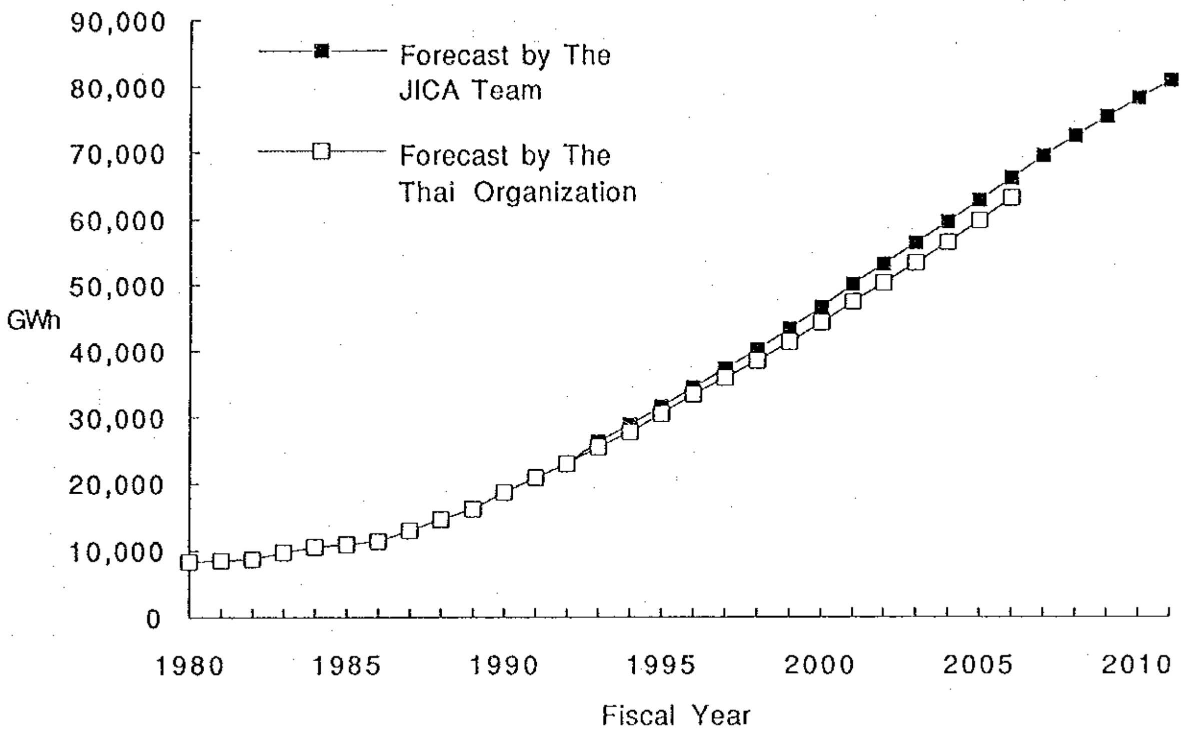
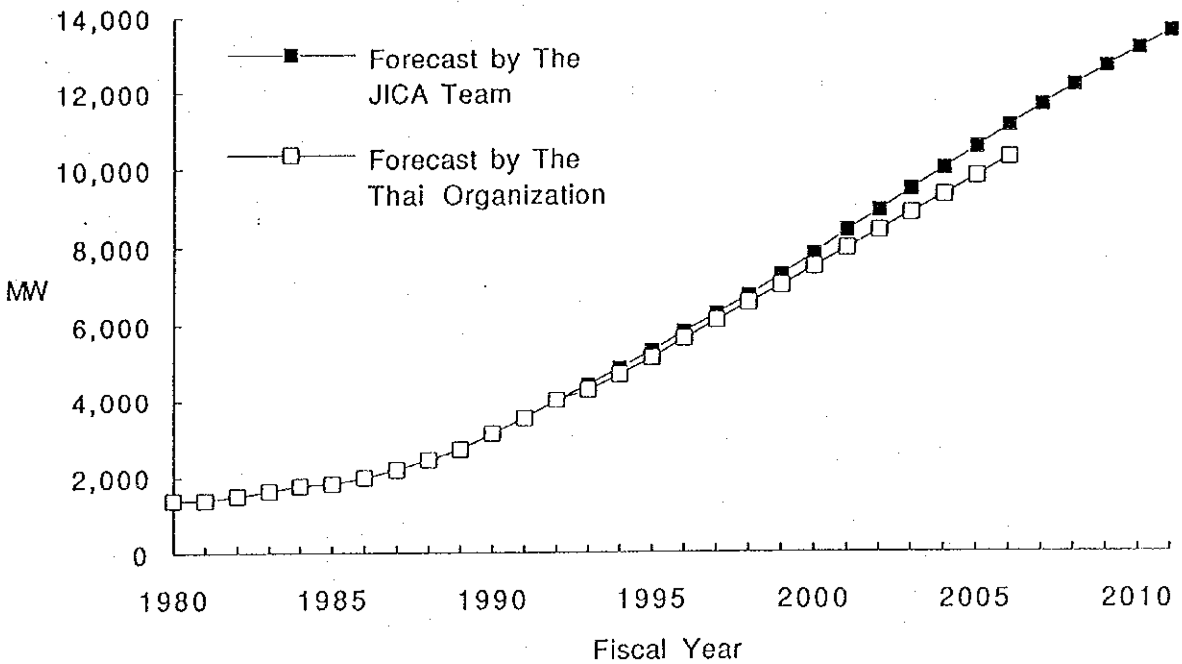



Fig. 2-5 Maximum Power Demand by MEA



# CHAPTER 3 POWER SYSTEM PLANNING OF THE GREATER BANGKOK AREA FOR A LONG FUTURE

## 3.1 The Power System of Thailand - Present Situation

Fig. 3-1 shows the outline of the power system of Thailand. Voltages of the transmission lines forming the power system of Thailand are 500 kV, 230 kV, 115 kV and 69 kV. The frequency of electricity is 50 Hz.

The power system is divided into the following four regions.

Region 1 : Metropolitan Area and its Surrounding Part of Thailand
Region 2 : Northeastern Part of Thailand
Region 3 : Southern Part of Thailand
Region 4 : Northern and Central Part of Thailand

Each region is connected by transmission lines of 500 kV, 230 kV and 115 kV.

The total capacity of power generating facilities is 11,033 MW as of September 1992. It consists of hydro-electric power 2,429.2 MW (accounting for 22.0% of the total), oil/gas and lignite fired thermal 5,506.5 MW (49.9%), combined cycle 2,859.6 MW (25.9%) and gas turbine 238.0 MW (2.2%).

### 3.1.1 Power Supply Capability And Electric Energy Demand of Each Region

Below is the feature of each region in respect of power supply and demand as of September 1992.

(1) In Region 1, there are thermal power stations and combined cycle plants of large scale such as SOUTH BANGKOK (1,330.0 MW), BANG PAKONG (3,074.6 MW), RAYON (1,130.0 MW), etc., and also reservoir type hydro-electric power stations of large scale such as SRINAGARIND (720.0 MW), KHAO LAEM (300.0 MW), etc. A total capacity of these facilities is 6,973.3 MW, accounting for about 63.2% of the total installed capacity of power sources in this country.

This region has a great demand for electric energy which accounts for about 75% of the total electric energy demand in the country.

(2) In Region 2, there are hydro-electric power stations of medium scale such as CHULABHORN (40.0 MW), SIRINDHORN (36.0 MW), a combined cycle power plant at NAM PONG (355.0 MW) and some gas turbines.

A total capacity of these facilities is 491.3 MW, accounting for 4.5% of the total installed capacity in the country.

These power sources are capable of load-frequency control and used effectively in an ordinal operation especially at the peaking time.

The power supplied for the base load is transmitted mainly from Region 4 through the 230 kV transmission lines and also from Region 1 through the 115 kV transmission lines.

Some of the power required in this region is supplied from Lao PDR, a neighboring country, based on a contract to purchase surplus energy (power) generated by the Nam Ngum hydro-electric power station (150 MW) which belongs to this country.

Demand for electric energy in this region accounts for nine to ten percent of the total demand of the country.

(3) In Region 3, there are thermal power stations such as KHANOM (150.0 MW), KRABI (34.0 MW), SURATANI (72.0 MW), etc. and also hydro-electric such as RAJJAPRABHA (240.0 MW), BANG LANG (72.0 MW), etc.

A total capacity of these facilities including the gas turbine (42.0 MW) at Hat Yai is 611.3 MW which accounts for 5.5% of the total installed capacity in the country.

Power for base load of this region is supplied from the Khanom and Krabi thermal and from Region 1 as well through the Second Central - Southern Tie line, a 230 kV double-circuit between PRACHUAP KHIRI KHAN and SURAT THANI.

This region and a neighboring country, Malaysia, are mutually exchanging electric power by means of the 115/132 kV power system interconnection which has been in operation between two countries since February 1981.

Demand for electric energy in this region accounts for six to seven percent of the total demand of the country.

(4) Power stations installed in Region 4 are the Mae Moh thermal power plant with the output of 2,025.0 MW, and hydro-electric of large scale such as BHUMIBOL (535.0 MW), SIRIKIT (375.0 MW), etc.

A total output of these facilities is 3,070.0 MW, which is about 28% of the total installed capacity of power sources of this country.

Demand for electric energy in this region accounts for eight to nine percent of the total demand of the country.

### 3.1.2 The Power Transmission among The Regions

Even though Region 1 has a very large supply capability of power, it cannot meet independently its great demand for power which accounts for approximately 75% of the total demand of the country.

A main load center of the region is the Greater Bangkok Area, namely Bangkok and its surroundings.

Table 3-1 shows the transition of power supply capability in Thailand which is estimated according to EGAT's power development plan, PDP 92-01(1). The sites of power development in near future are centered on the Mae Moh area in the northern district of Region 4 and the eastern seaboard area of Region 1.

The JICA team has estimated power transmission among the regions in 2006. Fig. 3-2 shows an example of this.

## 3.2 Approach to The Future Power Systems of The Greater Bangkok Area

### 3.2.1 Present Situation of The Transmission System

In the Greater Bangkok Area, there are two thermal power plants at present, namely NORTH BANGKOK (237.5 MW) and SOUTH BANGKOK (1,330 MW). They are connected to the 230 kV transmission lines which encircle the metropolitan area forming three loops.

Power to serve the Greater Bangkok Area is supplied from these two power plants and from this ring of 230 kV transmission lines.

To this ring of 230 kV transmission lines, electric power is sent not only from the above power plants but also from the power plants located in Region 1, such as BANG PAKONG (2,276.6 MW), SRINAGARIND (720 MW), KHAO LAEM (300 MW) and so forth by means of 230 kV transmission lines.

Further more, some of electric power generated at the power plants located in Region 3, namely MAE MOH (2,025 MW), BHUMIBOL (535 MW) and SIRIKIT (375 MW), is sent to the Greater Bangkok Area by means of 500 kV and 230 kV transmission lines.

Substations connected with the 230 kV transmission lines of the Greater Bangkok Area, such as SAI NOI, NORTH BANGKOK, BANG KAPI, BANGKOK NOI, SOUTH BANGKOK, BANG PHLI and RANGSIT, play currently a very important role to collect electric power from the above power plants and send it to the other substations to distribute in the area.

The transmission system composed of these substations and the 230 kV transmission lines can fulfill its function at the present time and will work for several years to come by adopting measures to increase the capacity of the existing facilities, such as the use of twin conductors on the transmission lines and installation of additional transformer banks in the substations.

### 3.2.2 The Power Demand of The Project Area

Below is the forecast of future power demand of the MEA service area which covers most part of the Greater Bangkok Area.

| Fiscal Year | Maximum Power Demand (MW) | |
|---|---|---|
| 1992 | 3,993 | (actual) |
| 1997 | 6,089 | (forecast by the Thai Organization) |
| 2001 | 7,952 | (forecast by the Thai Organization) |
| 2006 | 10,264 | (forecast by the Thai Organization) |
| 2011 | 13,569 | (forecast by the JICA team) |

Such a high growth of power demand of the project area needs to construct new substations and transmission lines, but in recent years there are problems to be encountered due to difficulties in the acquisition of land for substations and rights-of-way for transmission lines to be constructed.

There is another problem that some of the substation buses will encounter excessive fault levels for the interrupting capacity (50 kA) of circuit breakers in the not long distant future.

### 3.2.3 Requirements for The Future Transmission System

The power system must be kept in adequate condition to generate the energy, convey it to the load areas and deliver it to the customers.

Therefore, as long as loads continue to increase, the power system must also continue to grow providing sufficient capacity of power generation, transmission and distribution for the increasing load.

### 3.2.4 Approach to The Transmission Expansion Planning

The expansion plan of the transmission system in the Greater Bangkok Area has been made based on the load forecasts predicted by the Thai organization and JICA team and the power development plan of EGAT.

Planning of future power systems has been implemented by the procedure shown in Fig. 3-2. The approach to be taken to transmission expansion planning begins by stepping from the present power system to the horizon year conditions, say about 20 year ahead.

The horizon year expansion plan of the transmission system of the Greater Bangkok Area has been implemented taking the matters of importance into account, namely conditions of the area for installation of facilities, criteria for power system planning, and problems and requirements to cope with. The matters will be described in the following sections in detail.

The basic designs of transmission lines and substations have been developed for each year of 1997, 2001, 2006 and 2011.

Power flow analyses, short circuit current calculation and stability analyses have been carried out for the power systems covering the whole country in order to define the needs of transmission network expansions and reinforcements of the Greater Bangkok Area.

### 3.3 Criteria for The Transmission System Planning

Power system facilities are planned against a wide range of potential contingencies, in terms of both their steady state and transient state behavior. The planning criteria are comprised in assumptions of such contingencies and their consequences.

Below are the criteria adopted for the transmission system planning in this study:

(1) The voltage variation in the transmission system should be within 98% -105% of the nominal voltage under normal condition and 92% - 108% under contingency (emergency) condition.

(2) The transmission system should be planned on the basis of a single contingency (n-1) criterion which is widely used in many developed countries, i.e. each system element such as one circuit of a line or one transformer bank can fail separately without causing loss of load and excessive overloads on the remaining equipment.

(3) The bulk power system should be maintained stable under the condition of a permanent three phase fault on any generator or transmission circuit, with normal fault clearing and without reclosing.

The fault clearing times to be used are as follows:

| | |
|---|---|
| 4 cycles | for 500 kV system |
| 5 cycles | for 230 kV system |

(4) Fault levels should below 50 kA at any bus bar both in the 500 kV and in the 230 kV transmission system.

### 3.4 Measures to Cope with Requirements

The power demand in the Greater Bangkok Area is anticipated to become more than doubled within the next ten years. Due to such a high growth of demand and resulting heavy load flows on the lines, the existing transmission system will not be able to meet the requirements in near future.

Reinforcements of the power system should be urgently implemented to increase the power supply capability, to maintain the system reliability, to improve voltage conditions, and to reduce system losses.

However, EGAT has encountered severe problems on the acquisition of land for substations and new rights-of-way for transmission lines needed to increase supply capability as well as some technical problems concerning excessive fault level and heavy loaded situation on the parallel 230 kV lines.

The measures, to cope with such problems, are envisaged as below.

(1) To increase transmission capacity

Transmission system of higher voltage, say 500 kV, should be introduced into the urban area. It implies installation of 500 kV transmission lines and substations in this area.

(2) To secure spaces for facilities

To obtain rights-of-way and land for 500 kV facilities, the existing transmission lines and substations should be replaced.

A space on the existing right-of-way should be examined to use for a new substation.

It should be examined to install compact substations, or underground or building substations. It is recommendable to adopt GIS equipment to make a substation's space smaller.

Equipment adopted should have larger capacity than the existing one to use the space effectively.

Compact 230 kV lines of large capacity should be constructed adopting multi-conductors and multi-circuits in a narrow right-of-way as well.

Underground transmission should be considered if necessary.

(3) To solve excessive short circuit levels

Circuit breakers with a larger interrupting current, say 50 kA, will have to be installed. At the least, at substations where fault levels are predicted to exceed the interrupting current rating,the existing circuit breakers should be replaced by breakers with a higher rating.

Operation with the system split is very effective in reducing short-circuit current, so bus sections will be separated by normally open circuit breakers at a few substations.

The system will be divided into two or three load areas which are bounded by circuit breakers and each of which has sufficient load-carrying capability to supply its load.

Introduction of a higher voltage level (500 kV) should be examined in place of the present voltage level (230 kV).

Adoption of high impedance transformers or current limiting reactors is also conceivable.

## 3.5 Main Points for Planning Horizon Year Transmission Systems

### 3.5.1 Expansion of the 500 kV System

The followings are the matters that JICA team has especially paid attention to the planning of the future transmission system in the Greater Bangkok Area.

(1) To make a great increase of power supply capability especially to the center of the city.

(2) Only the existing rights-of-way will be available for strengthening the transmission system, because it is extremely difficult or impossible to obtain new rights-of-way,especially inside the existing 230 kV ring.

(3) To control a fault level below 50 kA without losing merits of interconnection between substations as much as possible.

### 3.5.2 Main Points of the Planned Horizon Year Transmission System

The main points of the planned horizon year transmission system are as follows.

(1) Introduction of 500 kV system into the Bangkok Noi substation

It is desirable to increase supply capability from the west side of the Greater Bangkok Area. For this purpose the voltage of 500 kV should be introduced into the Bangkok Noi substation.

To introduce 500 kV into the Bangkok Noi substation, the existing 230 kV SAI NOI - BANGKOK NOI line should be replaced by a 500 kV double-circuit line because it is extremely difficult or rather impossible to obtain a new route for the 500 kV line. The conductor of the line should be ACSR 1272 MCM x 4.

When the 500 kV line is completed, the 500 kV system in the Greater Bangkok Area will be formed linking the Nong Chok, Wang Noi, Sai Noi and Bangkok Noi substations.

(2) Introduction of 500 kV system into the North Bangkok substation

500 kV should be introduced into the North Bangkok substation in order to increase power supply capability for the area which is to be supplied by the North Bangkok, Lat Phrao and Ratchada Phisek substations.

A 500 kV double-circuit line should be installed using the right-of-way of the existing 230 kV SAI NOI - RANGSIT - NORTH BANGKOK line for this purpose.

The 500 kV line will connect the two substations, SAI NOI and NORTH BANGKOK, directly, because the Rangsit substation is not large enough to install necessary 500 kV equipment to connect with the 500 kV system.

In the section between Rangsit and North Bangkok, the structures of the line should be equipped with four circuits, a 500 kV double-circuit and 230 kV double-circuit, except for a restricted area on the height of structures between the Rangsit substation and Chaeng Wattana substation in the vicinity of the Don Muang airport.

In this area, the structures are restricted below 45 meters in height and so should be equipped with a 500 kV double-circuit only. Therefore, for the 230 kV line, underground cables will have to be used.

The 230 kV double-circuit placed in juxtaposition with the 500 kV double-circuit should be connected with the Rangsit substation, Chaeng Wattana substation in the course of construction, a proposed substation " A ", and the North Bangkok substation.

Conductors ACSR 1272 MCM x 4 should be used for the 500 kV line and also for the 230 kV line in the section of overhead transmission. For the section of underground transmission, cross linked polyethylene cables with load carrying capability of about 600 MW per circuit will be used as the initial scale. In future, however, additional cables should be laid in accordance with the increase of power demand at the Chaeng Wattana substation.

It is desirable that the present 230 kV single-circuit line between BANGKOK NOI and NORTH BANGKOK is replaced by a 500 kV line regarding reliability of the system and flexibility of system operation.

The 230 kV double-circuit should be placed in juxtaposition with the 500 kV double-circuit between the North Bangkok substation and the substation "F " ( TALINGCHAN ) which will be installed in around 2010.

(3) Installation of a new 230 kV substation " A "

A new substation " A " will be installed at the spot where the 230 kV line to the Lat Phrao substation is branched by 1 pi ($\pi$) connection from the RANGSIT - NORTH BANGKOK line at present.

The 230 kV transmission lines should connect this substation with the Chaeng Wattana, North Bangkok and Lat Phrao substations. That will balance power flow of each circuit and increase loading capability of the lines especially to the Chaeng Wattana and Lat Phrao substations.

In addition, the installation of the A substation will make it easier to develop routes of transmission lines to send power to the substations which will be built in a populated area in future.

(4) Reinforcement of the NONG CHOK - ON NUCH line

In order to increase power supply capability of the Nong Chok substation, the present line between the Nong Chok and On Nuch substations should be reinforced with the four-circuit line,the conductor of which is ACSR 1272 MCM x 2.

(5) Installation of a new substation " C ", and reinforcement of the BANG PAKONG - NONG CHOK and BANG PAKONG - ON NUCH Lines

In addition to reinforcement of the NONG CHOK - ON NUCH line, a new 500 kV substation " C " should be installed at the crossing where the BANG PAKONG - NONG CHOK line and the BANG PAKONG 2 - ON NUCH line meet, and the existing 230 kV lines should be reinforced in the sections between C and the On Nuch substation and between C and the Nong Chok substation.

This will increase capability and reliability of power supply to the eastern area of Bangkok, which is to be supplied from ON NUCH, BANG KAPI, CHIDLOM and new substations, H and B, which will be installed in future.

One of the 230 kV transmission line ( double-circuit ) which run from Bang Pakong power station to the Nong Chok substation should be replaced in the section of NONG CHOK - site of C by a 230 kV four-circuit line which will be connected to the existing lines coming from the Bang Pakong power station.

The other 230 kV transmission line constructed between Bang Pakong power station and Nong Chok substation should be replaced in the section of NONG CHOK - C by a 500 kV-designed transmission line and should be pulled into the C substation.

The present 230 kV BANG PAKONG - ON NUCH line should be pulled into the C station as well to form a pass of power flow from NONG CHOK to ON NUCH together with the above 500 kV-designed transmission line by way of the C station. 500 kV will be introduced into the C substation in around 2010.

The 230 kV double-circuit transmission line between the On Nuch and C substations should be replaced with four circuits using conductor ACSR 1272 MCM x 2.

The present right-of-way of this line is so adjacent to the proposed site of a new international airport that the line route will have to be moved to avoid the area controlled by the regulation concerning height restriction of structures built around an airport.

Otherwise it will be necessary to lay underground cables instead of an overhead line near the site of the airport. In this case, cross linked polyethylene cables with load carrying capability of about 600 MW per circuit will be laid as the initial scale and an additional cable will be laid in accordance with the increase of power flow of the line.

(6) Power supply to the Rangsit area and its vicinity

In order to increase capability of power supply to the Rangsit area, one more substation, e.g. Rangsit 2, will be necessary. Installation of the new substation should be examined concerning 115 kV and 69 kV transmission system, i.e. capacity of the present lines, possibility of their reinforcement, acquisition of rights-of-way of new lines from the existing substation to the distribution substations.

230 kV four circuits using ACSR 1272 MCM x 2 should be installed between WANG NOI and RANGSIT. These circuits will assure power supply with high reliability together with the other 230 kV NONG CHOK - RANGSIT line.

(7) Installation of substations in the populated areas

In order to increase power supply capability for densely populated areas, new 230 kV substations G, H, J and F should be installed.

The final scale of the transformer banks which supply power to the secondary voltage 115 kV or 69 kV of these substations should be 300 MVA x 3 or 4 banks.

Power will be supplied to these substations from the key stations such as North Bangkok, A, BANG KAPI, SOUTH THONBURI and BANGKOK NOI by 230 kV underground cables.

The transmission system should adopt unit system in which the abovesubstations are not equipped with circuit breakers and bus bars at the side of 230 kV transmission lines so as to be simply and compactly designed.

The capacity of 230 kV cable used should correspond to the capacity of transformer bank.

(8) Replacement of the 230 kV BAN PONG 2 - SAI NOI Line by a 500 kV Double-circuit Transmission Line

A 500 kV transmission system will have to be constructed to send power from the power plants located in the western seaboard and/or southern seaboard to Sai Noi substation. To secure a right-of-way for the transmission system, the existing 230 kV BAN PONG 2 - SAI NOI line should be replaced by a 500 kV transmission line.

That is also effective to control an increasing fault level at the 230 kV bus of the Sai Noi substation.

(9) Reinforcement of the 230 kV BANGKOK NOI - SAM PHRAN 1 - SOUTH THONBURI line

The above transmission line will be heavily loaded as demand for power increases in the areas situated to the southwest of the Greater Bangkok Area. Reinforcement of this line will be necessary about the middle of 2000s.

The single circuit between BANGKOK NOI and SAM PHRAN 1 and also the one between SAM PHRAN 1 and SOUTH THONBURI should be strengthened with two circuits of 230 kV lines using a conductor ACSR 1272MCM x 4.

In the section between SAM PHRAN 1 and the present right-of-way of the BANGKOK NOI - SOUTH THONBURI line, structures of the line will have to be equipped with four circuits because of only one right-of-way available.

It is recommended the line which links directly between BANGKOK NOI and SOUTH THONBURI is reinforced with a conductor ACSR 1272MCM x 4.

### 3.5.3 Description of the Study Cases of a Horizon Year Transmission System

For the study on a 2011 year (a horizon year) transmission system of the Greater Bangkok Area, the JICA team has supposed several cases with regard to power sources and connection of transmission lines.

Figs. 3-4 and 3-5 are typical power flow diagrams obtained as a result of the study on a horizon year power system.

In Case 1, power sources are developed mainly in the western seaboard and southern seaboard, while in Case 2, power sources are developed in the eastern seaboard and western seaboard almost equally. In either case there will be many rights-of-way necessary for the 500 kV lines to send power from the sources to the Greater Bangkok Area.

Table 3-2 shows the study results of fault levels at the 230 kV bus of each substation in the Greater Bangkok Area.

The transmission system shown as Fig. 3-6 will be fundamentally adaptable to the future requirements of power supply, reliability and fault levels, irrespective of configuration of power sources developed in future.

In case most of the power sources are developed in the western and/or southern areas, the 500 kV transmission system between SAI NOI and WANG NOI will need three circuits due to the heavy load flow.

Tables 3-3 and 3-4 show transmission lines and transformer banks and line equipment of the substations respectively which are proposed to be installed or reinforced to form the 2011 year transmission system of the Greater Bangkok Area.

Fig. 3-7 shows the transmission systems of the Greater Bangkok Area at present and in a horizon year.

Table 3-1 POWER DEVELOPMENT PLAN AND TRANSITION OF POWER SUPPLY CAPABILITY OF THAILAND

As per EGAT's power development plan, PDP 92-01(1)

| Fiscal Year | Developed Power Plant | Fuel,Type | Rated Capacity (MW) | Accumulated Installed Capacity: Whole Country (MW) | Region1 (MW) | Region2 (MW) | Region3 (MW) | Region4 (MW) | Peak Generation (MW) |
|---|---|---|---|---|---|---|---|---|---|
| 1991 | Existing | | | 9,610.3 | 5,550.3 | 378.3 | 611.3 | 3,070.4 | 8,045 |
| 1992 | Rayong cc Block 1(ST) Unit 1 | Gas | 102 | 9,712.3 | 5,652.3 | | | | |
| | Bang Pakong Unit 3 | Oil/Gas | 600 | 10,312.3 | 6,252.3 | | | | |
| | Bang Pakong cc Block 3 (ST) Unit 1 | Gas | 99 | 10,411.3 | 6,351.3 | | | | |
| | Rayong cc Block 2 (ST) Unit 1 | Gas | 102 | 10,513.3 | 6,453.3 | | | | |
| | Bang Pakong cc Block 4 (ST) Unit 1 | Gas | 99 | 10,612.3 | 6,552.3 | | | | |
| | Rayong cc Block 3 (ST) Unit 1 | Gas | 102 | 10,714.3 | 6,654.3 | | | | |
| | Nam Phong cc Block1(ST) Unit 1 | Gas | 113 | 10,827.3 | | 491.3 | | | |
| | Rayong cc Block 4 (GT) Unit 1-2 | Gas | 206 | 11,033.3 | 6,860.3 | | | | 9,000 |
| 1993 | Bang Pakong Unit 4 | Oil/Gas | 600 | 11,633.3 | 7,460.3 | | | | |
| | Nam Phong cc Block2 (GT) Unit 1-2 | Gas | 242 | 11,875.3 | | 733.3 | | | |
| | South Bangkok cc Block1(GT) Unit 1-2 | Gas | 220 | 12,095.3 | 7,680.3 | | | | |
| | Rayong cc Block 4 (ST) Unit 1 | Gas | 102 | 12,197.3 | 7,782.3 | | | | 9,924 |
| 1994 | R2 Gas Turbine Retired | Gas | -28 | 12,169.3 | | 705.3 | | | |
| | Khanom cc Block 1(GT) Unit 1-4 | Gas | 448 | 12,617.3 | | | 1,059.3 | | |
| | Nam Phong cc Block2 (ST) Unit 1 | Gas | 113 | 12,730.3 | | 818.3 | | | |
| | Pak Mun Unit 1-2 | Hydro | 68 | 12,798.3 | | 886.3 | | | |
| | South Bangkok cc Block1(ST) Unit 1 | Gas | 115 | 12,913.3 | 7,897.3 | | | | |
| | Khanom cc Block 1(ST) Unit 1 | Gas | 226 | 13,139.3 | | | 1,285.3 | | 10,892 |
| 1995 | Pak Mun Unit 3-4 | Hydro | 68 | 13,207.3 | | 954.3 | | | |
| | Sirikit Unit 4 | Hydro | 125 | 13,332.3 | | | | 3,195.4 | |
| | South Bangkok cc Block1(GT) Unit 1-2 | Gas | 400 | 13,732.3 | 8,297.3 | | | | |
| | Mae Moh Unit 12 | Lignite | 300 | 14,032.3 | | | | 3,495.4 | 11,946 |
| 1996 | R3 Gas Turbine Retired | Gas | -70 | 13,962.3 | | | 1,215.3 | | |
| | Krabi Retired | Lignite | -34 | 13,928.3 | | | 1,181.3 | | |
| | Mae Moh Unit 13 | Lignite | 300 | 14,228.3 | | | | 3,795.4 | |
| | Bhumibol Unit 8 | Hydro | 175 | 14,403.3 | | | | 3,970.4 | |
| | Wang Noi Gas Turbine | Oil/Gas | 600 | 15,003.3 | 8,897.3 | | | | 13,075 |
| 1997 | Mae Kham FBC Unit 1 | Lignite | 150 | 15,153.3 | | | | 4,120.4 | |
| | Kaeng Krung Unit 1-2 | Hydro | 80 | 15,233.3 | | | 1,261.3 | | |
| | Lower Central cc Block1 | Gas | 600 | 15,833.3 | 9,497.3 | | | | |
| | South Bangkok cc Block2(ST) Unit 1 | Gas | 200 | 16,033.3 | 9,697.3 | | | | |
| | Mae Kham FBC Unit 2 | Lignite | 150 | 16,183.3 | | | | 4,270.4 | |
| | Lower Central cc Block2 | Gas | 600 | 16,783.3 | 10,297.3 | | | | 14,205 |
| 1998 | Lam Takhong Unit 1-2 | Hydro | 500 | 17,283.3 | | 1,454.3 | | | |
| | Lower Central cc Block3 | Gas | 600 | 17,883.3 | 10,897.3 | | | | 15,354 |
| 1999 | Ao Phai Unit 1 | Oil/Coal | 700 | 18,583.3 | 11,597.3 | | | | |
| | Surat Thani Unit1 Retired | Oil | -30 | 18,553.3 | | | 1,231.3 | | |
| | Mae Lama Luang Unit 1-2 | Hydro | 160 | 18,713.3 | | | | 4,430.4 | |
| | Ao Phai Unit 2 | Oil/Coal | 700 | 19,413.3 | 12,297.3 | | | | 16,531 |
| 2000 | Ao Phai Unit 3 | Oil/Coal | 700 | 20,113.3 | 12,997.3 | | | | |
| | New Thermal Unit 1 | Oil/Coal | 1000 | 21,113.3 | 13,997.3 | | | | 17,765 |
| 2001 | Region 3 cc Block1 | Gas | 300 | 21,413.3 | | | 1,531.3 | | |
| | Mae Taeng Unit 1-2 | Hydro | 26 | 21,439.3 | | | | 4,456.4 | |
| | New Thermal Unit 2 | Oil/Coal | 1000 | 22,439.3 | 14,997.3 | | | | 19,000 |
| 2002 | Lampang Unit 1 | Lignite | 300 | 22,739.3 | | | | 4,756.4 | |
| | Lam Takhong Unit 3-4 | Hydro | 500 | 23,239.3 | | 1,954.3 | | | |
| | Lampang Unit 2 | Lignite | 300 | 23,539.3 | | | | 5,056.4 | |
| | Lampang Unit 3 | Lignite | 300 | 23,839.3 | | | | 5,356.4 | 20,219 |
| 2003 | Bang Pakong cc Block 1 Retired | Gas | -380.3 | 23,459.0 | 14,617.0 | | | | |
| | Lan Krabu Gas Turbine Retired | Gas | -140 | 23,319.0 | | | | 5,216.4 | |
| | Lampang Unit 4 | Lignite | 300 | 23,619.0 | | | | 5,516.4 | |
| | Region 3 cc Block2 | Gas | 300 | 23,919.0 | | | 1,831.3 | | |
| | New Thermal Unit 3 | Oil/Coal | 1000 | 24,919.0 | 15,617.0 | | | | |
| | Lampang Unit 5 | Lignite | 300 | 25,219.0 | | | | 5,816.4 | |
| | Nam Khek Pumped-Storage Unit 1-2 | Hydro | 300 | 25,519.0 | | | | 6,116.4 | |
| | Lampang Unit 6 | Lignite | 300 | 25,819.0 | | | | 6,416.4 | 21,482 |
| 2004 | North Bangkok Unit 1-3 Retired | Oil | -237.5 | 25,581.5 | 15,379.5 | | | | |
| | Bang Pakong cc Block 2 Retired | Gas | -380.3 | 25,201.2 | 14,999.2 | | | | |
| | Mae Moh Unit 1-2 Retired | Lignite | -150 | 25,051.2 | | | | 6,266.4 | |
| | New Thermal Unit 4 | Oil/Coal | 1000 | 26,051.2 | 15,999.2 | | | | |
| | New Thermal Unit 5 | Oil/Coal | 1000 | 27,051.2 | 16,999.2 | | | | 22,795 |
| 2005 | New Thermal Unit 6 | Oil/Coal | 1000 | 28,051.2 | 17,999.2 | | | | |
| | Lampang Unit 7 | Lignite | 300 | 28,351.2 | | | | 6,566.4 | |
| | Lampang Unit 8 | Lignite | 300 | 28,651.2 | | | | 6,866.4 | 24,150 |
| 2006 | Nuclear Unit 1 | Nuclear | 1000 | 29,651.2 | | | 2,831.3 | | |
| | Nuclear Unit 2 | Nuclear | 1000 | 30,651.2 | | | 3,831.3 | | 25,515 |
| | Total Installed Capacity As Of 2006 | | | | 17,999.2 | 1,954.3 | 3,831.3 | 6,866.4 | |

Table 3-2 COMPARISON OF THREE-PHASE SHORT CIRCUIT CURRENTS OF THE 2011 YEAR SYSTEMS REGARDING POWER PLANT CONFIGURATION

| 230kV bus | Case 1 | Case 2 |
|---|---|---|
| | kA | kA |
| SAI NOI | 24.9 | 25.4 |
| WANG NOI | 44.9 | 47.2 |
| BANGKOK NOI | 44.6 | 44.3 |
| NONG CHOK (bus A) | 44.7 | 48.8 |
| NONG CHOK (bus B) | 22.8 | 23.3 |
| NORTH BANGKOK | 30.1 | 30.6 |
| C | 40.5 | 42.9 |
| A | 26.9 | 27.2 |
| RANGSIT | 26.6 | 27.3 |
| LAT PHRAO | 25.2 | 25.6 |
| RATCHADA PHISEK | 29.3 | 30.7 |
| BANG KAPI | 36.6 | 38.9 |
| ON NUCH | 41.7 | 44.6 |
| BANG PHLI | 32.0 | 33.6 |
| SOUTH TONBURI | 37.9 | 37.8 |
| SOUTH BANGKOK | 35.2 | 35.1 |

Note The 230 kV system is split at CHAENG WATTANA, RATCHADA PHISEK, KHLONG MAI, BANG PHLI and NONG CHOK as shown on Fig.s 5-9 and 5-10.

Case 1 : Power sources are developed mainly in the western seaboard and southern seaboard areas.

Case 2 : Power sources are developed in the eastern seaboard and western seaboard areas almost equally.

Table 3-3 REINFORCEMENT OF TRANSMISSION LINES IN THE GREATER BANGKOK AREA

| No. | Transmission lines From | Transmission lines To | 1992 year system Length (km) | 1992 Voltage (kV) | 1992 No. of Circuits | 1992 Conductor n x MCM | 2011 year system Length (km) | 2011 Voltage (kV) | 2011 No. of Circuits | 2011 Conductor n x MCM | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | WANG NOI | NONG CHOK | - | - | - | - | 64 | 500 | 2 | 4 x 795 | 500kV line construction |
| 28 | SAI NOI | WANG NOI | - | - | - | - | 56 | 500 | 2 | 4 x 795 | 500kV line construction |
| | BANG PHLI | BANG PAKONG | 44.1 | 230 | 2 | 2 x 1272 | - | - | - | - | |
| 26 | BANG PHLI | D (BANG BOR) | - | - | - | - | 17.5 | 230 | 2 | 2 x 1272 | 2 pi (π) connection at D |
| 26 | D (BANG BOR) | BANG PAKONG | - | - | - | - | 27.5 | 230 | 2 | 2 x 1272 | 2 pi (π) connection at D |
| 22 | ON NUCH | BANG PHLI | 10.5 | 230 | 2 | 1 x 1272 | 10.5 | 230 | 2 | 2 x 1272 | Change to the bundle-conductor |
| 15 | ON NUCH | BANG KAPI | 10 | 230 | 2 | 2 x 1272 | 10 | 230 | 4 | 2 x 1272 | Increase of the number of circuits |
| | ON NUCH | BANG KAPI | 10 | 230 | 2 | 2 x 1272 | 10 | 230 | 2 | 2 x 1272 | |
| 16 | B (PATANAKARN) | BANG KAPI | - | - | - | - | 5 | 230 | 2 | 2 x 1272 | New line construction for the new substation |
| | LAT PHRAO | BANG KAPI | 10.4 | 230 | 2 | 2 x 1272 | - | - | - | - | |
| | LAT PHRAO | RATCHADA PHISEK | - | - | - | - | 4.5 | 230 | 2 | 2 x 1272 | 2 pi (π) connection at RATCHADA PHISEIK |
| | RATCHADA PHISEK | BANG KAPI | - | - | - | - | 6.5 | 230 | 2 | 2 x 1272 | 2 pi (π) connection at RATCHADA PHISEIK |
| | SOUTH BANGKOK | BANG PHLI | 15.9 | 230 | 2 | 2 x 1272 | - | - | - | - | |
| 27 | SOUTH BANGKOK | E (TEPARAK) | - | - | - | - | 11.5 | 230 | 2 | 2 x 1272 | 2 pi (π) connection at E |
| 27 | E (TEPARAK) | BANG PHLI | - | - | - | - | 5.5 | 230 | 2 | 2 x 1272 | 2 pi (π) connection at E |
| | NONG CHOK | BANG PAKONG 2 | 42.3 | 230 | 2 | 2 x 1272 | - | - | - | - | |
| 23,24 | NONG CHOK | BANG PAKONG 2 | - | - | - | - | 43 | 230 | 2 | 2 x 1272 | Change of a line connection |
| 23,25 | NONG CHOK | BANG PAKONG 2 | - | - | - | - | 55 | 230 | 2 | 2 x 1272 | Change of a line connection |
| | NONG CHOK | KHLONG MAI | 34.3 | 230 | 2 | 2 x 1272 | - | - | - | - | |
| 18 | NONG CHOK | C | - | - | - | - | 19 | 500 | 2 | 4 x 1272 | 500kV line construction using the right-of-way of the existing 230kV line |
| | C | KHLONG MAI | - | - | - | - | 15.5 | 230 | 2 | 2 x 1272 | Connection to C |
| | ON - NUCH | BANG PAKONG 2 | 56 | 230 | 2 | 2 x 1272 | - | - | - | - | |
| 19,20,21 | ON - NUCH | C | - | - | - | - | 22 | 230 | 4 | 2 x 1272/cable | Increase of the number of circuits and connection to C. |
| | | | | | ( Overhead line 12 km, underground line 10 km ) | | | | | | Underground cables are used in part |
| | KHLONG MAI | BANG PAKONG | 8 | 230 | 2 | 2 x 1272 | 8 | 230 | 2 | 2 x 1272 | |
| | SAI NOI | RANGSIT | 24.5 | 230 | 2 | 2 x 1272 | - | - | - | - | |
| | RANGSIT | NORTH BANGKOK | 19.4 | 230 | 1 | 1 x 1272 | - | - | - | - | |
| | RANGSIT | LAT PHRAO | 17.7 | 230 | 1 | 1 x 1272 | - | - | - | - | |
| | NORTH BANGKOK | LAT PHRAO | 7 | 230 | 1 | 1 x 1272 | - | - | - | - | |
| 3,13,5,6 | SAI NOI | NORTH BANGKOK | - | - | - | - | 44 | 500 | 2 | 4 x 1272 | 500kV line construction using the right-of-way of the existing 230kV line |
| 13 | RANGSIT | CHAENG WATTANA | - | - | - | - | 10 | 230 | 2 | 4 x 1272/cable | 2 pi (π) connection at CHAENG WATTANA |
| | | | | | ( Overhead line 5 km, underground line 5 km ) | | | | | | Underground cables are used in part |
| 5 | CHAENG WATTANA | A | - | - | - | - | 7.1 | 230 | 2 | 4 x 1272 | Connection to A |
| 6 | A | NORTH BANGKOK | - | - | - | - | 4.4 | 230 | 2 | 4 x 1272 | Connection to A |
| 7 | A | LAT PHRAO | - | - | - | - | 2.7 | 230 | 2 | 4 x 1272 | Connection to A |
| 14 | NONG CHOK | ON - NUCH | 16.8 | 230 | 2 | 2 x 1272 | 16.8 | 230 | 4 | 2 x 1272 | Increase of the number of circuits |
| 26 | BAN PONG2 | SAI NOI | 53.6 | 230 | 2 | 1 x 1272 | 53.6 | 500 | 2 | 4 x 1272 | 500kV line construction using BANG PONG 2 - SAI NOI line route |
| 2 | SAI NOI | BANGKOK NOI | 29.6 | 230 | 2 | 2 x 1272 | 29.6 | 500 | 2 | 4 x 1272 | 500kV line construction using the right-of-way of the existing 230kV line |
| 1,4 | BANGKOK NOI | NORTH BANGKOK | 18.4 | 230 | 1 | 1 x 1272 | 18.4 | 500 | 2 | 4 x 1272 | 500kV line construction using the right-of-way of the existing 230kV line |
| | NORTH BANGKOK | F (TALINGCHAN) | - | - | - | - | 9.2 | 230 | 2 | 2 x 1272 | New line construction for the new substation |
| 12 | WANG NOI | RANGSIT/RNAGSIT 2 | - | - | - | - | 50 | 230 | 4 | 2 x 1272 | Connection of ANG THONG 1 - RANGSIT line to WANG NOI |
| | RANGSIT | RANGSIT 2 | - | - | - | - | 4 | 230 | 2 | 2 x 1272 | Connection of the two substations |
| 8,9 | BANGKOK NOI | SAM PHRAN 1 | 12 | 230 | 1 | 2 x 1272 | 12 | 230 | 2 | 4 x 1272 | Reinforcement of the existing line |
| 9,10 | SAM PHRAN 1 | SOUTH THONBURI | 19.8 | 230 | 1 | 2 x 1272 | 19.8 | 230 | 2 | 4 x 1272 | Reinforcement of the existing line |
| 11 | BANGKOK NOI | SOUTH THONBURI | 8.1 | 230 | 2 | 1 x 1272 | 8.1 | 230 | 1 | 4 x 1272 | Reinforcement of the existing line |
| | A | G (SANAMPAO) | - | - | - | - | 9 | 230 | 6 | Cable | New line construction for the new substation |
| | SOUTH TONBURI | I (THANONTOK) | - | - | - | - | 10 | 230 | 4 | Cable | New line construction for the new substation |
| | BANGKOK NOI | J (THONBURI) | - | - | - | - | 11 | 230 | 3 | Cable | New line construction for the new substation |
| | BANG KAPI | H (KLONG TOEY) | - | - | - | - | 8 | 230 | 6 | Cable | New line construction for the new substation |

Table 3-4 CONSTRUCTION PLAN OF SUBSTATIONS FOR POWER SYSTEM REINFORCEMENT IN THE GREATER BANGKOK AREA

| Substation | 1992 year system | | | | | 2011 year system | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Line equipment | | Transformer | | | Line equipment | | Transformer | | | Ind. peak load (MVA) |
| | Voltage (kV) | No. of Circuits | Voltage (kV) | Capacity (MVA) | Max. loading (MVA) | Voltage (kV) | No. of Circuits | Voltage (kV) | Capacity (MVA) | Max. loading (MVA) | |
| NONG CHOK | 500 | 1 | 500/230 | 2x600 | 760 | 500 | 8 *2 | 500/230 | 2x600 + 2x750 | 2270 | |
| | 230 | 2 | 230/121 | 1 x 200 | 200 | 230 | 10 | 230/115 | 3x300 | 720 | 629 |
| WANG NOI | - | - | - | - | - | 500 | 12 | 500/230 | 4 x 750 | 2580 | |
| | - | - | - | - | - | 230 | 4 | - | - | - | - |
| SAI NOI | - | - | - | - | - | 500 | 14 - 16 *4 | 500/230 | 4 x 750 | 2580 | |
| | 230 | - | - | - | - | 230 | 2 | 230/115 | 4 x 200 | 690 | 511 |
| BANGKOK NOI | | | | | | 500 | 4 | 500/230 | 5x750 | 3370 | |
| | 230 | 6 | 230/69 | 2x200 + 2x100 | 480 | 230 | 6 | 230/69 | 3x200 + 2x100 | 690 | 565 |
| | | | 230/115 | 2 x 200 | 250 | | | 230/115 | 3 x 200 | 480 | 486 |
| NORTH BANGKOK | | | | | | 500 | 4 | 500/230 | 4 x 750 | 2580 | |
| | 230 | 3 | 230/72.5 | 1 x 200 + 1 x 100 | 135 | 230 | 5 | 230/72.5 | 3x200+1x300 | 720 | 712 |
| C | - | - | - | - | - | 500 | 2 | 500/230 | 4 x 750 | 2580 | |
| | - | - | - | - | - | 230 | 6 | - | - | - | |
| BANG KAPI | 230 | 8 | 230/69 | 3 x 200 | 480 | 230 | 18 | 230/69 | 6 x 200 | 1100 | 973 |
| BANG PHLI | 230 | 6 | 230/69 | 2 x 200 | 250 | 230 | 6 | 230/69 | 3 x 200 | 480 | 481 |
| | | | 230/115 | 2 x 200 | 250 | | | 230/115 | 3 x 200 | 480 | 474 |
| CHIDLOM | 230 | 2 | 230/66 | 2 x 250 | 320 | 230 | 2 | 230/66 | 2 x 250 | 320 | 343 |
| CHAENG WATTANA | - | - | - | - | - | 230 | 4 | 230/115 | 4 x 300 | 1040 | 777 |
| LAT PHRAO | 230 | 4 | 230/69 | 3 x 200 | 480 | 230 | 4 | 230/69 | 4 x 300 *1 | 1040 | 777 |
| ON - NUCH | - | - | - | - | - | 230 | 16 | 230/115 | 4 x 300 | 1040 | 1063 |
| A | - | - | - | - | - | 230 | 12 | - | - | - | - |
| RANGSIT *3 | | | 230/72.5 | 3x200 | 480 | | | 230/72.5 | 5 x 300 | 1350 | 1133 |
| | 230 | 8 | 230/115 | 1 x 200 + 1 x 100 | 135 | 230 | 8 | 230/115 | 5 x 300 | 1350 | 1147 |
| RATCHADA PHISEK | 230 | - | - | - | - | 230 | 4 | 230/69 | 3 x 300 | 720 | 479 |
| | | | | | | | | 230/115 | 3 x 200 | 480 | 417 |
| SOUTH BANGKOK | 230 | 5 | 230/72.5 | 4 x 200 | 690 | 230 | 5 | 230/72.5 | 5 x 200 | 900 | 893 |
| | | | 230/115 | 1 x 200 | 200 | | | 230/115 | 3 x 200 | 480 | 220 |
| SOUTH TONBURI | 230 | 6 | - | - | - | 230 | 10 | 230/72.5 | 4 x 200 | 690 | 607 |
| B (PATANAKARN) | - | - | - | - | - | 230 | 4 | 230/66 | 3 x 300 | 720 | 477 |
| | | | | | | | | 230/115 | 2 x 300 | 380 | 384 |
| D (BANG BOR) | - | - | - | - | - | 230 | 4 | 230/115 | 3 x 300 | 720 | 647 |
| H (KHLONG TOEY) | - | - | - | - | - | 230 | 6 | 230/66 | 3 x 300 | 720 | 444 |
| | | | | | | | | 230/115 | 3 x 300 | 720 | 401 |
| F (TALINGCHAN) | - | - | - | - | - | 230 | 2 | 230/115 | 3 x 300 | 720 | 581 |
| E (TEPARAK) | - | - | - | - | - | 230 | 4 | 230/66 | 3 x 300 | 720 | 469 |
| | | | - | - | - | | | 230/115 | 3 x 300 | 720 | 498 |
| I (THANONTOK) | - | - | - | - | - | 230 | 4 | 230/66 | 4 x 300 | 1040 | 793 |
| J (THONBURI) | - | - | - | - | - | 230 | 3 | 230/66 | 3 x 300 | 720 | 601 |
| G (SANAMPAO) | - | - | - | - | - | 230 | 6 | 230/66 | 3 x 300 | 720 | 467 |
| | | | | | | | | 230/115 | 3 x 300 | 720 | 438 |
| SAM PHRAN 1 | 230 | 2 | - | - | - | 230 | 6 *5 | 230/115 | 5 x 200 | 900 | |

*1 The transformer banks should be replaced by larger ones.
*2 Two circuits of eight are for the power source developed following the Ao Phai project.
*3 It is required that the substation load which includes PEA's load is divided into two or three, and new substations are constructed in future.
*4 Number of circuits depends on the development of the power sources in the west and south.
*5 Two circuits of six are for a future-built substation, e.g. SAMUT SAKHON 3.

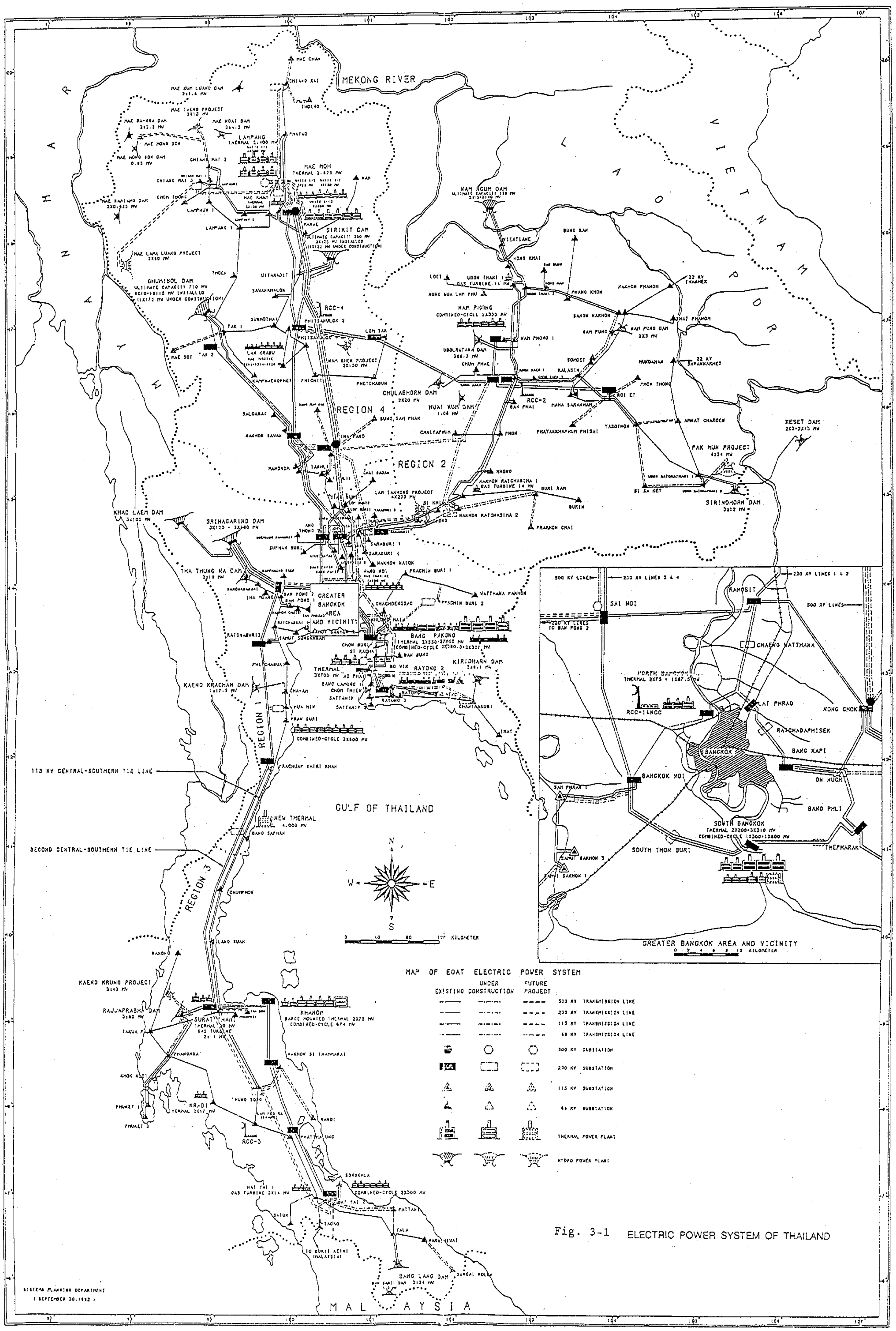



Fig. 3-1 ELECTRIC POWER SYSTEM OF THAILAND

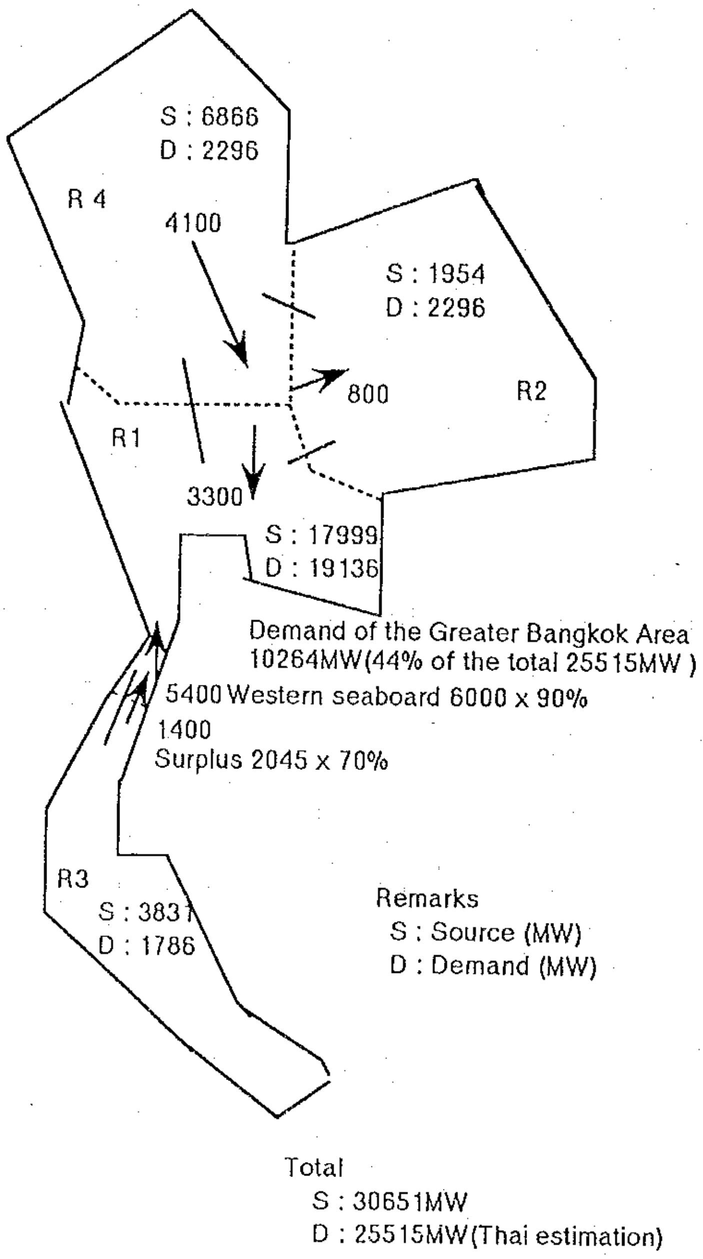
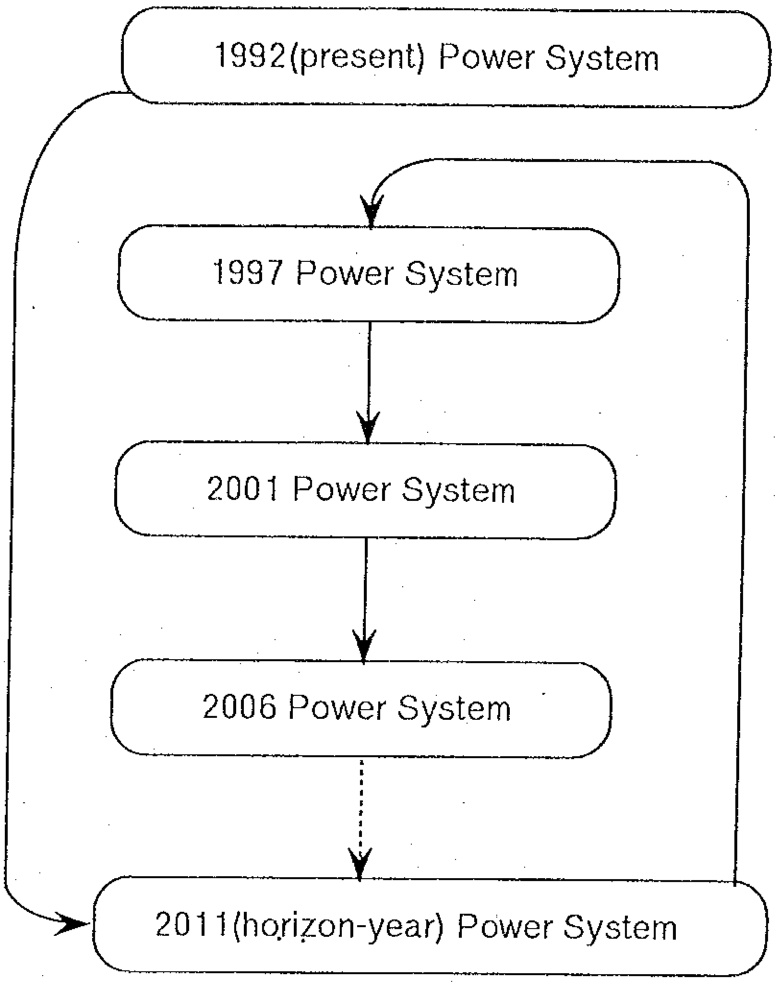



Fig. 3-2 ESTIMATED POWER TRANSMISSION AMONG REGIONS IN 2006

Fig. 3-3 APPROACH TO FUTURE POWER SYSTEMS

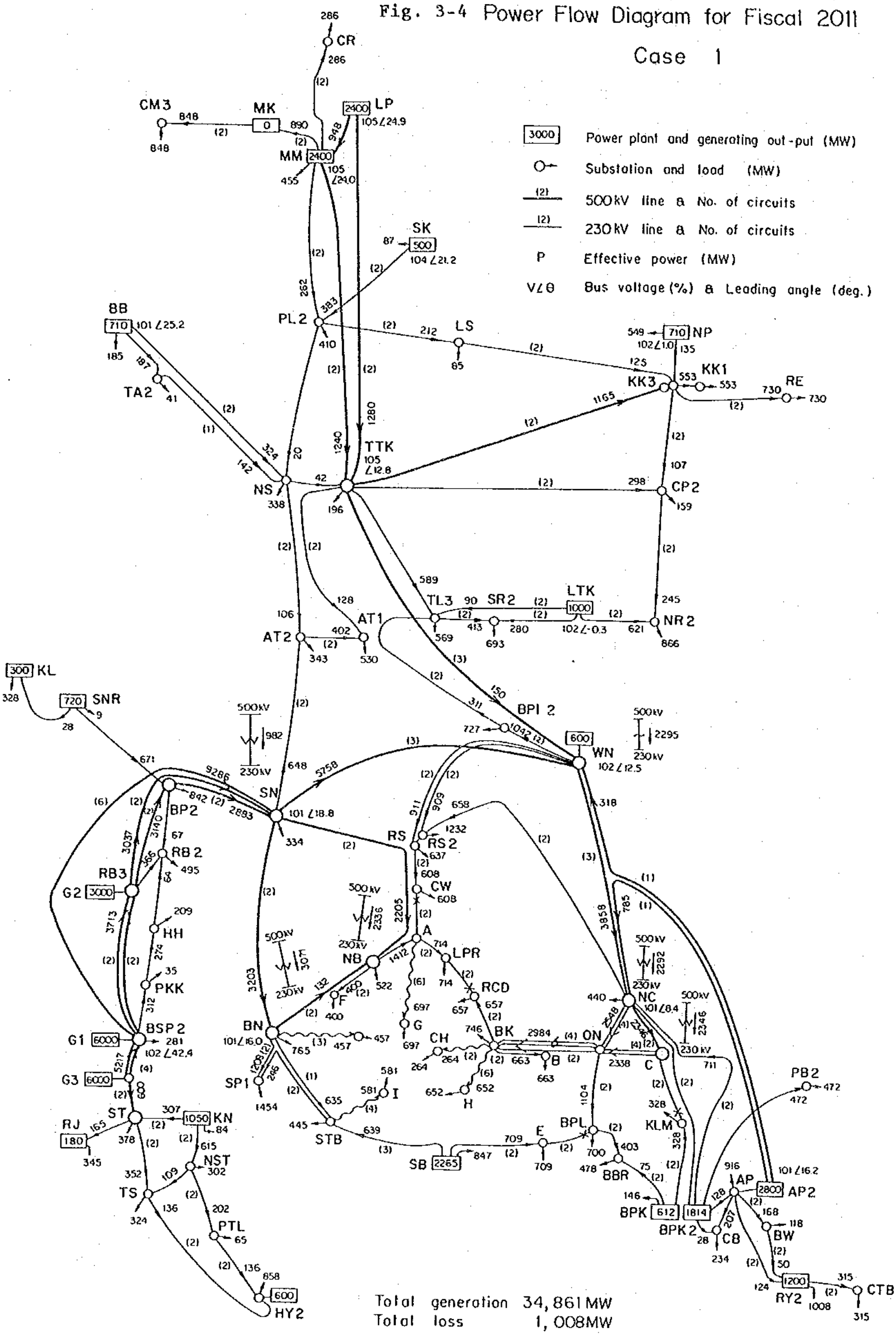



Factors for future power system planning

1. Power demand forecast
2. Power development plan
3. Capacity of equipment
4. Short circuit current
5. Power system stability
6. Reliability of power supply
7. Environmental restrictions

Fig. 3-4 Power Flow Diagram for Fiscal 2011

Case 1




Total generation 34,861MW
Total loss 1,008MW

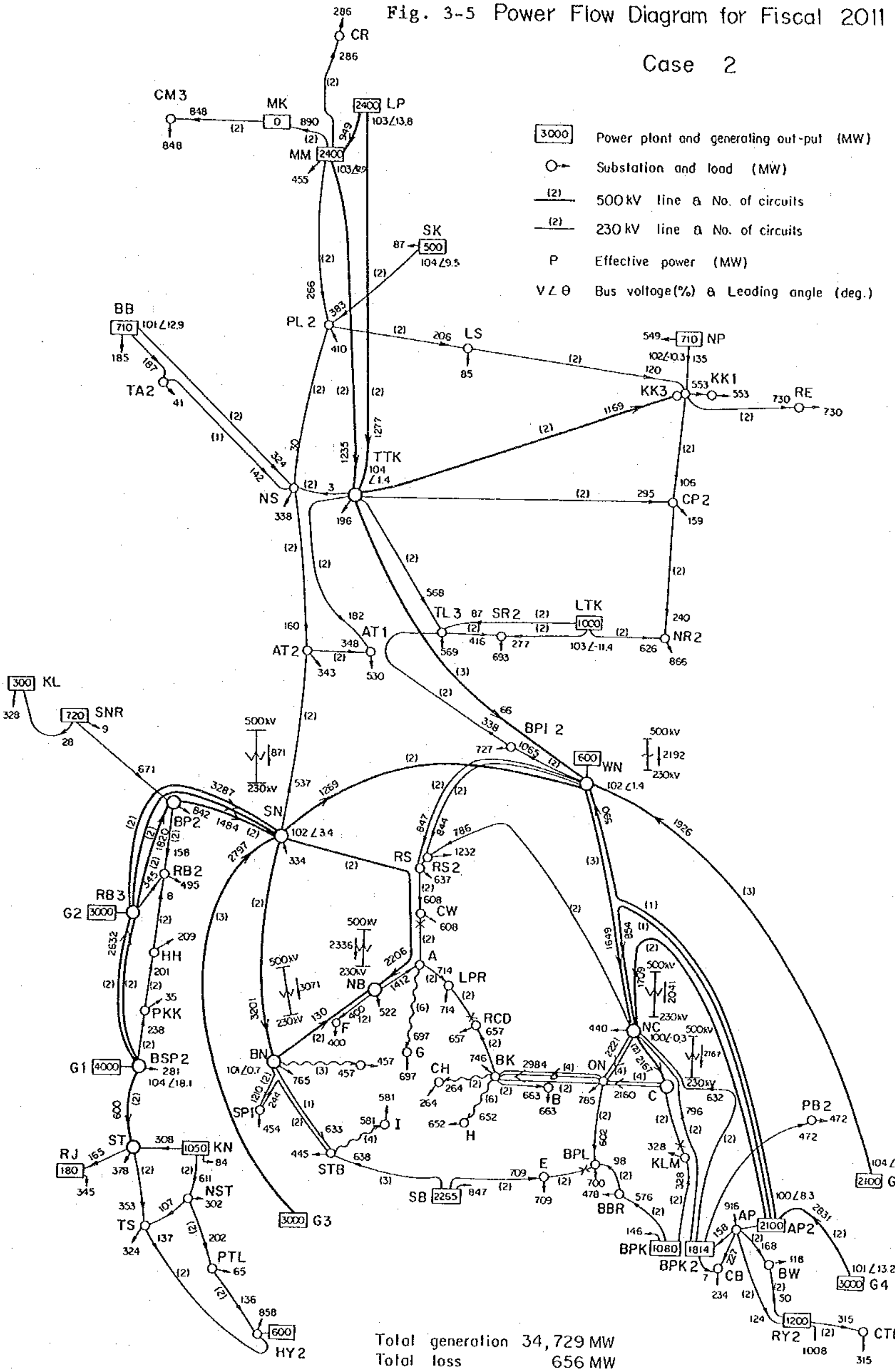
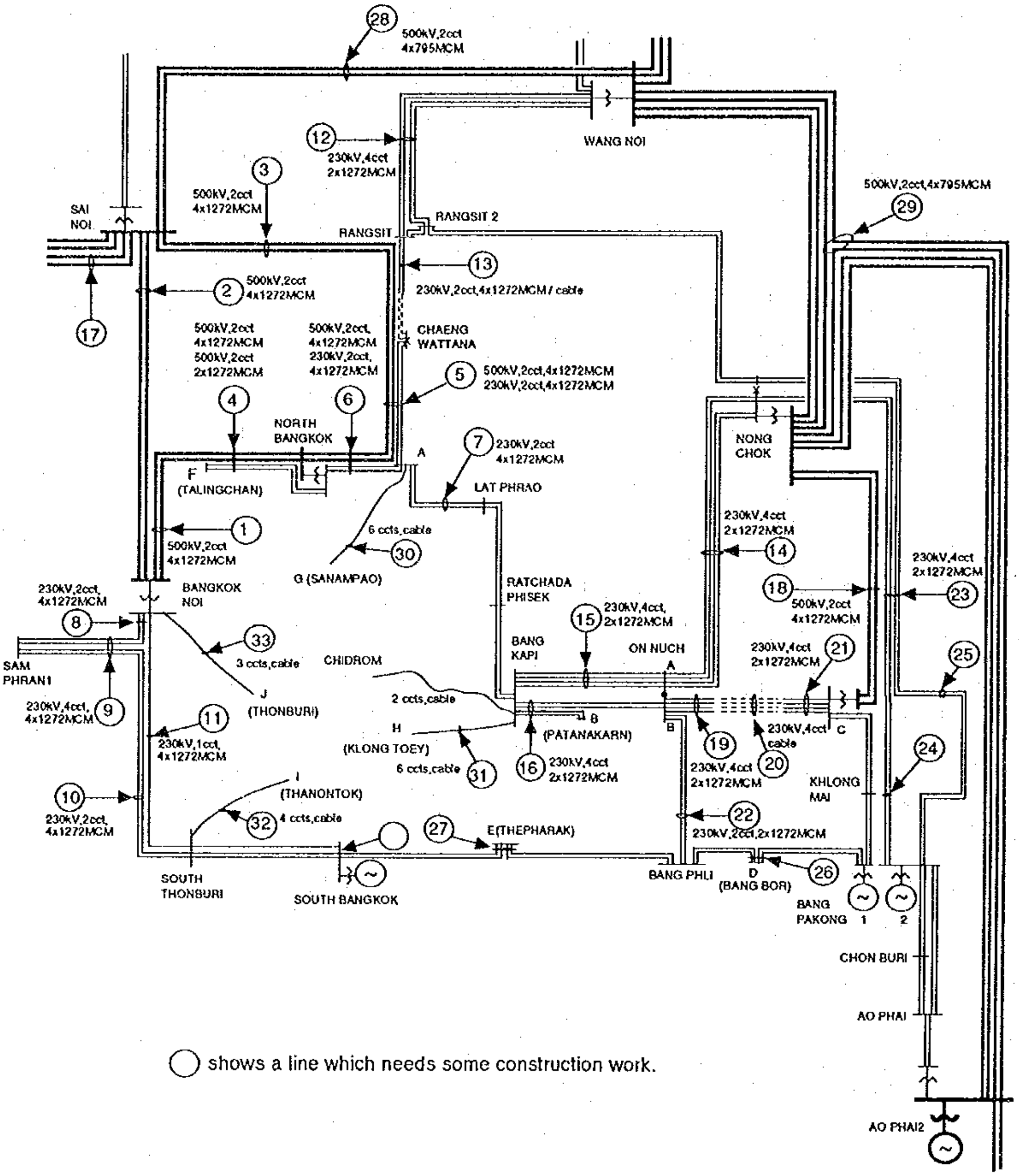
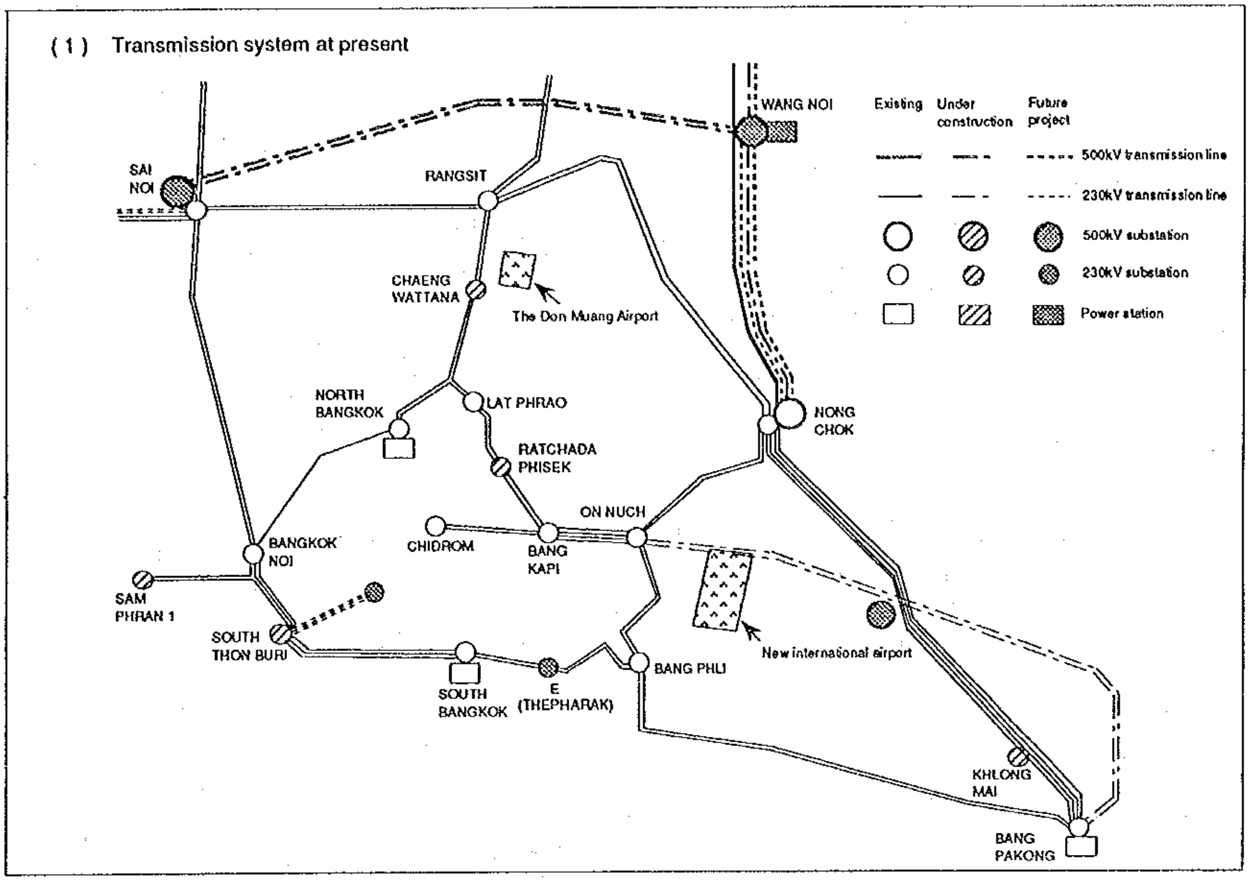



Fig. 3-5 Power Flow Diagram for Fiscal 2011




◯ shows a line which needs some construction work.

Fig. 3-6 TRANSMISSION SYSTEM OF THE GREATER BANGKOK AREA AFTER 2011



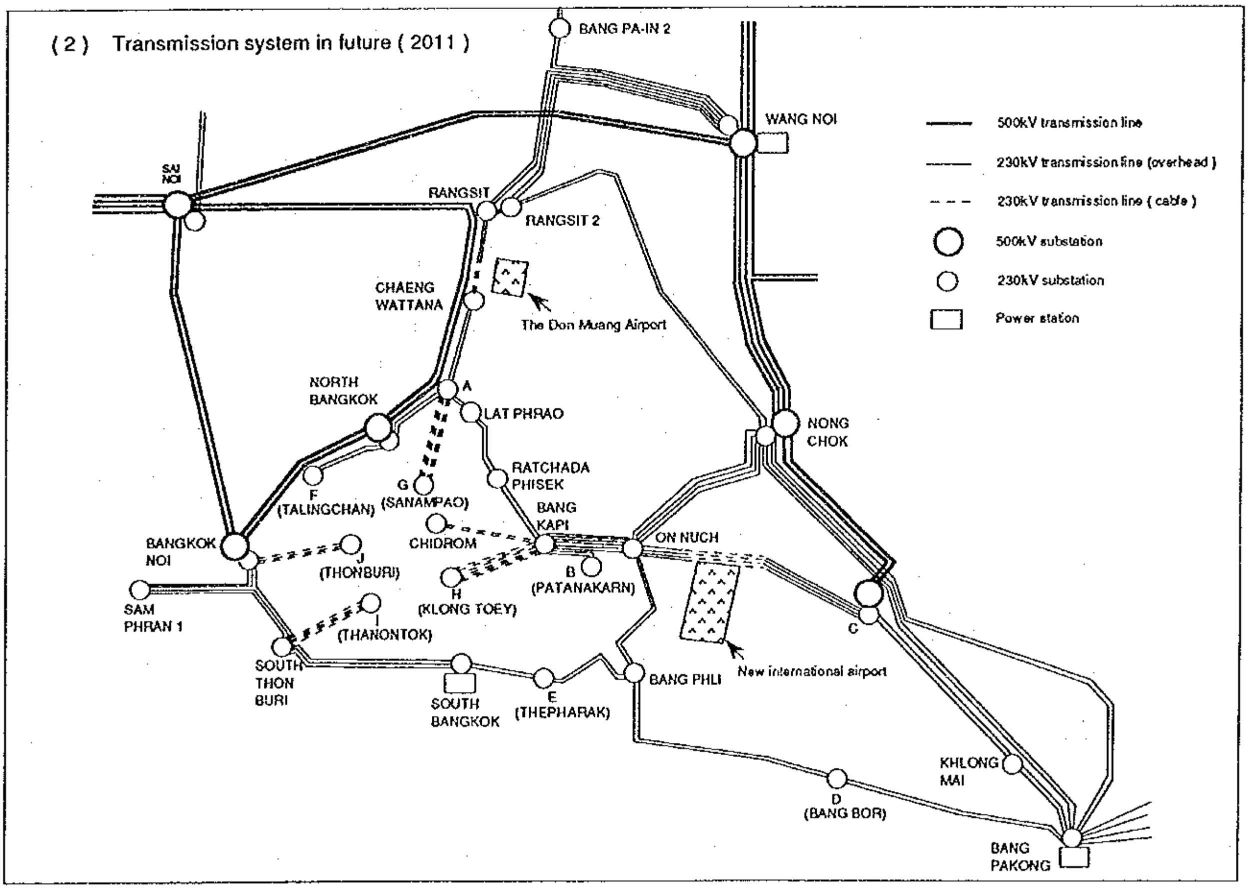




Fig. 3-7 TRANSMISSION SYSTEMS OF THE GREATER BANGKOK AREA AT PRESENT AND IN FUTURE

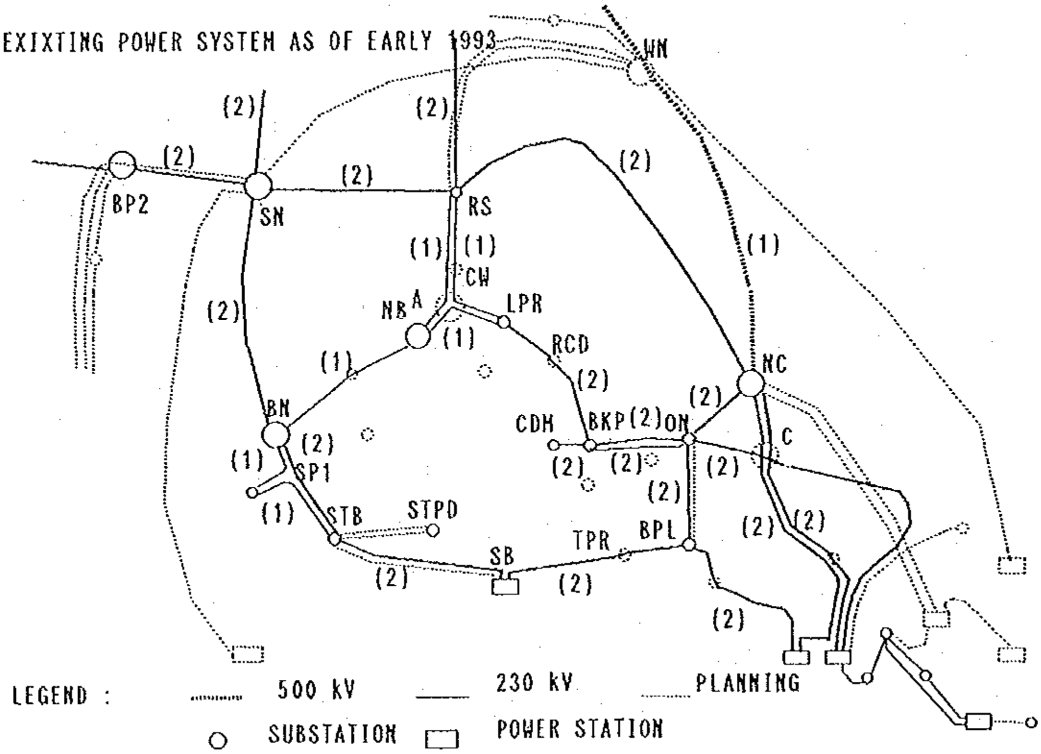
## CHAPTER 4 POWER SYSTEM CONFIGURATION OF PLANNED YEARS

### 4.1 Present

Existing power system as of early 1993 is as shown below (Fig.4-1).

The outline of power system configurations of planned years are as follows:

Fig.4-1



### 4.2 Up to 1997

a) New 500 kV double lines between SAI NOI and NONG CHOK via WANG NOI (1995).

b) New 500 kV double lines to SAI NOI from lower central seaboard via BAN PONG 2.

c) New 500 kV double lines to SAI NOI from western seaboard.

d) 230 kV double lines replaced by 500/230 kV 4 lines between RANGSIT and CHAENG WATTHANA and operated at 230 kV (1997).

e) Tap to TEPARAK of existing 230 kV double lines (SOUTH BANGKOK-BANG PHLI- 1996).

f) New 230 kV double lines with four circuit tower between RANGSIT and WANG NOI (1995).

g) New 230 kV triple lines (Underground Cable) from BANG KAPI to KHRONG TOEY (1996).

h) New 230 kV triple lines (Underground Cable) from SOUTH THONBURI to SATU PRADIT by 1996.

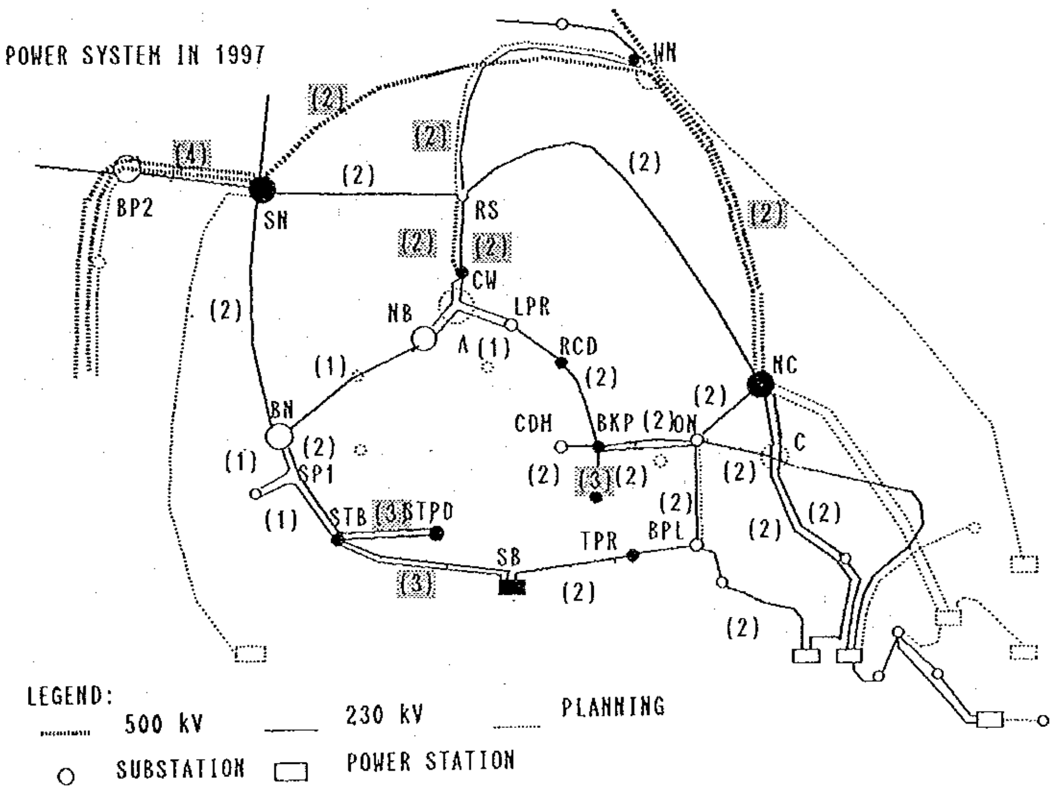
i) New 230 kV single line from SOUTH BANGKOK to SOUTH THONBURI by 1997.

j) Tap to RAICHADAPISEK of existing 230 kV double lines (LATPRO-BANG KAPI, 1994)

k) New substations; 230 kV WANG NOI, CHAENG WATHANA (1997), TEPARAK (1997).

Fig.4-2

POWER SYSTEM IN 1997



### 4.3 Up to 2001

a) New 500 kV double lines to NONG CHOK from AO PHAI.

b) 230 kV double lines replaced by 500 kV double lines between SAI NOI and BANGKOK NOI and operated at 230 kV (2000).

c) 230 kV single line replaced by 500 kV double lines between NORTH BANGKOK and BANGKOK NOI and operated at 230 kV (2000).

d) 230 kV double lines replaced by 500/230 kV 4 lines between <A> and NORTH BANGKOK and between <A> and CHAENG WATTHANA (2002).

e) 230 kV double lines replaced by 4 conductor double lines between <A> and LAT PHRAO (2002).

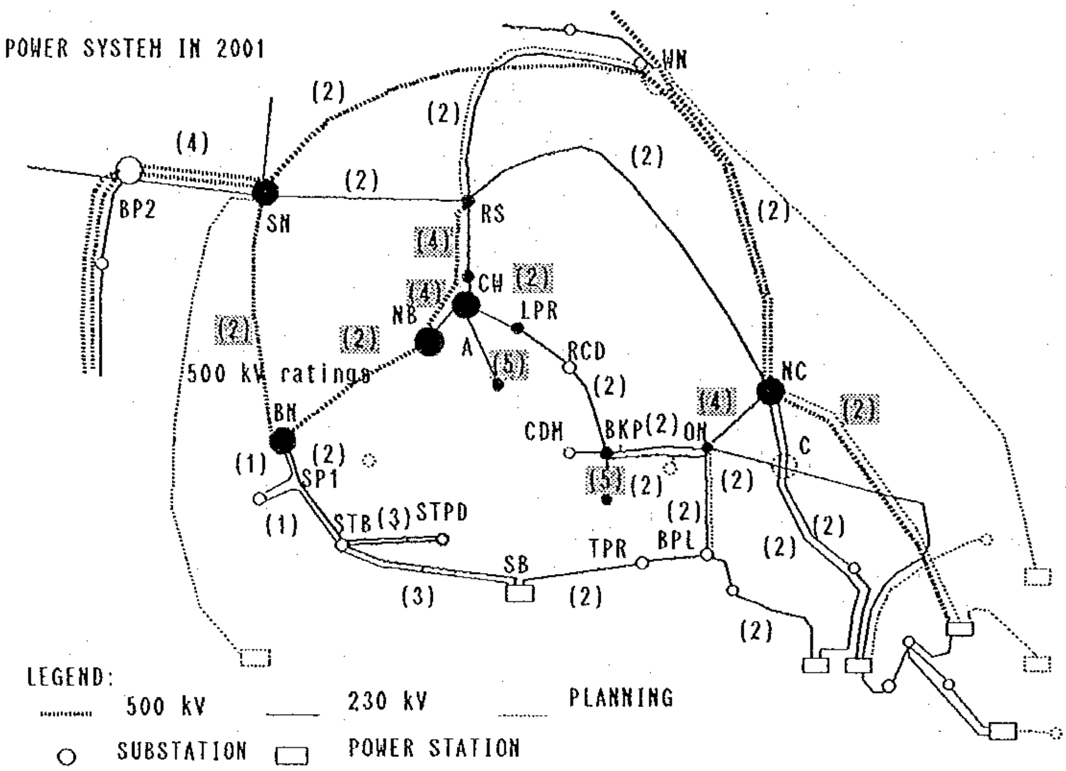
f) 230 kV double lines replaced by 230 kV 4 lines between NONG CHOK and ON NUCH (1998).

g) Lay additional 230 kV double lines (Underground Cable) from BANG KAPI to KHRONG TOEY (2000).

h) New 230 kV five lines (Underground Cable) from <A> to SANANPAO (2000).

i) New substation; <A> (2001).

Fig.4-3



## 4.4 Up to 2006

a) Operate SAI NOI-BANGKOK NOI lines at 500 kV (2002).

b) 230 kV double lines replaced by 500 kV double lines between SAI NOI and RANGSIT site (2004).

c) Operate SAI NOI-NORTH BANGKOK lines via RANGSIT site and NORTH BANGKOK-BANGKOK NOI lines at 500 kV (2005).

d) String additional 230 kV double lines between RANGSIT and WANG NOI (2003).

e) 230 kV triple lines replaced by 230 kV 4 conductor triple lines between BANGKOK NOI and tap point to SAM PHRAN 1, two of which tap to SAM PHRAN 1 (2003).

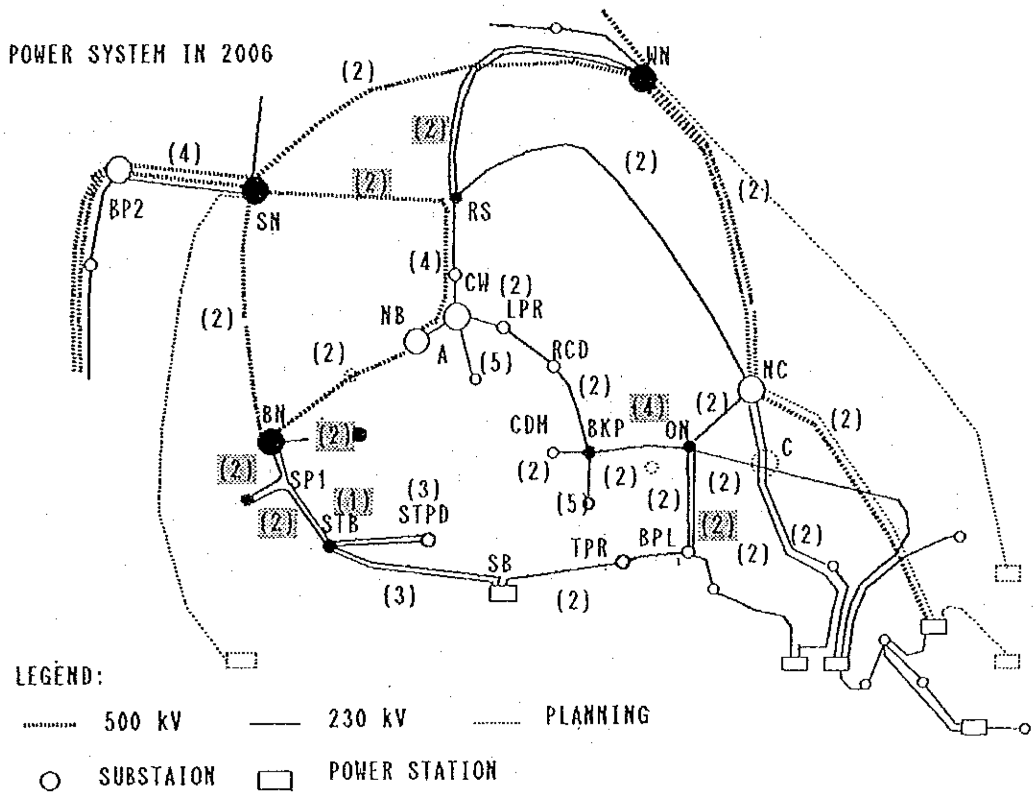
f) 230 kV triple line replaced by 230 kV 4 conductor triple lines between SOUTH THONBURI and tap point to SAM PHRAN 1, two of which tap to SAM PHRAN 1 and the other to BANGKOK NOI line (2004).

g) Existing 230 kV lines replaced by 230 kV 4 lines between ON NUCH and BANG KAPI (2005).

h) New 230 kV double lines from BANGKOK NOI to THONBURI (2005).

i) New 230 kV double lines between ON NUCH and BANG PHLI (2005).

Fig.4-4



## 4.5 Up to 2011

a) New 500 kV double lines to NONG CHOK from AO PHAI.

b) Tap to <C> of existing 230 kV lines (NONG CHOK - BANG PAKONG, ON NUCH - BANG PAKONG, 2009).

c) 230 kV double overhead lines replaced by 230 kV 4 lines (underground cable crossing airport area and overhead line in the other area) between <C> and ON NUCH (2007).

d) Existing 230 kV lines replaced by 230 kV 4 lines between <C> and NONG CHOK (2009).

e) New 500 kV double lines between <C> and NONG CHOK (2010).

f) Tap to TALINGCHAN just below the line (500/230 kV line from NORTH BANGKOK, 2009)

g) Lay additional 230 kV single line (Underground Cable) from BANGKOK NOI to THONBURI (2011)

h) Lay additional 230 kV single line (Underground Cable) from BANG KAPI to KHRONG TOEY (2010).

i) Lay additional 230 kV single line (Underground Cable) from SOUTH THONBURI to SATU PRADIT (2010)

j) Lay additional 230 kV single line (Underground Cable) from <a> to SANAMPAO

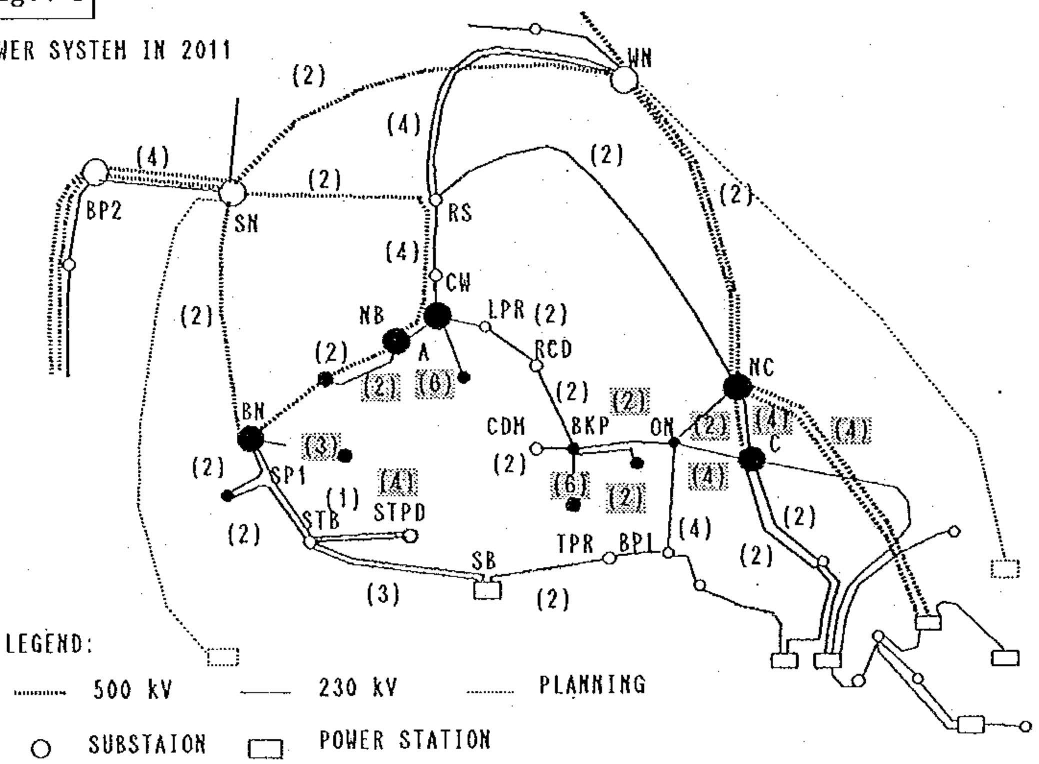
k) 230 kV double lines replaced by 230 kV 4 lines between BANG KAPI and tap point to PATANAKAN, 2 of which tap to PATANAKAN (2010).

l) Tap to KHLONG MAI of existing 230 kV double lines (<C> - BANG PAKONG, 2009)

m) New substation; <C> (2008).

Fig.4-5

POWER SYSTEM IN 2011



# CHAPTER 5 COST ESTIMATION AND CONSTRUCTION SCHEDULING

## 5.1 Cost Estimation

The construction cost is tabulated in the following page, expressed in the price level in 1993.

Much importance was placed on the use the existing right of way in planning transmision line routes on account of dificulties in acquiring new right of way in the Gtreater Bangkok Area and together with the expectation to minimize the construction cost.

Eventhough overhead line is preferable to underground cable from economical point of view, some sections which are not wide enough to reconstruct new lines required or deemed to obstruct aviation or others, are planned by underground cables as listed below.

- RANGSIT to CHAENG WATTHANA (EGAT)
- SOUTH THONBURI to THANONTOK (MEA)
- BANG KAPI to KHLONG TOEY (MEA)
- <A> S.S. to SANAMPAO (MEA)
- BANGKOK NOI to THONBURI (MEA)
- ON NUCH to <C> S.S. (EGAT)

The construction cost of transmission line much differs depending on the cost for tower footing for overhead line or that for tunnel excavation for underground cable owing to the nature of soil (poor or fair) of the route.

As it is considered that the poor soil covers most of the Greater Bangkok Area, the estimation in case of poor soil will give a rather realistic value for the construction cost of transmission line.

As for substation, pad or pile type foundation will be adopted depending on the nature of soil for bus support, steel structure or equipment such as transformer, circuit breaker, disconnecting switch and others, but it has less affect on the total construction cost of substations, of which the foundation cost occupies small part.

## 5.2 Construction Scheduling

In accordance with optimal power system plan of each planned year (1997, 2001, 2006 and 2011) described in Chapter 3, the construction schedule is planned as indicated in the attached bar charts.

In planning, in addition to the result of power system analysis (i.e., the time when the short circuit current or power flow exceeds the existing equipment ratings ), the following items are taken into consideration to determine the critical path for construction scheduling.

(1) To make a small roop of 500 kV system via SAI NOI, RANGSIT, NORTH BANGKOK and BANGKOK NOI by 2006 without reduce or cutting power supply to the central consumers area during

construction, the loop is to be reconstructed and completed in four time-related divisions, the first of which is the portion between Rangsit and Chaeng Watthana.

This first portion (between Rangsit and Chaeng Watthana) is estimated to be overloaded with the existing lines and to be reinforced (replaced by 500/230 kV 4 lines and operated at 230 kV tentatively) by 1997, and in addition, power transmission to central consumers area will be secured by this route during the construction period of the other part of the loop, in the case this portion is reconstructed prior to start reconstruction of the other part of the loop.

Followed by this, replacement of line between North Bangkok and Bangkok Noi (by 500 kV double lines), which portion has less capability of power transmission than the other part in the loop as it is a single line, and replacement of lines between Sai Noi and Bangkok Noi (by 500 kV double lines) are to be performed and completed by 2000.

Replacement of lines between North Bangkok and Chaeng Watthana by 500/230 kV 4 lines together with construction of 230 kV new substation <A> at junction point of lines among Rangsit, North Bangkok and Lat Phrao will be completed by 2002, and Sai Noi-Bangkok Noi line start operation at 500 kV by 2002.

The remaining part of the loop between Sai Noi and Rangsit site is to be completed by 2004 replacing the existing line by 500 kV double lines, and the small 500 kV loop start 500 kV operation by 2005.

(2) To increase the transmission capability to central consumers area through On Nuch, <C> substation is to be constructed by 2008 and number of lines will be tapped to <C> substation.

The construction of <C> substation will be followed by :

- Tap to <C> of existing 230 kV lines (Nong Chok-Bang Pakong, On Nuch-Bang Pakong -2008)

- 230 kV double overhead lines replaced by 230 kV 4 lines (underground cable crossing airport area and overhead line in the other area) between <C> and On Nuch (2008)

- New 230 kV 4 lines between <C> and Nong Chok (2009)

- New 500 kV double lines between <C> and Nong Chok (2011)

(3) The other lines are to be reinforced depending on the capability of power transmission corresponding the growth of power demand in each consumers area.

CONSTRUCTION COST DISBURSEMENT (TOTAL-PRICE LEVEL IN YEAR 1992) UNIT: mill.US$

| From | To | kV/ km/ cct/ cond. | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | TOTAL | EGAT | MEA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NONG CHOK | | | | | | 36.003 | | | | 9.231 | | | | | 9.046 | | | | | 16.815 | 71.095 | 71.095 | 0 |
| | - ON NUCH | 230/ 16.8/ 4/ 2 | | | | | 14.85 | | | | | | | | | | | | | | 14.85 | 14.85 | 0 |
| | - <C> | 230/ 19.0/ 4/ 2 | | | | | | | | | | | | | | | | 16.79 | | | 16.79 | 16.79 | 0 |
| | - <C> | 500/ 19.0/ 2/ 4 | | | | | | | | | | | | | | | | | 13.75 | | 13.75 | 13.75 | 0 |
| | - WANG NOI | 500/ 64.0/ 2/ 4 | | 59.24 | | | | | | | | | | | | | | | | | 59.24 | 59.24 | 0 |
| SAI NOI | | | | | | 53.755 | | | | 44.377 | | | | | 0.139 | | | | | 2.218 | 100.489 | 100.489 | 0 |
| | - BANGKOK NOI | 500/ 29.6/ 2/ 4 | | | | | | | 21.42 | | | | | | | | | | | | 21.42 | 21.42 | 0 |
| | - RANGSIT | 500/ 24.5/ 2/ 4 | | | | | | | | | | | 17.73 | | | | | | | | 17.73 | 17.73 | 0 |
| | - WANG NOI | 500/ 56.0/ 2/ 4 | | 51.84 | | | | | | | | | | | | | | | | | 51.84 | 51.84 | 0 |
| NORTH BANGKOK | | | | | | 2.218 | | | | 33.805 | | | | | 29.529 | | | | | 4.527 | 70.079 | 70.079 | 0 |
| | - BANGKOK NOI | | | | | | | | | | | | | | | | | | | | | | |
| | (NB-TAL) | 500/230 /9.2/ 2/ 2 | | | | | | | 17.3 | | | | | | | | | | | | 17.3 | 17.3 | 0 |
| | (TAL-BN) | 500/ 9.2/ 2/ 4 | | | | | | | 6.65 | | | | | | | | | | | | 6.65 | 6.65 | 0 |
| | - <A> | 500/230 /4.4/ 2/2 / 4/4 | | | | | | | | | 8.28 | | | | | | | | | | 8.28 | 8.28 | 0 |
| BANGKOK NOI | | | | | | 6.654 | | | | 71.424 | | | | | 34.102 | | | | | 6.882 | 119.062 | 119.062 | 0 |
| | (- SAI NOI) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- NORTH BANGKOK) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | - SANPHRAN 1 | 230/ 0.3/ 2/ 4 | | | | | | | | | | 0.15 | | | | | | | | | 0.15 | 0.15 | 0 |
| | | 230/ 11.7/ 4/ 4 | | | | | | | | | | 14.93 | | | | | | | | | 14.93 | 14.93 | 0 |
| | - SOUTH THONBURI | 230/ 8.1/ 1/ 4 | | | | | | | | | | | 4.1 | | | | | | | | 4.1 | 4.1 | 0 |
| | - THONBURI | 230/ 11.0/ 3/ CABLE | | | | | | | | | | | | 117.46 | | | | | | 28.29 | 145.75 | 0 | 145.75 |
| RANGSIT | | | | | | 6.654 | | | | 2.218 | | | | | 4.436 | | | | | | 13.308 | 13.308 | 0 |
| | - CHAENG WATTHANA | 500/230 / 5/ 2/2/ 4/4 | | | | 9.41 | | | | | | | | | | | | | | | 9.41 | 9.41 | 0 |
| | | 500/ 4.0/ 2/ 4 | | | | 2.9 | | | | | | | | | | | | | | | 2.9 | 2.9 | 0 |
| | | 230/ 4.0/ 2/ CABLE | | | | 69.1 | | | | | | | | | | | | | | | 69.1 | 69.1 | 0 |
| | - WANG NOI | 230/ 50.0/ 4/ 2 | | 50.2 | | | | | | | | 0 | | | | | | | | | 50.2 | 50.2 | 0 |
| | (- SAI NOI) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| SOUTH BANGKOK | | | | | | 15.645 | | | | | | | | | 2.218 | | | | | | 17.863 | 17.863 | 0 |
| SAMPHRAN 1 | | | | | | 2.218 | | | | | | | | | 7.949 | | | | | 0.109 | 10.276 | 10.276 | 0 |
| | (- BANGKOK NOI) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | - SOUTH THONBURI | 230/ 8.1/ 2/ 4 | | | | | | | | | | | 4.1 | | | | | | | | 4.1 | 4.1 | 0 |
| SOUTH THONBURI | | | | | | 4.653 | | | | | | | | | | | | | | | 4.653 | 4.653 | 0 |
| | - THANONTOK | 230/ 10.0/ 4/ CABLE | | | 136.22 | | | | | | | | | | | | | | 25.96 | | 162.18 | 0 | 162.18 |
| | (- SAMPHRAN 1) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- BANGKOK NOI) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| RATCHADAPISEK | | | | | | | | | | 4.436 | | | | | | | | | | 2.218 | 6.654 | 6.654 | 0 |
| | - LAT PHRAO | 230/ 0.5/ 2/ 2 | 0.15 | | | | | | | | | | | | | | | | | | 0.15 | 0.15 | 0 |
| | - BANG KAPI | 230/ 0.5/ 2/ 2 | 0.15 | | | | | | | | | | | | | | | | | | 0.15 | 0.15 | 0 |
| BANG KAPI | | | | | | 7.497 | | | | 7.484 | | | | | | | | | | 0.054 | 15.035 | 15.035 | 0 |
| | - KHLONG TOEY | 230/ 8.0/ 6/ CABLE | | | 110.08 | | | | 41.49 | | | | | | | | | | 20.75 | | 172.32 | 0 | 172.32 |
| | (- RATCHADAPISEK) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | - ON NUCH | 230/ 10.0/ 4/ 2 | | | | | | | | | | | | 8.83 | | | | | | | 8.83 | 8.83 | 0 |
| | - PATANAKAN | 230/ 5.0/ 2/ 2 | | | | | | | | | | | | | | | | | 2.35 | | 2.35 | 0 | 2.35 |
| ON NUCH | | | | | | 6.654 | | | | 0.109 | | | | | 2.218 | | | | | | 8.981 | 8.981 | 0 |
| | (- NONG CHOK) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- BANG KAPI) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | - BANG PHLI | 230/ 10.5/ 2/ 2 | | | | | | | | | | | | 3.68 | | | | | | | 3.68 | 3.68 | 0 |
| | - <C> | 230/ 10.0/ 4/ CABLE | | | | | | | | | | | | | | 164.58 | | | | | 164.58 | 164.58 | 0 |
| | - <C> | 230/ 12.0/ 4/ 2 | | | | | | | | | | | | | | 10.6 | | | | | 10.6 | 10.6 | 0 |
| | (- PATANAKAN) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| LAT PHRAO | | | | | | | | | | | | | | | 8.872 | | | | | | 8.872 | 8.872 | 0 |
| | (- RATCHADAPISEK) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | - <A> | 230/ 2.7/ 2/ 4 | | | | | | | | | 1.36 | | | | | | | | | | 1.36 | 1.36 | 0 |
| BANG PHLI | | | | | | 4.436 | | | | | | | | | | | | | | 2.521 | 6.957 | 6.957 | 0 |
| | - BANG BOR | 230/ 1.0/ 2/ 2 | | | | | | | 0.47 | | | | | | | | | | | | 0.47 | 0 | 0.47 |
| (BANG PAKONG) | -BANG BOR | 230/ 1.0/ 2/ 2 | | | | | | | 0.47 | | | | | | | | | | | | 0.47 | 0 | 0.47 |
| | (- ON NUCH) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| TEPARAK | | | | | | 26.343 | | | | | | | | | 2.218 | | | | | 2.218 | 30.779 | 30.779 | 0 |
| CHAENG WATTHANA | | | | | | 14.413 | | | | 2.218 | | | | | | | | | | 2.218 | 18.849 | 18.849 | 0 |
| | (- RANGSIT) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | - <A> | 500/230 / 7.1/ 2/2 / 4/2 | | | | | | | | | 13.36 | | | | | | | | | | 13.36 | 13.36 | 0 |
| WANG NOI | | | | | | 19.852 | | | | | | | | | 71.061 | | | | | | 90.913 | 90.913 | 0 |
| | (- NONG CHOK) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- SAI NOI) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- RANGSIT) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| <A> S.S. | | | | | | | | | | 18.607 | | | | | | | | | | | 18.607 | 18.607 | 0 |
| | - SAMAMPAO | 230/ 9.0/ 6/ CABLE | | | | | | | 174.18 | | | | | | | | | | 23.36 | | 197.54 | 0 | 197.54 |
| | (- NORTH BANGKOK) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- LAT PHRAO) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- CHAENG WATTHANA) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| <C> S.S. | | | | | | | | | | | | | | | | | | | | 72.738 | 72.738 | 72.738 | 0 |
| | - BANG PAKONG 2 | 230/ 2.0/ 2/ 2 | | | | | | | | | | | | | | | | 0.7 | | | 0.7 | 0.7 | 0 |
| | - BANG PAKONG 2 | 230/ 2.0/ 2/ 2 | | | | | | | | | | | | | | | | 0.7 | | | 0.7 | 0.7 | 0 |
| | (- NONG CHOK) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- NONG CHOK) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- ON NUCH) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | (- ON NUCH) | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 |
| | - KHLONG MAI | 230/ 2.0/ 2/ 2 | | | | | | | | | | | | | | | | 0.94 | | | 0.94 | 0 | 0.94 |
| TOTAL | | | 0.3 | 161.28 | 246.3 | 288.405 | 14.85 | 0 | 261.98 | 193.909 | 23 | 15.08 | 25.93 | 129.97 | 171.788 | 175.18 | 0 | 19.13 | 86.17 | 140.808 | 1954.08 | 1272.06 | 682.02 |
| EGAT PORTION | | | 0.3 | 161.28 | 0 | 288.405 | 14.85 | 0 | 45.37 | 193.909 | 23 | 15.08 | 25.93 | 12.51 | 171.788 | 175.18 | 0 | 18.19 | 13.75 | 112.518 | 1272.06 | | |
| MEA PORTION | | | 0 | 0 | 246.3 | 0 | 0 | 0 | 216.61 | 0 | 0 | 0 | 0 | 117.46 | 0 | 0 | 0 | 0.94 | 72.42 | 28.29 | 682.02 | | |

Table 5-1 CONSTRUCTION AND EXPANSION SCHDULE OF THE TRANSMISSION LINES IN THE GREATER BANGKOK AREA

| No | Transmission Lines: From | To | Length (km) | Construction length (km) | Scale in 1992: Voltage (kV) | No. of Circuits | Conductor n x MCM | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | Scale in 2011: Voltage (kV) | No. of Circuits | Conductor n x MCM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | WANG NOI | NONG CHOK | 64 | 64 | | | | | *** | ****** | | | | | | | | | | | | | | | | | 500 | 2 | 4 x 795 |
| 28 | SAI NOI | WANG NOI | 56 | 56 | | | | | *** | ****** | | | | | | | | | | | | | | | | | 500 | 2 | 4 x 795 |
| | BANG PHLI | BANG PAKONG | 44.1 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| 26 | BANG PHLI | D ( BANG BOR ) | 17.5 | 1.0 | | | | | | | | | | | *** | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| 26 | D ( BANG BOR) | BANG PAKONG | 27.5 | 1.0 | | | | | | | | | | | *** | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| 22 | ON NUCH | BANG PHLI | 10.5 | 10.5 | 230 | 2 | 1 x 1272 | | | | | | | | | | | | | ****** | | | | | | | 230 | 2 | 2 x 1272 |
| 15 | ON NUCH | BANG KAPI | 10 | 10 | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | ****** | | | | | | | 230 | 4 | 2 x 1272 |
| | ON NUCH | BANG KAPI | 10 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| 16 | B ( PATANAKARN ) | BANG KAPI | 5 | 5.0 | | | | | | | | | | | | | | | | | | | | | ****** | | 230 | 2 | 2 x 1272 |
| | LAT PHRAO | BANG KAPI | 10.4 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| | LAT PHRAO | RATCHADA PHISEK | 4.5 | 0.5 | | | | | **** | | | | | | | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| | RATCHADA PHISEK | BANG KAPI | 6.5 | 0.5 | | | | | **** | | | | | | | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| | SOUTH BANGKOK | BANG PHLI | 15.9 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| 27 | SOUTH BANGKOK | E (TEPARAK) | 11.5 | 2.0 | | | | | | | ****** | | | | | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| 27 | E (TEPARAK) | BANG PHLI | 5.5 | 2.0 | | | | | | | ****** | | | | | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| | NONG CHOK | BANG PAKONG 2 | 42.3 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| 23 | NONG CHOK | Site C | 19 | 19 | | | | | | | | | | | | | | | | | | | ****** | *** | | | 230 | 4 | 2 x 1272 |
| 24 | Site C | BANG PAKONG 2 | 24 | 2.0 | | | | | | | | | | | | | | | | | | | | *** | | | 230 | 2 | 2 x 1272 |
| | ON NUCH | BANG PAKONG 2 | 56 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| | ON NUCH | C | 22 | 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19,21 | | | Overhead 12 | Overhead 12 | | | | | | | | | | | | | | | | | *** | ****** | | | | | 230 | 4 | 2 x 1272 |
| 20 | | | Cable 10 | Cable 10 | | | | | | | | | | | | | | | | | *** | ****** | | | | ****** | 230 | 4 | cable |
| 25 | Site C | BANG PAKONG 2 | 36 | 2.0 | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | *** | | | 230 | 2 | 2 x 1272 |
| | NONG CHOK | KHLONG MAI | 34.3 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| 18 | NONG CHOK | C | 19 | 19 | | | | | | | | | | | | | | | | | | | | *** | ****** | | 500 | 2 | 4 x 1272 |
| | C | KHLONG MAI | 15.5 | 2.0 | | | | | | | | | | | | | | | | | | | | *** | | | 230 | 2 | 2 x 1272 |
| | KHLONG MAI | BANG PAKONG | 8 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| 2 | SAI NOI | BANGKOK NOI | 29.6 | 29.6 | 230 | 2 | 2 x 1272 | | | | | | | ********* | *** | | | | | | | | | | | | 500 | 2 | 4 x 1272 |
| | BANGKOK NOI | NORTH BANGKOK | 18.4 | | 230 | 1 | 1 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| 1 | BANGKOK NOI | Site F (TALINGCHAN) | 9.2 | 9.2 | | | | | | | | | | | *** | | | | | | | | | | | | 500 | 2 | 4 x 1272 |
| 4 | Site F (TALINGCHAN) | NORTH BANGKOK | 9.2 | 9.2 | | | | | | | | | | | *** | | | | | | | | | | | | 500 | 2 | 4 x 1272 |
| 4 | F (TALINGCHAN) | NORTH BANGKOK | 9.2 | 9.2 | | | | | | | | | | | | | | | | | | | | | *** | | 230 | 2 | 2 x 1272 |
| | SAI NOI | RANGSIT | 24.5 | | 230 | 2 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| 3 | SAI NOI | Site RANGSIT | 24.5 | 24.5 | | | | | | | | | | | | | | | ****** | | | | | | | | 500 | 2 | 4 x 1272 |
| | RANGSIT | NORTH BANGKOK | 19.4 | | 230 | 1 / 2 | 1 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| | RANGSIT | LAT PHRAO | 17.7 | | 230 | 1 / 2 | 1 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| | RANGSIT | CHAENG WATTANA | 10 | 1.0 | 230 | 2 | 1 x 1272 | | *** | | | | | | | | | | | | | | | | | | | | |
| 3 | Site RANGSIT | Site CHAENG WATTANA | 10 | 10 | | | | | | | | ****** | | | | | | | | | | | | | | | 500 | 2 | 4 x 1272 |
| 13 | RANGSIT | CHAENG WATTANA | 10 | 10 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | Overhead 5 | Overhead 5 | | | | | | | | ****** | | | | | | | | | | | | | | | 230 | 2 | 4 x 1272 |
| | | | Cable 5 | Cable 5 | | | | | | | | ****** | | | | | | | | | | | | | | | 230 | 2 | cable |
| | CHAENG WATTANA | NORTH BANGKOK | 11.4 | 1.0 | 230 | 1 / 2 | 1 x 1272 | | *** | | | | | | | | | | | | | | | | | | | | |
| | CHAENG WATTANA | LAT PHRAO | 9.7 | 1.0 | 230 | 1 / 2 | 1 x 1272 | | *** | | | | | | | | | | | | | | | | | | | | |
| | NORTH BANGKOK | LAT PHRAO | 7 | | 230 | 1 / 2 | 1 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| 5 | Site CHAENG WATTANA | Site A | 7.1 | 7.1 | | | | | | | | | | | | ****** | *** | | | | | | | | | | 500 | 2 | 4 x 1272 |
| 5 | CHAENG WATTANA | A | 7.1 | 7.1 | | | | | | | | | | | | ****** | *** | | | | | | | | | | 230 | 2 | 2 x 1272 |
| 6 | Site A | NORTH BANGKOK | 4.4 | 4.4 | | | | | | | | | | | | ****** | *** | | | | | | | | | | 500 | 2 | 4 x 1272 |
| 6 | A | NORTH BANGKOK | 4.4 | 4.4 | | | | | | | | | | | | ****** | *** | | | | | | | | | | 230 | 2 | 4 x 1272 |
| 7 | A | LAT PHRAO | 2.7 | 2.7 | | | | | | | | | | | | ****** | *** | | | | | | | | | | 230 | 2 | 4 x 1272 |
| 14 | NONG CHOK | ON - NUCH | 16.8 | 16.8 | 230 | 2 | 2 x 1272 | | | | | | ****** | | | | | | | | | | | | | | 230 | 4 | 2 x 1272 |
| 17 | BAN PONG2 | SAI NOI | 53.6 | 53.6 | 230 | 2 | 1 x 1272 | | | | | | | *** | ****** | | | | | | | | | | | | 500 | 2 | 4 x 1272 |
| 12 | WANG NOI | RANGSIT | 50 | 50 | | | | | ***** | ****** | | | | | | | | | | | | | | | | | 230 | 2 | 2 x 1272 |
| 12 | WANG NOI | RANGSIT(orRANGSIT 2) | 50 | 50 | | | | | | | | | | | | | *** | ****** | | | | | | | | | 230 | 2 | 2 x 1272 |
| | RANGSIT | RANGSIT 2 | 4.0 | 4.0 | | | | | | | | | | | | | | *** | | | | | | | | | 230 | 2 | 2 x 1272 |
| | BANGKOK NOI | SAM PHRAN 1 | 12 | | 230 | 1 | 2 x 1272 | | | | | | | | | | | | | | | | | | | | | | |
| 8 | BANGKOK NOI | Junction near BANGKOK NOI | 0.3 | 0.3 | 230 | 1 | 2 x 1272 | | | | | | | | | | *** | ****** | | | | | | | | | 230 | 2 | 4 x 1272 |
| 9 | Junction near BANGKOK NOI | SAM PHRAN 1 | 11.7 | 11.7 | 230 | 2 | 2 x 1272 | | | | | | | | | | *** | ****** | | | | | | | | | 230 | 4 | 4 x 1272 |
| 10 | Junction near BANGKOK NOI | SOUTH THONBURI | 8.1 | 8.1 | 230 | 1 | 2 x 1272 | | | | | | | | | | | | ****** | | | | | | | | 230 | 2 | 4 x 1272 |
| 11 | BANGKOK NOI | SOUTH THONBURI | 8.1 | 8.1 | 230 | 2 | 2 x 1272 | | | | | | | | | | | | ****** | | | | | | | | 230 | 1 | 4 x 1272 |
| 30 | A | G (SANAMPAO) | 9 | 9 | | | | | | | | | | *** 5ccts *** | | | | | | | | | | ** 1cct ** | | | 230 | 6 | Cable |
| 32 | SOUTH TONBURI | I (THANONTOK) | 10 | 10 | | | | | | *** 3ccts *** | | | | | | | | | | | | | | ** 1cct ** | | | 230 | 4 | Cable |
| 33 | BANGKOK NOI | J (THONBURI) | 11 | 11 | | | | | | | | | | | | | | | *** 2ccts *** | | | | | | ** 1cct ** | | 230 | 3 | Cable |
| 31 | BANG KAPI | H (KLONG TOEY) | 8 | 8 | | | | | | *** 3ccts *** | | | | *** 2ccts *** | | | | | | | | | | ** 1cct ** | | | 230 | 6 | Cable |

Note : (1) **** shows a period of construction work. (2) [shaded] shows recomended reinforcement, though outside the Greater Bangkok Area.

# CHAPTER 6 ENVIRONMENTAL IMPACT STUDY

## 6.1 General

The ultimate plan for horizon year transmission system covers introduction of 500 kV system into Bangkok Noi and North Bangkok substations, with replacement of existing 230 kV loop lines, Sai Noi - Bangkok Noi - North Bangkok - Rangsit - Sai Noi with 500 kV transmission lines. Since it is extremely difficult or rather impossible to obtain a new line-route, therefore existing 230 kV right of way of 40 m. will be rather restricted for the 500 kV line construction.

The objective of the study includes environmental problem, protective measure and compensation cost to build 500 kV transmission line on the existing 230 kV line right of way around the Bangkok Metropolitan Area.

## 6.2 Recent EGAT Experience with Re-built 230 kV Multiple Circuit on Single Right of Way

### 6.2.1 Transmission Lines

The principal problem and its solution are briefly summarized as follows:

(1) Design Stage

a) Due consideration has to be made prior to the bids as the condition that either the construction can be carried out with the existing line shut-off during off- peak period (e.g. during 8-16 hours daily) only, or that line section can be taken out of service for 2-3 months for the purpose of erection of tower and/or stringing of conductor.

b) Locate the new tower on the spot closed to former site so that middle span reinforced tower can be set up in the middle of the span.

c) Problem of conflict with new infrastructure, e.g. the crossing of new expressway, or the new elevated railroad etc. can be easily solved during the design stage.

(2) Construction Stage

a) During construction period, two options are available, i.e. the temporary detour line or the planned permanent additional line - to be built on the edge of the Right of Way, for instance.

b) Transportation of major equipment or supplies - e.g. long concrete piles - can pose as one of major problem to deal with very narrow Right of Way.

### 6.2.2 Substation

(1) In general, the existing substation occupy rather small area. It is therefore necessary to modify the substation layout, either by replacing the equipment with higher capacity rating, or

(2) Re-build the substation with Gas Insulated Switchgear (GIS) equipment, which occupy small space than the conventional type.

Attention is drawn here concerning the construction of the new 500 kV lines and substations as part of the Bulk Power Supply in the Greater Bangkok Area will pose similar and/or rather more difficult problems to the above-mentioned project.

## 6.3 Environmental Problem : Superimpose 500 kV Line on Existing 230 kV Line Right of Way

Mae-Moh-Tha Tako-Nong chok 500 kV line was built in most of the rural area, i.e. running through the forest, rice field etc. In another word, it occupies the area of rural environment. The proposed lines of the Bulk Power Supply Project, Sai Noi-Bangkok Noi-North Bangkok-Rangsit-Sai Noi loop line would be built on the existing 230 kV Right of Way, which lie within the sub-urban as well as the urban one. This loop line will go through very-densely populated community, commercial center and all kinds of social infrastructure. In another words, it will occupy the area in sub-urban and urban environment.

## 6.4 Static Induction under Extra-High Voltage Overhead Transmission Line

The study of the static induction under transmission lines has been started as a part of the research program for clarification of technical problems introduction by the 500 kV transmission lines.

When a man carrying an umbrella passes beneath a 500 kV transmission line, a part of his body, such as his cheek may touch the metallic part of the umbrella stem to sense the static induction, or a man touching metallic part of a car, building, fence, etc. may sense the static induction. Concerning these circumstances, the following subjects were studied.

* Effect on human body and the strength of the sensing.

* The relation between the strength of electric field under the transmission line and the strength of the sensing.

* Measurement method and prediction method of electric field strength.

* Target of reduction and measures for reduction.

# CHAPTER 7 ECONOMIC AND FINANCIAL ANALYSES

## 7.1 Economic Analysis

### 7.1.1 Outline

In the economic evaluation of this bulk power supply project, the economic internal rate of return (EIRR) by which the total benefit [B] and the total cost [C] become equal has been calculated, and at the same time the surplus benefit (B-C) and the benefit to cost ratio (B/C) have also been calculated as the bases of overall judgment.

The following benefits and costs are considered:

Benefit: 1) The incremental electric energy which is made available to the customers by this Project.

2) The reduction in the electric energy lost by power supply failures which is expected to be brought about by this Project.

3) The reduction of operating/maintenance costs which is expected to be brought about by this Project.

Cost : 1) Total project investment

2) Operation and maintenance costs of completed facilities.

### 7.1.2 Basic Assumptions/Conditions

The calculations in the economic evaluation were performed based on the following assumptions and conditions.

(1) The Electricity Tariff Rate

The average selling price of EGAT based on the current tariff structure was used in the study. This average selling price is the tariff rate at transmission level and based on the investment and expense of EGAT on generation and transmission system. The transmission costs have been considered to include only EGAT investment and expenses. (Transmission or sub-transmission costs by MEA and PEA are assumed to be part of distribution.)

(2) Total Project Investment

It has been agreed in principle that any transmission or sub-transmission line that should be constructed along the public right-of-way will be implemented by MEA or PEA. Therefore, some part of the works recommended in the project will be implemented by MEA. Corresponding to the current tariff structure which based on the investment of each power utility, the investment costs on the MEA's portions were taken out and not included in the study.

The total project investment (only EGAT's investment) was calculated as the construction cost of the Project excluding the interests during construction, import duties, VAT (Value Added Tax) and escalation. The total construction cost has been added up on the 1992 price base.

(3) Foreign Currency Exchange Rate

It was assumed that 1 US$ = 25 Bahts

(4) Operation and Maintenance Cost

In line with the economic analysis standard of EGAT, the annual operation and maintenance cost was assumed to be 1.0% of the construction cost (without import duty and VAT) for transmission and distribution lines and 2.0% of the same for substation equipment respectively.

(5) Period of Calculation

The amortization period of the related facilities is set forth by the economic analysis standard of EGAT as follows:

| | | |
|---|---|---|
| Transmission and Distribution lines | : | 40 years |
| Substation equipment | : | 25 years |

The amortization period for this Project was calculated by averaging the above figures using weighing factors for transmission and substation facilities which are proportional to the relative weight of each sector in the total investment. The calculated amortization period was 32 years.

Considering that the facilities to be constructed under this Project will be completed one by one from 1994 to 2011, the period of calculation for the economic evaluation was set from the middle point of the construction period (from 1994 to 2011), that is, 2002, until 32 years later, that is 2034.

(6) Discount Rate

The discount rate was selected at 10% per annum based on the discussion with EGAT.

(7) Generation Cost

In line with the economic analysis standard of EGAT and taking transmission loss into account, the energy cost was assumed to be 0.6998 Baht/kWh and the capacity cost was assumed to be 4,409.16 Baht/kW (per annum).

### 7.1.3 Result of Economic Evaluation

The flow of benefit and cost of this Project is shown in Table 7-3 and calculation of EIRR is shown in Table 7-4.

The Economic Internal Rate of Return (EIRR), the excess Benefit (B-C) and the Benefit to Cost ratio (B/C) as obtained by these benefit and cost are as below.

EIRR: 17.54% (Table 7-4)
B-C : 668,715 Thousand US$ (Table 7-3, discount rate 10% p.a.)
B/C : 2.18 (Table 7-3, discount rate 10% p.a.)

In judging the economic soundness of this Project, the JICA Study Team rates that all of EIRR, B-C and B/C values are good, and this Project is economically feasible.

## 7.2 Financial Analysis

### 7.2.1 Outline

The following values shall be calculated based on the value of incremental electric energy (sales revenue) and the total cost of this Project in terms of domestic price in the Kingdom of Thailand.

<1> Financial internal rate of return (FIRR)

<2> Development of disbursement schedule table

<3> Production of profit and loss statement

<4> Cash flow

<5> Calculation of Debt Service Ratio

### 7.2.2 Analytical Methodology

(1) Calculation of Financial Internal Rate of Return (FIRR)

The financial internal rate of return, by which the yearly sums of costs and revenues are equal (the financial internal rate of return), has been calculated, and this value has been compared with the opportunity cost of capital. The cost applicable to this evaluation will include the total investment (construction cost with import duty) without consideration of the financing conditions, such as interest, interest during construction, repayment of principal, repayment period, etc., and the operation and maintenance cost.

In this evaluation, the profitability of the investment for the project will be judged regardless of financial conditions.

(2) Calculation of Debt Service Ratio

Debt Service Ratio is the ratio of the corporate internal financing, which is business profit plus depreciation, to the reimbursement plus interest of borrowed money.

To calculated this value, the following three works were required.

1) Development of reimbursement plan

2) Development of profit and loss statement

3) Cash flow analysis

The costs that are applicable to this evaluation consist of the operation and maintenance cost and depreciation cost. The depreciation cost will be calculated based on the total construction cost including import duties, interest during construction and escalation.

### 7.2.3 Basic Conditions

This financial analysis has been conducted by the following basic conditions.

(1) Financial Internal Rate of Return (FIRR)

1) Electricity Sales Revenue

The benefit value of this Project calculated in the Economic Evaluation (7.1) is used.

2) Construction Cost

Same as in Economic Evaluation, only EGAT's portion of the construction cost was considered and the construction cost including import duties, which was excluded in the Economic Evaluation, is used.

However, VAT, interest and interest during construction are excluded.

VAT is excluded since VAT will be refunded to EGAT as a governmental body.

3) Operation & Maintenance Cost

The cost calculated in 7.1 (Economic Evaluation) is used.

4) Escalation

Not considered.

(2) Debt Service Ratio

1) Electricity Sales Revenue

Same as in the calculation of FIRR, but escalation is considered.

2) Construction Cost

The construction cost including import duties, interest during construction and escalation.

3) Operation & Maintenance Cost

Same as FIRR, but escalation is considered.

4) Escalation

Escalation of 5% per annum is considered.

5) Capital Procurement Condition

(a) Foreign Currency

An interest rate of 8% per annum. The principal and interest to be uniformly reimbursed for 20 years.

Amount borrowed from year 1994 to 1997 will be reimbursed from year 1998.

In the same manner, amount borrowed, from 1998 to 2001, amount borrowed from 2002 to 2006 and amount borrowed from 2007 to 2011 will be reimbursed from 2002, 2007 and 2012 respectively.

(b) Local Currency

An interest rate of 10% per annum on 50% of the construction cost to be provided by local currency.

The principal and interest to be uniformly reimbursed for 10 years in the same manner as Foreign Currency amount.

6) Depreciation

As mentioned in Economic Evaluation, the economic life of facilities is assumed to be 32 years. The depreciation has been calculated on the straight line method with no residual value.

### 7.2.4 Financial Internal Rate of Return (FIRR)

(1) Construction Cost

The construction cost for calculation of FIRR is shown in Table 7-5.

(2) FIRR

The flows of expenditures and revenues of this Project based on the construction cost above-mentioned and other assumptions is as presented in Table 7-6, and the FIRR is estimated 17.10%.

Based on this estimation, it can be concluded that this project is financially sound.

### 7.2.5 Debt Service Ratio

(1) Reimbursement Plan

The reimbursement plan based on the conditions of capital procurement shown in Paragraph 7.2.3 (2) is presented in Table 7-9 to 7-13.

It has been assumed that the interest during construction and escalation are included in the construction cost (Shown in Table 7-7 and 7-8) which is the basis of calculation of the borrowed money, and these accounts are recovered as a part of depreciation.

(2) Profit and Loss Statement and Cash Flow

The profit and loss statement and the cash flow are presented in Table 7-14 and 7-15 respectively.

(3) Debt Service Ratio

The calculated debt service ratio is presented in Table 7-16.

The debt service ratio up to year 2020 is 6.85, which shows this Project is sound also in the aspect of profitability.

Table 7-1 Construction Cost for Economic Analysis

(1,000 US$)

| Year | Total Construction Cost for Transmission Line | Value Added Tax | Import Duty | Construction Cost (Transmission Line) for Analysis | Total Construction Cost for Substation Equipment | Value Added Tax | Import Duty | Construction Cost (Substation) for Analysis | Total Construction Cost for Analysis |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D=A-(B+C) | E | F | G | H=E-(F+G) | D+H |
| 1994 | 300 | 16 | 10 | 274 | | | | | 274 |
| 1995 | 161,280 | 6,692 | 3,950 | 150,638 | | | | | 150,638 |
| 1996 | | | | | | | | | 0 |
| 1997 | 81,410 | 650 | 298 | 80,462 | 206,995 | 11,358 | 14,337 | 181,300 | 261,762 |
| 1998 | 14,850 | 764 | 322 | 13,764 | | | | | 13,764 |
| 1999 | | | | | | | | | 0 |
| 2000 | 45,370 | 2,347 | 1,318 | 41,705 | | | | | 41,705 |
| 2001 | | | | | 193,909 | 10,660 | 12,506 | 170,743 | 170,743 |
| 2002 | 23,000 | 1,215 | 490 | 21,295 | | | | | 21,295 |
| 2003 | 15,080 | 791 | 445 | 13,844 | | | | | 13,844 |
| 2004 | 25,930 | 1,307 | 927 | 23,696 | | | | | 23,696 |
| 2005 | 12,510 | 4,718 | 298 | 7,494 | | | | | 7,494 |
| 2006 | | | | | 171,788 | 9,435 | 9,748 | 152,605 | 152,605 |
| 2007 | 175,180 | 555 | 250 | 174,375 | | | | | 174,375 |
| 2008 | | | | | | | | | 0 |
| 2009 | 18,190 | 8,701 | 405 | 9,084 | | | | | 9,084 |
| 2010 | 13,750 | 700 | 474 | 12,576 | | | | | 12,576 |
| 2011 | | | | | 112,518 | 6,184 | 7,314 | 99,020 | 99,020 |
| 2012 - 2034 | | | | 0 | | | | 0 | 0 |
| Total | 586,850 | 28,456 | 9,187 | 549,207 | 685,210 | 37,637 | 43,905 | 603,668 | 1,152,875 |

Table 7-2 Operation and Maintenance Cost

(1,000 US$)

| Year | Construction Cost (Transmission Line) without VAT and Import Duty | Operation and Maintenance Cost for Transmission Line | Construction Cost (Substation) without VAT and Import Duty | Operation and Maintenance Cost for Substation Equipment | Total Operation and Maintenance Cost |
|---|---|---|---|---|---|
| 1994 | 274 | | 0 | | |
| 1995 | 150,638 | | 0 | | |
| 1996 | 0 | | 0 | | |
| 1997 | 80,462 | | 181,300 | | |
| 1998 | 13,764 | 2,314 | 0 | 3,626 | 5,940 |
| 1999 | 0 | 2,314 | 0 | 3,626 | 5,940 |
| 2000 | 41,705 | 2,314 | 0 | 3,626 | 5,940 |
| 2001 | 0 | 2,314 | 170,743 | 3,626 | 5,940 |
| 2002 | 21,295 | 2,868 | 0 | 7,041 | 9,909 |
| 2003 | 13,844 | 2,868 | 0 | 7,041 | 9,909 |
| 2004 | 23,696 | 2,868 | 0 | 7,041 | 9,909 |
| 2005 | 7,494 | 2,868 | 0 | 7,041 | 9,909 |
| 2006 | 0 | 2,868 | 152,605 | 7,041 | 9,909 |
| 2007 | 174,375 | 3,532 | 0 | 10,093 | 13,625 |
| 2008 | 0 | 3,532 | 0 | 10,093 | 13,625 |
| 2009 | 9,084 | 3,532 | 0 | 10,093 | 13,625 |
| 2010 | 12,576 | 3,532 | 0 | 10,093 | 13,625 |
| 2011 | 0 | 3,532 | 99,020 | 10,093 | 13,625 |
| 2012 – 2034 | | 5,492 | | 12,073 | 17,565 |
| Total | 549,207 | 167,573 | 603,668 | 377,860 | 545,434 |

Table 7-3 Benefit Flow and Cost Flow of the Project

(1,000 US$)

| Discount Rate | | Year | Cost | | | | Benefit | | NPV |
|---|---|---|---|---|---|---|---|---|---|
| | | | Costruction | O&M | Total | PV | Total | PV | |
| 10.00 | 1 | 1994 | 274 | | 274 | 226 | | | -226 |
| % pa | 2 | 1995 | 150,638 | | 150,638 | 113,177 | | | -113,177 |
| | 3 | 1996 | 0 | | 0 | 0 | | | 0 |
| | 4 | 1997 | 261,762 | | 261,762 | 162,534 | | | -162,534 |
| | 5 | 1998 | 13,764 | 5,940 | 19,704 | 11,122 | 982 | 554 | -10,568 |
| | 6 | 1999 | 0 | 5,940 | 5,940 | 3,048 | 12,564 | 6,447 | 3,399 |
| | 7 | 2000 | 41,705 | 5,940 | 47,645 | 22,227 | 17,553 | 8,189 | -14,038 |
| | 8 | 2001 | 170,743 | 5,940 | 176,683 | 74,931 | 50,317 | 21,339 | -53,592 |
| | 9 | 2002 | 21,295 | 9,909 | 31,204 | 12,030 | 72,051 | 27,779 | 15,748 |
| | 10 | 2003 | 13,844 | 9,909 | 23,753 | 8,325 | 98,470 | 34,513 | 26,188 |
| | 11 | 2004 | 23,696 | 9,909 | 33,605 | 10,708 | 129,166 | 41,156 | 30,449 |
| | 12 | 2005 | 7,494 | 9,909 | 17,403 | 5,041 | 164,153 | 47,549 | 42,508 |
| | 13 | 2006 | 152,605 | 9,909 | 162,514 | 42,795 | 204,188 | 53,769 | 10,974 |
| | 14 | 2007 | 174,375 | 13,625 | 188,000 | 45,006 | 248,047 | 59,380 | 14,375 |
| | 15 | 2008 | 0 | 13,625 | 13,625 | 2,965 | 294,906 | 64,180 | 61,215 |
| | 16 | 2009 | 9,084 | 13,625 | 22,709 | 4,493 | 344,805 | 68,218 | 63,725 |
| | 17 | 2010 | 12,576 | 13,625 | 26,201 | 4,712 | 397,573 | 71,507 | 66,795 |
| | 18 | 2011 | 99,020 | 13,625 | 112,645 | 18,418 | 452,606 | 74,005 | 55,586 |
| | 19 | 2012 | | 17,565 | 17,565 | 2,611 | 452,606 | 67,277 | 64,666 |
| | 20 | 2013 | | 17,565 | 17,565 | 2,374 | 452,606 | 61,161 | 58,787 |
| | 21 | 2014 | | 17,565 | 17,565 | 2,158 | 452,606 | 55,601 | 53,443 |
| | 22 | 2015 | | 17,565 | 17,565 | 1,962 | 452,606 | 50,546 | 48,585 |
| | 23 | 2016 | | 17,565 | 17,565 | 1,783 | 452,606 | 45,951 | 44,168 |
| | 24 | 2017 | | 17,565 | 17,565 | 1,621 | 452,606 | 41,774 | 40,153 |
| | 25 | 2018 | | 17,565 | 17,565 | 1,474 | 452,606 | 37,976 | 36,502 |
| | 26 | 2019 | | 17,565 | 17,565 | 1,340 | 452,606 | 34,524 | 33,184 |
| | 27 | 2020 | | 17,565 | 17,565 | 1,218 | 452,606 | 31,385 | 30,167 |
| | 28 | 2021 | | 17,565 | 17,565 | 1,107 | 452,606 | 28,532 | 27,425 |
| | 29 | 2022 | | 17,565 | 17,565 | 1,007 | 452,606 | 25,938 | 24,932 |
| | 30 | 2023 | | 17,565 | 17,565 | 915 | 452,606 | 23,580 | 22,665 |
| | 31 | 2024 | | 17,565 | 17,565 | 832 | 452,606 | 21,437 | 20,605 |
| | 32 | 2025 | | 17,565 | 17,565 | 756 | 452,606 | 19,488 | 18,731 |
| | 33 | 2026 | | 17,565 | 17,565 | 688 | 452,606 | 17,716 | 17,029 |
| | 34 | 2027 | | 17,565 | 17,565 | 625 | 452,606 | 16,106 | 15,481 |
| | 35 | 2028 | | 17,565 | 17,565 | 568 | 452,606 | 14,641 | 14,073 |
| | 36 | 2029 | | 17,565 | 17,565 | 517 | 452,606 | 13,310 | 12,794 |
| | 37 | 2030 | | 17,565 | 17,565 | 470 | 452,606 | 12,100 | 11,631 |
| | 38 | 2031 | | 17,565 | 17,565 | 427 | 452,606 | 11,000 | 10,573 |
| | 39 | 2032 | | 17,565 | 17,565 | 388 | 452,606 | 10,000 | 9,612 |
| | 40 | 2033 | | 17,565 | 17,565 | 353 | 452,606 | 9,091 | 8,738 |
| | 41 | 2034 | | 17,565 | 17,565 | 321 | 452,606 | 8,265 | 7,944 |
| | Total | | 1,152,875 | 545,425 | 1,698,300 | 567,272 | 12,897,319 | 1,235,986 | 668,715 |

B-C 668,715

B/C 2.1788264

Table 7-4 Calculation of EIRR

(1,000 US$)

| Discount Rate | | Year | Cost | | | | Benefit | | NPV |
|---|---|---|---|---|---|---|---|---|---|
| | | | Costruction | O&M | Total | PV | Total | PV | |
| 17.53573 | 1 | 1994 | 274 | | 274 | 198 | | | -198 |
| % pa | 2 | 1995 | 150,638 | | 150,638 | 92,774 | | | -92,774 |
| | 3 | 1996 | 0 | | 0 | 0 | | | 0 |
| | 4 | 1997 | 261,762 | | 261,762 | 116,696 | | | -116,696 |
| | 5 | 1998 | 13,764 | 5,940 | 19,704 | 7,474 | 982 | 372 | -7,101 |
| | 6 | 1999 | 0 | 5,940 | 5,940 | 1,917 | 12,564 | 4,055 | 2,138 |
| | 7 | 2000 | 41,705 | 5,940 | 47,645 | 13,082 | 17,553 | 4,819 | -8,262 |
| | 8 | 2001 | 170,743 | 5,940 | 176,683 | 41,273 | 50,317 | 11,754 | -29,519 |
| | 9 | 2002 | 21,295 | 9,909 | 31,204 | 6,202 | 72,051 | 14,320 | 8,118 |
| | 10 | 2003 | 13,844 | 9,909 | 23,753 | 4,017 | 98,470 | 16,651 | 12,634 |
| | 11 | 2004 | 23,696 | 9,909 | 33,605 | 4,835 | 129,166 | 18,583 | 13,748 |
| | 12 | 2005 | 7,494 | 9,909 | 17,403 | 2,130 | 164,153 | 20,093 | 17,963 |
| | 13 | 2006 | 152,605 | 9,909 | 162,514 | 16,924 | 204,188 | 21,264 | 4,340 |
| | 14 | 2007 | 174,375 | 13,625 | 188,000 | 16,657 | 248,047 | 21,978 | 5,320 |
| | 15 | 2008 | 0 | 13,625 | 13,625 | 1,027 | 294,906 | 22,231 | 21,204 |
| | 16 | 2009 | 9,084 | 13,625 | 22,709 | 1,456 | 344,805 | 22,115 | 20,658 |
| | 17 | 2010 | 12,576 | 13,625 | 26,201 | 1,430 | 397,573 | 21,695 | 20,265 |
| | 18 | 2011 | 99,020 | 13,625 | 112,645 | 5,230 | 452,606 | 21,013 | 15,783 |
| | 19 | 2012 | | 17,565 | 17,565 | 694 | 452,606 | 17,878 | 17,184 |
| | 20 | 2013 | | 17,565 | 17,565 | 590 | 452,606 | 15,211 | 14,620 |
| | 21 | 2014 | | 17,565 | 17,565 | 502 | 452,606 | 12,941 | 12,439 |
| | 22 | 2015 | | 17,565 | 17,565 | 427 | 452,606 | 11,011 | 10,583 |
| | 23 | 2016 | | 17,565 | 17,565 | 364 | 452,606 | 9,368 | 9,004 |
| | 24 | 2017 | | 17,565 | 17,565 | 309 | 452,606 | 7,970 | 7,661 |
| | 25 | 2018 | | 17,565 | 17,565 | 263 | 452,606 | 6,781 | 6,518 |
| | 26 | 2019 | | 17,565 | 17,565 | 224 | 452,606 | 5,769 | 5,546 |
| | 27 | 2020 | | 17,565 | 17,565 | 190 | 452,606 | 4,909 | 4,718 |
| | 28 | 2021 | | 17,565 | 17,565 | 162 | 452,606 | 4,176 | 4,014 |
| | 29 | 2022 | | 17,565 | 17,565 | 138 | 452,606 | 3,553 | 3,415 |
| | 30 | 2023 | | 17,565 | 17,565 | 117 | 452,606 | 3,023 | 2,906 |
| | 31 | 2024 | | 17,565 | 17,565 | 100 | 452,606 | 2,572 | 2,472 |
| | 32 | 2025 | | 17,565 | 17,565 | 85 | 452,606 | 2,188 | 2,103 |
| | 33 | 2026 | | 17,565 | 17,565 | 72 | 452,606 | 1,862 | 1,790 |
| | 34 | 2027 | | 17,565 | 17,565 | 61 | 452,606 | 1,584 | 1,523 |
| | 35 | 2028 | | 17,565 | 17,565 | 52 | 452,606 | 1,348 | 1,295 |
| | 36 | 2029 | | 17,565 | 17,565 | 45 | 452,606 | 1,147 | 1,102 |
| | 37 | 2030 | | 17,565 | 17,565 | 38 | 452,606 | 976 | 938 |
| | 38 | 2031 | | 17,565 | 17,565 | 32 | 452,606 | 830 | 798 |
| | 39 | 2032 | | 17,565 | 17,565 | 27 | 452,606 | 706 | 679 |
| | 40 | 2033 | | 17,565 | 17,565 | 23 | 452,606 | 601 | 578 |
| | 41 | 2034 | | 17,565 | 17,565 | 20 | 452,606 | 511 | 491 |
| | Total | | 1,152,875 | 545,425 | 1,698,300 | 337,859 | 12,897,319 | 337,859 | 0 |

B-C 0
B/C 1.0000000

Table 7-5 Construction Cost for Financial Analysis

(1,000 US$)

| Year | Total Construction Cost for Transmission Line | Value Added Tax | Construction Cost (Transmission Line) for Analysis | Total Construction Cost for Substation Equipment | Value Added Tax | Construction Cost (Substation) for Analysis | Total Construction Cost for Analysis |
|---|---|---|---|---|---|---|---|
| | A | B | C=A-B | D | E | F=D-E | C+F |
| 1994 | 300 | 16 | 284 | | | | 284 |
| 1995 | 161,280 | 6,692 | 154,588 | | | | 154,588 |
| 1996 | | | | | | | 0 |
| 1997 | 81,410 | 650 | 80,760 | 206,995 | 11,358 | 195,637 | 276,397 |
| 1998 | 14,850 | 764 | 14,086 | | | | 14,086 |
| 1999 | | | | | | | 0 |
| 2000 | 45,370 | 2,347 | 43,023 | | | | 43,023 |
| 2001 | | | | 193,909 | 10,660 | 183,249 | 183,249 |
| 2002 | 23,000 | 1,215 | 21,785 | | | | 21,785 |
| 2003 | 15,080 | 791 | 14,289 | | | | 14,289 |
| 2004 | 25,930 | 1,307 | 24,623 | | | | 24,623 |
| 2005 | 12,510 | 4,718 | 7,792 | | | | 7,792 |
| 2006 | | | | 171,788 | 9,435 | 162,353 | 162,353 |
| 2007 | 175,180 | 555 | 174,625 | | | | 174,625 |
| 2008 | | | | | | | 0 |
| 2009 | 18,190 | 8,701 | 9,489 | | | | 9,489 |
| 2010 | 13,750 | 700 | 13,050 | | | | 13,050 |
| 2011 | | | | 112,518 | 6,184 | 106,334 | 106,334 |
| 2012 - 2034 | | | 0 | | | 0 | 0 |
| Total | 586,850 | 28,456 | 558,394 | 685,210 | 37,637 | 647,573 | 1,205,967 |

Table 7-6　Calculation of FIRR

(1,000 US$)

| Discount Rate | | Year | Cost | | | | Revenue | | NPV |
|---|---|---|---|---|---|---|---|---|---|
| | | | Costruction | O&M | Total | PV | Total | PV | |
| 17.10040 | 1 | 1994 | 284 | | 284 | 207 | | | -207 |
| % pa | 2 | 1995 | 154,588 | | 154,588 | 96,272 | | | -96,272 |
| | 3 | 1996 | 0 | | 0 | 0 | | | 0 |
| | 4 | 1997 | 276,397 | | 276,397 | 125,528 | | | -125,528 |
| | 5 | 1998 | 14,086 | 5,940 | 20,026 | 7,767 | 982 | 381 | -7,386 |
| | 6 | 1999 | 0 | 5,940 | 5,940 | 1,967 | 12,564 | 4,161 | 2,194 |
| | 7 | 2000 | 43,023 | 5,940 | 48,963 | 13,848 | 17,553 | 4,965 | -8,884 |
| | 8 | 2001 | 183,249 | 5,940 | 189,189 | 45,695 | 50,317 | 12,153 | -33,542 |
| | 9 | 2002 | 21,785 | 9,909 | 31,694 | 6,537 | 72,051 | 14,861 | 8,324 |
| | 10 | 2003 | 14,289 | 9,909 | 24,198 | 4,262 | 98,470 | 17,345 | 13,082 |
| | 11 | 2004 | 24,623 | 9,909 | 34,532 | 5,194 | 129,166 | 19,429 | 14,235 |
| | 12 | 2005 | 7,792 | 9,909 | 17,701 | 2,274 | 164,153 | 21,086 | 18,812 |
| | 13 | 2006 | 162,353 | 9,909 | 172,262 | 18,896 | 204,188 | 22,398 | 3,502 |
| | 14 | 2007 | 174,625 | 13,625 | 188,250 | 17,634 | 248,047 | 23,236 | 5,601 |
| | 15 | 2008 | 0 | 13,625 | 13,625 | 1,090 | 294,906 | 23,591 | 22,501 |
| | 16 | 2009 | 9,489 | 13,625 | 23,114 | 1,579 | 344,805 | 23,555 | 21,976 |
| | 17 | 2010 | 13,050 | 13,625 | 26,675 | 1,556 | 397,573 | 23,193 | 21,637 |
| | 18 | 2011 | 106,334 | 13,625 | 119,959 | 5,976 | 452,606 | 22,548 | 16,572 |
| | 19 | 2012 | | 17,565 | 17,565 | 747 | 452,606 | 19,255 | 18,508 |
| | 20 | 2013 | | 17,565 | 17,565 | 638 | 452,606 | 16,444 | 15,805 |
| | 21 | 2014 | | 17,565 | 17,565 | 545 | 452,606 | 14,042 | 13,497 |
| | 22 | 2015 | | 17,565 | 17,565 | 465 | 452,606 | 11,992 | 11,526 |
| | 23 | 2016 | | 17,565 | 17,565 | 397 | 452,606 | 10,240 | 9,843 |
| | 24 | 2017 | | 17,565 | 17,565 | 339 | 452,606 | 8,745 | 8,406 |
| | 25 | 2018 | | 17,565 | 17,565 | 290 | 452,606 | 7,468 | 7,178 |
| | 26 | 2019 | | 17,565 | 17,565 | 247 | 452,606 | 6,377 | 6,130 |
| | 27 | 2020 | | 17,565 | 17,565 | 211 | 452,606 | 5,446 | 5,235 |
| | 28 | 2021 | | 17,565 | 17,565 | 180 | 452,606 | 4,651 | 4,470 |
| | 29 | 2022 | | 17,565 | 17,565 | 154 | 452,606 | 3,972 | 3,817 |
| | 30 | 2023 | | 17,565 | 17,565 | 132 | 452,606 | 3,392 | 3,260 |
| | 31 | 2024 | | 17,565 | 17,565 | 112 | 452,606 | 2,896 | 2,784 |
| | 32 | 2025 | | 17,565 | 17,565 | 96 | 452,606 | 2,473 | 2,377 |
| | 33 | 2026 | | 17,565 | 17,565 | 82 | 452,606 | 2,112 | 2,030 |
| | 34 | 2027 | | 17,565 | 17,565 | 70 | 452,606 | 1,804 | 1,734 |
| | 35 | 2028 | | 17,565 | 17,565 | 60 | 452,606 | 1,540 | 1,481 |
| | 36 | 2029 | | 17,565 | 17,565 | 51 | 452,606 | 1,315 | 1,264 |
| | 37 | 2030 | | 17,565 | 17,565 | 44 | 452,606 | 1,123 | 1,080 |
| | 38 | 2031 | | 17,565 | 17,565 | 37 | 452,606 | 959 | 922 |
| | 39 | 2032 | | 17,565 | 17,565 | 32 | 452,606 | 819 | 787 |
| | 40 | 2033 | | 17,565 | 17,565 | 27 | 452,606 | 700 | 672 |
| | 41 | 2034 | | 17,565 | 17,565 | 23 | 452,606 | 597 | 574 |
| | Total | | 1,205,967 | 545,425 | 1,751,392 | 361,266 | 12,897,319 | 361,266 | 0 |

B-C　0
B/C　1.0000000

Table 7-7 Construction Cost divided into Foreign and Local Currency Portion

(1,000 US$)

| | Construction Cost for Transmission Line | | | | Construction Cost for Substation Equipment | | | | Total Const. Cost |
|---|---|---|---|---|---|---|---|---|---|
| Year | Total (a)+(b) | Foreign (a) | Local (b) | (Local) (VAT) (c) | Total (d)+(e) | Foreign (d) | Local (e) | (Local) (VAT) (f) | (a)+(b)+(d)+(e) |
| 1994 | 300 | 20 | 280 | 16 | 0 | | | | 300 |
| 1995 | 161,280 | 11,280 | 150,000 | 6,692 | 0 | | | | 161,280 |
| 1996 | 0 | 0 | 0 | 0 | 0 | | | | 0 |
| 1997 | 81,410 | 24,160 | 57,250 | 650 | 206,996 | 138,528 | 68,468 | 11,358 | 288,406 |
| | 242,990 | | | | 206,996 | | | | 449,986 |
| 1998 | 14,850 | 920 | 13,930 | 764 | 0 | | | | 14,850 |
| 1999 | 0 | 0 | 0 | 0 | 0 | | | | 0 |
| 2000 | 45,370 | 3,770 | 41,600 | 2,347 | 0 | | | | 45,370 |
| 2001 | 0 | 0 | 0 | 0 | 193,906 | 136,943 | 56,963 | 10,660 | 193,906 |
| | 60,220 | | | | 193,906 | | | | 254,126 |
| 2002 | 23,000 | 1,400 | 21,600 | 1,215 | 0 | | | | 23,000 |
| 2003 | 15,080 | 1,270 | 13,810 | 791 | 0 | | | | 15,080 |
| 2004 | 25,930 | 2,650 | 23,280 | 1,307 | 0 | | | | 25,930 |
| 2005 | 12,510 | 850 | 11,660 | 4,718 | 0 | | | | 12,510 |
| 2006 | 0 | 0 | 0 | 0 | 171,786 | 124,385 | 47,401 | 9,435 | 171,786 |
| | 76,520 | | | | 171,786 | | | | 248,306 |
| 2007 | 175,180 | 59,700 | 115,480 | 555 | 0 | | | | 175,180 |
| 2008 | 0 | 0 | 0 | 0 | 0 | | | | 0 |
| 2009 | 18,190 | 1,160 | 17,030 | 8,701 | 0 | | | | 18,190 |
| 2010 | 13,750 | 1,350 | 12,400 | 700 | 0 | | | | 13,750 |
| 2011 | 0 | 0 | 0 | 0 | 112,519 | 77,580 | 34,939 | 6,184 | 112,519 |
| | 207,120 | | | | 112,519 | | | | 319,639 |
| Total | 586,850 | 108,530 | 478,320 | 28,456 | 685,207 | 477,436 | 207,771 | 37,637 | 1,272,057 |

Table 7-8 Calculation of Interest during Construction

(1,000 US$)

| | Construction cost without VAT before escalation | | | Construction cost without VAT after escalation | | | Interest during Construction | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Foreign (a)+(d) | Local (b)-(c)+(e)-(f) | Total | Foreign | Local | Total | Foreign | Local | Total | Foreign | Local | Grand total |
| 1994 | 20 | 264 | 284 | 22 | 291 | 313 | 1 | 7 | 8 | 23 | 298 | 321 |
| 1995 | 11,280 | 143,308 | 154,588 | 13,058 | 165,897 | 178,955 | 524 | 4,162 | 4,686 | 13,582 | 170,059 | 183,641 |
| 1996 | 0 | 0 | 0 | 0 | 0 | 0 | 1,046 | 8,309 | 9,356 | 1,046 | 8,309 | 9,356 |
| 1997 | 162,688 | 113,710 | 276,398 | 207,636 | 145,126 | 352,762 | 9,352 | 11,938 | 21,289 | 216,988 | 157,064 | 374,051 |
| | | | 431,270 | | | 532,030 | | | 35,339 | | | 567,369 |
| 1998 | 920 | 13,166 | 14,086 | 1,233 | 17,644 | 18,877 | 49 | 441 | 490 | 1,282 | 18,085 | 19,367 |
| 1999 | 0 | 0 | 0 | 0 | 0 | 0 | 99 | 882 | 981 | 99 | 882 | 981 |
| 2000 | 3,770 | 39,253 | 43,023 | 5,570 | 57,995 | 63,565 | 321 | 2,332 | 2,653 | 5,891 | 60,327 | 66,218 |
| 2001 | 136,943 | 46,303 | 183,246 | 212,444 | 71,831 | 284,275 | 9,042 | 5,578 | 14,620 | 221,486 | 77,409 | 298,894 |
| | | | 240,355 | | | 366,716 | | | 18,744 | | | 385,460 |
| 2002 | 1,400 | 20,385 | 21,785 | 2,280 | 33,205 | 35,485 | 91 | 830 | 921 | 2,372 | 34,035 | 36,407 |
| 2003 | 1,270 | 13,019 | 14,289 | 2,172 | 22,267 | 24,439 | 269 | 2,217 | 2,486 | 2,441 | 24,484 | 26,925 |
| 2004 | 2,650 | 21,973 | 24,623 | 4,759 | 39,460 | 44,219 | 547 | 3,760 | 4,307 | 5,306 | 43,220 | 48,526 |
| 2005 | 850 | 6,942 | 7,792 | 1,603 | 13,090 | 14,693 | 801 | 5,074 | 5,875 | 2,404 | 18,164 | 20,568 |
| 2006 | 124,385 | 37,966 | 162,351 | 246,274 | 75,170 | 321,444 | 10,716 | 7,280 | 17,996 | 256,990 | 82,450 | 339,440 |
| | | | 230,840 | | | 440,281 | | | 31,586 | | | 471,866 |
| 2007 | 59,700 | 114,925 | 174,625 | 124,112 | 238,921 | 363,033 | 4,964 | 5,973 | 10,938 | 129,076 | 244,894 | 373,970 |
| 2008 | 0 | 0 | 0 | 0 | 0 | 0 | 9,929 | 11,946 | 21,875 | 9,929 | 11,946 | 21,875 |
| 2009 | 1,160 | 8,329 | 9,489 | 2,659 | 19,090 | 21,749 | 10,035 | 12,423 | 22,459 | 12,694 | 31,514 | 44,208 |
| 2010 | 1,350 | 11,700 | 13,050 | 3,249 | 28,157 | 31,406 | 10,272 | 13,604 | 23,876 | 13,521 | 41,762 | 55,282 |
| 2011 | 77,580 | 28,755 | 106,335 | 196,041 | 72,662 | 268,703 | 18,243 | 16,125 | 34,368 | 214,284 | 88,787 | 303,071 |
| | | | 303,499 | | | 684,891 | | | 113,515 | | | 738,407 |
| Total | 585,966 | 619,998 | 1,205,964 | 1,023,111 | 1,000,807 | 2,023,918 | 86,302 | 112,882 | 199,185 | 1,109,413 | 1,113,689 | 2,223,103 |

Table 7-9 Financing for Construction

(1,000 US$)

| | Construction cost after escalation | | Interest during Construction | | Financing for Construction | | |
|---|---|---|---|---|---|---|---|
| Year | Foreign | Local | Foreign | Local | Foreign | Local | Total |
| 1994 | 22 | 291 | 1 | 7 | 23 | 153 | 176 |
| 1995 | 13,058 | 165,897 | 524 | 4,162 | 13,582 | 87,110 | 100,693 |
| 1996 | 0 | 0 | 1,046 | 8,309 | 1,046 | 8,309 | 9,356 |
| 1997 | 207,636 | 145,126 | 9,352 | 11,938 | 216,988 | 84,501 | 301,488 |
| | | | | | 231,639 | 180,073 | 411,712 |
| 1998 | 1,233 | 17,644 | 49 | 441 | 1,282 | 9,263 | 10,545 |
| 1999 | 0 | 0 | 99 | 882 | 99 | 882 | 981 |
| 2000 | 5,570 | 57,995 | 321 | 2,332 | 5,891 | 31,330 | 37,221 |
| 2001 | 212,444 | 71,831 | 9,042 | 5,578 | 221,486 | 41,493 | 262,979 |
| | | | | | 228,758 | 82,968 | 311,727 |
| 2002 | 2,280 | 33,205 | 91 | 830 | 2,371 | 17,433 | 19,804 |
| 2003 | 2,172 | 22,267 | 269 | 2,217 | 2,441 | 13,350 | 15,792 |
| 2004 | 4,759 | 39,460 | 547 | 3,760 | 5,306 | 23,490 | 28,796 |
| 2005 | 1,603 | 13,090 | 801 | 5,074 | 2,404 | 11,619 | 14,023 |
| 2006 | 246,274 | 75,170 | 10,716 | 7,280 | 256,990 | 44,865 | 301,855 |
| | | | | | 269,512 | 110,757 | 380,269 |
| 2007 | 124,112 | 238,921 | 4,964 | 5,973 | 129,076 | 125,434 | 254,510 |
| 2008 | 0 | 0 | 9,929 | 11,946 | 9,929 | 11,946 | 21,875 |
| 2009 | 2,659 | 19,090 | 10,035 | 12,423 | 12,694 | 21,968 | 34,663 |
| 2010 | 3,249 | 28,157 | 10,272 | 13,604 | 13,521 | 27,683 | 41,204 |
| 2011 | 196,041 | 72,662 | 18,243 | 16,125 | 214,284 | 52,456 | 266,740 |
| | | | | | 379,505 | 239,487 | 618,991 |
| Total | 1,023,111 | 1,000,807 | 86,302 | 112,882 | 1,109,413 | 613,285 | 1,722,698 |

Table 7-10 Repayment Schedule of Debt (loan supplied 1994-1997)

(1,000 US$)

| | | Financing for Construction | | | Repayment of foreign Currency | | | | Repayment of local Currency | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Year | Foreign | Local | Total | Interest | Principal | Total | Balance | Interest | Principal | Total | Balance |
| | 1994 | 23 | 153 | 176 | | | | | | | | |
| | 1995 | 13,582 | 87,110 | 100,693 | | | | | | | | |
| | 1996 | 1,046 | 8,309 | 9,356 | | | | | | | | |
| | 1997 | 216,988 | 84,501 | 301,488 | | | | 231,639 | | | | 180,073 |
| 1 | 1998 | | | | 18,531 | 5,062 | 23,593 | 226,577 | 18,007 | 11,299 | 29,306 | 168,774 |
| 2 | 1999 | | | | 18,126 | 5,467 | 23,593 | 221,110 | 16,877 | 12,429 | 29,306 | 156,346 |
| 3 | 2000 | | | | 17,689 | 5,904 | 23,593 | 215,206 | 15,635 | 13,671 | 29,306 | 142,674 |
| 4 | 2001 | | | | 17,217 | 6,376 | 23,593 | 208,830 | 14,267 | 15,039 | 29,306 | 127,635 |
| 5 | 2002 | | | | 16,706 | 6,887 | 23,593 | 201,943 | 12,764 | 16,543 | 29,306 | 111,093 |
| 6 | 2003 | | | | 16,155 | 7,437 | 23,593 | 194,506 | 11,109 | 18,197 | 29,306 | 92,896 |
| 7 | 2004 | | | | 15,560 | 8,032 | 23,593 | 186,473 | 9,290 | 20,016 | 29,306 | 72,880 |
| 8 | 2005 | | | | 14,918 | 8,675 | 23,593 | 177,798 | 7,288 | 22,018 | 29,306 | 50,862 |
| 9 | 2006 | | | | 14,224 | 9,369 | 23,593 | 168,429 | 5,086 | 24,220 | 29,306 | 26,642 |
| 10 | 2007 | | | | 13,474 | 10,119 | 23,593 | 158,311 | 2,664 | 26,642 | 29,306 | 0 |
| 11 | 2008 | | | | 12,665 | 10,928 | 23,593 | 147,382 | | | | |
| 12 | 2009 | | | | 11,791 | 11,802 | 23,593 | 135,580 | | | | |
| 13 | 2010 | | | | 10,846 | 12,747 | 23,593 | 122,834 | | | | |
| 14 | 2011 | | | | 9,827 | 13,766 | 23,593 | 109,067 | | | | |
| 15 | 2012 | | | | 8,725 | 14,868 | 23,593 | 94,200 | | | | |
| 16 | 2013 | | | | 7,536 | 16,057 | 23,593 | 78,143 | | | | |
| 17 | 2014 | | | | 6,251 | 17,342 | 23,593 | 60,801 | | | | |
| 18 | 2015 | | | | 4,864 | 18,729 | 23,593 | 42,072 | | | | |
| 19 | 2016 | | | | 3,366 | 20,227 | 23,593 | 21,845 | | | | |
| 20 | 2017 | | | | 1,748 | 21,845 | 23,593 | 0 | | | | |
| | Total | 231,639 | 180,073 | 411,713 | 240,220 | 231,639 | 471,859 | | 112,988 | 180,073 | 293,061 | |

Table 7-11 Repayment Schedule of Debt (loan supplid 1998-2001)

(1,000 US$)

| | | Financing for Construction | | | Repayment of foreign Currency | | | | Repayment of local Currency | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Year | Foreign | Local | Total | Interest | Principal | Total | Balance | Interest | Principal | Total | Balance |
| | 1994 | | | | | | | | | | | |
| | 1995 | | | | | | | | | | | |
| | 1996 | | | | | | | | | | | |
| | 1997 | | | | | | | | | | | |
| | 1998 | 1,282 | 9,263 | 10,545 | | | | | | | | |
| | 1999 | 99 | 882 | 981 | | | | | | | | |
| | 2000 | 5,891 | 31,330 | 37,221 | | | | | | | | |
| | 2001 | 221,486 | 41,493 | 262,979 | | | | 228,758 | | | | 82,968 |
| 1 | 2002 | | | | 18,301 | 4,999 | 23,300 | 223,759 | 8,297 | 5,206 | 13,503 | 77,762 |
| 2 | 2003 | | | | 17,901 | 5,399 | 23,300 | 218,360 | 7,776 | 5,726 | 13,503 | 72,036 |
| 3 | 2004 | | | | 17,469 | 5,831 | 23,300 | 212,530 | 7,204 | 6,299 | 13,503 | 65,737 |
| 4 | 2005 | | | | 17,002 | 6,297 | 23,300 | 206,233 | 6,574 | 6,929 | 13,503 | 58,808 |
| 5 | 2006 | | | | 16,499 | 6,801 | 23,300 | 199,432 | 5,881 | 7,622 | 13,503 | 51,186 |
| 6 | 2007 | | | | 15,955 | 7,345 | 23,300 | 192,087 | 5,119 | 8,384 | 13,503 | 42,802 |
| 7 | 2008 | | | | 15,367 | 7,933 | 23,300 | 184,154 | 4,280 | 9,222 | 13,503 | 33,579 |
| 8 | 2009 | | | | 14,732 | 8,567 | 23,300 | 175,587 | 3,358 | 10,145 | 13,503 | 23,434 |
| 9 | 2010 | | | | 14,047 | 9,253 | 23,300 | 166,334 | 2,343 | 11,159 | 13,503 | 12,275 |
| 10 | 2011 | | | | 13,307 | 9,993 | 23,300 | 156,342 | 1,228 | 12,275 | 13,503 | 0 |
| 11 | 2012 | | | | 12,507 | 10,792 | 23,300 | 145,549 | | | | |
| 12 | 2013 | | | | 11,644 | 11,656 | 23,300 | 133,894 | | | | |
| 13 | 2014 | | | | 10,712 | 12,588 | 23,300 | 121,306 | | | | |
| 14 | 2015 | | | | 9,704 | 13,595 | 23,300 | 107,711 | | | | |
| 15 | 2016 | | | | 8,617 | 14,683 | 23,300 | 93,028 | | | | |
| 16 | 2017 | | | | 7,442 | 15,857 | 23,300 | 77,171 | | | | |
| 17 | 2018 | | | | 6,174 | 17,126 | 23,300 | 60,045 | | | | |
| 18 | 2019 | | | | 4,804 | 18,496 | 23,300 | 41,549 | | | | |
| 19 | 2020 | | | | 3,324 | 19,976 | 23,300 | 21,574 | | | | |
| 20 | 2021 | | | | 1,726 | 21,574 | 23,300 | 0 | | | | |
| | Total | 228,758 | 82,968 | 311,726 | 237,232 | 228,758 | 465,990 | | 52,059 | 82,968 | 135,027 | |

Table 7-12

Repayment Schedule of Debt (loan supplied 2002-2006)

(1,000 US$)

| | | Financing for Construction | | | Repayment of foreign Currency | | | | Repayment of local Currency | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Year | Foreign | Local | Total | Interest | Principal | Total | Balance | Interest | Principal | Total | Balance |
| | 1994 | | | | | | | | | | | |
| | 1995 | | | | | | | | | | | |
| | 1996 | | | | | | | | | | | |
| | 1997 | | | | | | | | | | | |
| | 1998 | | | | | | | | | | | |
| | 1999 | | | | | | | | | | | |
| | 2000 | | | | | | | | | | | |
| | 2001 | | | | | | | | | | | |
| | 2002 | 2,371 | 17,433 | 19,804 | | | | | | | | |
| | 2003 | 2,441 | 13,350 | 15,792 | | | | | | | | |
| | 2004 | 5,306 | 23,490 | 28,796 | | | | | | | | |
| | 2005 | 2,404 | 11,619 | 14,023 | | | | | | | | |
| | 2006 | 256,990 | 44,865 | 301,855 | | | | 269,512 | | | | 110,757 |
| 1 | 2007 | | | | 21,561 | 5,889 | 27,450 | 263,623 | 11,076 | 6,949 | 18,025 | 103,808 |
| 2 | 2008 | | | | 21,090 | 6,361 | 27,450 | 257,262 | 10,381 | 7,644 | 18,025 | 96,163 |
| 3 | 2009 | | | | 20,581 | 6,869 | 27,450 | 250,393 | 9,616 | 8,409 | 18,025 | 87,754 |
| 4 | 2010 | | | | 20,031 | 7,419 | 27,450 | 242,974 | 8,775 | 9,250 | 18,025 | 78,504 |
| 5 | 2011 | | | | 19,438 | 8,013 | 27,450 | 234,961 | 7,850 | 10,175 | 18,025 | 68,330 |
| 6 | 2012 | | | | 18,797 | 8,654 | 27,450 | 226,308 | 6,833 | 11,192 | 18,025 | 57,137 |
| 7 | 2013 | | | | 18,105 | 9,346 | 27,450 | 216,962 | 5,714 | 12,311 | 18,025 | 44,826 |
| 8 | 2014 | | | | 17,357 | 10,093 | 27,450 | 206,868 | 4,483 | 13,543 | 18,025 | 31,283 |
| 9 | 2015 | | | | 16,549 | 10,901 | 27,450 | 195,967 | 3,128 | 14,897 | 18,025 | 16,387 |
| 10 | 2016 | | | | 15,677 | 11,773 | 27,450 | 184,194 | 1,639 | 16,387 | 18,025 | 0 |
| 11 | 2017 | | | | 14,736 | 12,715 | 27,450 | 171,480 | | | | |
| 12 | 2018 | | | | 13,718 | 13,732 | 27,450 | 157,747 | | | | |
| 13 | 2019 | | | | 12,620 | 14,831 | 27,450 | 142,917 | | | | |
| 14 | 2020 | | | | 11,433 | 16,017 | 27,450 | 126,900 | | | | |
| 15 | 2021 | | | | 10,152 | 17,298 | 27,450 | 109,601 | | | | |
| 16 | 2022 | | | | 8,768 | 18,682 | 27,450 | 90,919 | | | | |
| 17 | 2023 | | | | 7,274 | 20,177 | 27,450 | 70,742 | | | | |
| 18 | 2024 | | | | 5,659 | 21,791 | 27,450 | 48,951 | | | | |
| 19 | 2025 | | | | 3,916 | 23,534 | 27,450 | 25,417 | | | | |
| 20 | 2026 | | | | 2,033 | 25,417 | 27,450 | 0 | | | | |
| | Total | 269,512 | 110,757 | 380,270 | 279,496 | 269,512 | 549,008 | | 69,495 | 110,757 | 180,252 | |

Table 7-13 Repayment Schedule of Debt (loan supplied 2007-2011)

(1,000 US$)

| | | Financing for Construction | | | Repayment of foreign Currency | | | | Repayment of local Currency | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Year | Foreign | Local | Total | Interest | Principal | Total | Balance | Interest | Principal | Total | Balance |
| | 1994 | | | | | | | | | | | |
| | 1995 | | | | | | | | | | | |
| | 1996 | | | | | | | | | | | |
| | 1997 | | | | | | | | | | | |
| | 1998 | | | | | | | | | | | |
| | 1999 | | | | | | | | | | | |
| | 2000 | | | | | | | | | | | |
| | 2001 | | | | | | | | | | | |
| | 2002 | | | | | | | | | | | |
| | 2003 | | | | | | | | | | | |
| | 2004 | | | | | | | | | | | |
| | 2005 | | | | | | | | | | | |
| | 2006 | | | | | | | | | | | |
| | 2007 | 129,076 | 125,434 | 254,510 | | | | | | | | |
| | 2008 | 9,929 | 11,946 | 21,875 | | | | | | | | |
| | 2009 | 12,694 | 21,968 | 34,663 | | | | | | | | |
| | 2010 | 13,521 | 27,683 | 41,204 | | | | | | | | |
| | 2011 | 214,284 | 52,456 | 266,740 | | | | 379,505 | | | | 239,487 |
| 1 | 2012 | | | | 30,360 | 8,293 | 38,653 | 371,212 | 23,949 | 15,027 | 38,975 | 224,460 |
| 2 | 2013 | | | | 29,697 | 8,956 | 38,653 | 362,256 | 22,446 | 16,529 | 38,975 | 207,931 |
| 3 | 2014 | | | | 28,980 | 9,673 | 38,653 | 352,583 | 20,793 | 18,182 | 38,975 | 189,749 |
| 4 | 2015 | | | | 28,207 | 10,447 | 38,653 | 342,136 | 18,975 | 20,001 | 38,975 | 169,748 |
| 5 | 2016 | | | | 27,371 | 11,283 | 38,653 | 330,853 | 16,975 | 22,001 | 38,975 | 147,747 |
| 6 | 2017 | | | | 26,468 | 12,185 | 38,653 | 318,668 | 14,775 | 24,201 | 38,975 | 123,547 |
| 7 | 2018 | | | | 25,493 | 13,160 | 38,653 | 305,508 | 12,355 | 26,621 | 38,975 | 96,926 |
| 8 | 2019 | | | | 24,441 | 14,213 | 38,653 | 291,295 | 9,693 | 29,283 | 38,975 | 67,643 |
| 9 | 2020 | | | | 23,304 | 15,350 | 38,653 | 275,945 | 6,764 | 32,211 | 38,975 | 35,432 |
| 10 | 2021 | | | | 22,076 | 16,578 | 38,653 | 259,368 | 3,543 | 35,432 | 38,975 | 0 |
| 11 | 2022 | | | | 20,749 | 17,904 | 38,653 | 241,464 | | | | |
| 12 | 2023 | | | | 19,317 | 19,336 | 38,653 | 222,127 | | | | |
| 13 | 2024 | | | | 17,770 | 20,883 | 38,653 | 201,244 | | | | |
| 14 | 2025 | | | | 16,100 | 22,554 | 38,653 | 178,690 | | | | |
| 15 | 2026 | | | | 14,295 | 24,358 | 38,653 | 154,332 | | | | |
| 16 | 2027 | | | | 12,347 | 26,307 | 38,653 | 128,025 | | | | |
| 17 | 2028 | | | | 10,242 | 28,411 | 38,653 | 99,614 | | | | |
| 18 | 2029 | | | | 7,969 | 30,684 | 38,653 | 68,929 | | | | |
| 19 | 2030 | | | | 5,514 | 33,139 | 38,653 | 35,790 | | | | |
| 20 | 2031 | | | | 2,863 | 35,790 | 38,653 | 0 | | | | |
| | Total | 379,504 | 239,487 | 618,992 | 393,563 | 379,505 | 773,068 | | 150,267 | 239,487 | 389,754 | |

Table 7-14 Statement of Profit and Loss

(1,000 US$)

| Year | Revenue | Business Expenses | | | Business Profit | Financial Cost | | | Net Profit |
|---|---|---|---|---|---|---|---|---|---|
| | | OM cost | Depreci-ation | Total | | Interest Dur.Const. | Interest | Total | |
| 1994 | | | | | | 8 | | 8 | -8 |
| 1995 | | | | | | 4,686 | | 4,686 | -4,686 |
| 1996 | | | | | | 9,356 | | 9,356 | -9,356 |
| 1997 | | | | | | 21,289 | | 21,289 | -21,289 |
| 1998 | 1,316 | 7,960 | 17,730 | 25,690 | -24,374 | 490 | 36,538 | 37,028 | -61,402 |
| 1999 | 17,679 | 8,358 | 17,730 | 26,088 | -8,409 | 981 | 35,003 | 35,984 | -44,393 |
| 2000 | 25,934 | 8,776 | 17,730 | 26,506 | -572 | 2,653 | 33,324 | 35,977 | -36,549 |
| 2001 | 78,058 | 9,215 | 17,730 | 26,945 | 51,113 | 14,620 | 31,484 | 46,104 | 5,009 |
| 2002 | 117,363 | 16,141 | 29,776 | 45,917 | 71,447 | 921 | 56,068 | 56,989 | 14,458 |
| 2003 | 168,417 | 16,948 | 29,776 | 46,724 | 121,693 | 2,486 | 52,941 | 55,427 | 66,266 |
| 2004 | 231,964 | 17,795 | 29,776 | 47,571 | 184,392 | 4,307 | 49,523 | 53,830 | 130,562 |
| 2005 | 309,535 | 18,685 | 29,776 | 48,461 | 261,074 | 5,875 | 45,782 | 51,657 | 209,417 |
| 2006 | 404,278 | 19,619 | 29,776 | 49,395 | 354,883 | 17,996 | 41,690 | 59,686 | 295,197 |
| 2007 | 515,672 | 28,325 | 44,522 | 72,847 | 442,825 | 10,938 | 69,849 | 80,787 | 362,038 |
| 2008 | 643,743 | 29,742 | 44,522 | 74,264 | 569,479 | 21,875 | 63,783 | 85,658 | 483,821 |
| 2009 | 790,299 | 31,229 | 44,522 | 75,751 | 714,549 | 22,459 | 60,078 | 82,537 | 632,012 |
| 2010 | 956,807 | 32,790 | 44,522 | 77,312 | 879,495 | 23,876 | 56,042 | 79,918 | 799,577 |
| 2011 | 1,143,713 | 34,430 | 44,522 | 78,952 | 1,064,761 | 34,368 | 51,650 | 86,018 | 978,743 |
| 2012 | 1,200,898 | 46,605 | 69,472 | 116,077 | 1,084,821 | | 101,171 | 101,171 | 983,650 |
| 2013 | 1,260,943 | 48,935 | 69,472 | 118,407 | 1,142,536 | | 95,142 | 95,142 | 1,047,394 |
| 2014 | 1,323,991 | 51,382 | 69,472 | 120,854 | 1,203,136 | | 88,576 | 88,576 | 1,114,560 |
| 2015 | 1,390,190 | 53,951 | 69,472 | 123,423 | 1,266,767 | | 81,427 | 81,427 | 1,185,340 |
| 2016 | 1,459,700 | 56,649 | 69,472 | 126,121 | 1,333,579 | | 73,645 | 73,645 | 1,259,934 |
| 2017 | 1,532,685 | 59,481 | 69,472 | 128,953 | 1,403,731 | | 65,169 | 65,169 | 1,338,562 |
| 2018 | 1,609,319 | 62,455 | 69,472 | 131,927 | 1,477,391 | | 57,740 | 57,740 | 1,419,651 |
| 2019 | 1,689,785 | 65,578 | 69,472 | 135,050 | 1,554,735 | | 51,558 | 51,558 | 1,503,177 |
| 2020 | 1,774,274 | 68,857 | 69,472 | 138,329 | 1,635,945 | | 44,825 | 44,825 | 1,591,120 |
| Total | 18,646,562 | 793,908 | 1,067,658 | 1,861,566 | 16,784,996 | 199,184 | 1,343,008 | 1,542,192 | 15,242,804 |

Table 7-15 Cash Flow

(1,000 US$)

| Year | Cash Inflow | | | | Cash Outflow | | | Balance | |
|---|---|---|---|---|---|---|---|---|---|
| | Financing | Net Profit | Depreciation | Total | Investment | Repayment of princi. | Total | Year | Accumlated |
| 1994 | 176 | -8 | | 168 | 176 | | 176 | -8 | -8 |
| 1995 | 100,693 | -4,686 | | 96,007 | 100,693 | | 100,693 | -4,686 | -4,694 |
| 1996 | 9,356 | -9,356 | | 0 | 9,356 | | 9,356 | -9,356 | -14,050 |
| 1997 | 301,488 | -21,289 | | 280,199 | 301,488 | | 301,488 | -21,289 | -35,339 |
| 1998 | 10,545 | -61,402 | 17,730 | -33,127 | 10,545 | 16,361 | 26,906 | -60,033 | -95,372 |
| 1999 | 981 | -44,393 | 17,730 | -25,682 | 981 | 17,896 | 18,877 | -44,559 | -139,932 |
| 2000 | 37,221 | -36,549 | 17,730 | 18,402 | 37,221 | 19,575 | 56,796 | -38,394 | -178,326 |
| 2001 | 262,979 | 5,009 | 17,730 | 285,718 | 262,979 | 21,415 | 284,394 | 1,324 | -177,002 |
| 2002 | 19,804 | 14,458 | 29,776 | 64,038 | 19,804 | 33,635 | 53,439 | 10,599 | -166,403 |
| 2003 | 15,792 | 66,266 | 29,776 | 111,834 | 15,792 | 36,759 | 52,551 | 59,283 | -107,119 |
| 2004 | 28,796 | 130,562 | 29,776 | 189,134 | 28,796 | 40,178 | 68,974 | 120,160 | 13,041 |
| 2005 | 14,023 | 209,417 | 29,776 | 253,216 | 14,023 | 43,919 | 57,942 | 195,274 | 208,315 |
| 2006 | 301,855 | 295,197 | 29,776 | 626,828 | 301,855 | 48,012 | 349,867 | 276,961 | 485,276 |
| 2007 | 254,510 | 362,038 | 44,522 | 661,070 | 254,510 | 65,328 | 319,838 | 341,232 | 826,508 |
| 2008 | 21,875 | 483,821 | 44,522 | 550,218 | 21,875 | 42,088 | 63,963 | 486,255 | 1,312,763 |
| 2009 | 34,663 | 632,012 | 44,522 | 711,197 | 34,663 | 45,792 | 80,455 | 630,742 | 1,943,504 |
| 2010 | 41,204 | 799,577 | 44,522 | 885,303 | 41,204 | 49,828 | 91,032 | 794,271 | 2,737,775 |
| 2011 | 266,740 | 978,743 | 44,522 | 1,290,005 | 266,740 | 54,222 | 320,962 | 969,043 | 3,706,818 |
| 2012 | | 983,650 | 69,472 | 1,053,122 | | 68,826 | 68,826 | 984,296 | 4,691,115 |
| 2013 | | 1,047,394 | 69,472 | 1,116,866 | | 74,855 | 74,855 | 1,042,011 | 5,733,125 |
| 2014 | | 1,114,560 | 69,472 | 1,184,032 | | 81,421 | 81,421 | 1,102,611 | 6,835,737 |
| 2015 | | 1,185,340 | 69,472 | 1,254,812 | | 88,570 | 88,570 | 1,166,242 | 8,001,979 |
| 2016 | | 1,259,934 | 69,472 | 1,329,406 | | 96,354 | 96,354 | 1,233,052 | 9,235,030 |
| 2017 | | 1,338,562 | 69,472 | 1,408,034 | | 86,803 | 86,803 | 1,321,231 | 10,556,262 |
| 2018 | | 1,419,651 | 69,472 | 1,489,123 | | 70,639 | 70,639 | 1,418,484 | 11,974,746 |
| 2019 | | 1,503,177 | 69,472 | 1,572,649 | | 76,823 | 76,823 | 1,495,826 | 13,470,572 |
| 2020 | | 1,591,120 | 69,472 | 1,660,592 | | 83,554 | 83,554 | 1,577,038 | 15,047,609 |
| Total | 1,722,701 | 15,242,804 | 1,067,658 | 18,033,163 | 1,722,701 | 1,262,853 | 2,985,554 | 15,047,609 | |

Table 7-16 Calculation of Debt Service Ratio

(1,000 US$)

| Year | Internal Fund Procured | | | | Repayment of Debt | | | | Debt Service Ratio |
|---|---|---|---|---|---|---|---|---|---|
| | Business Profit | Depreci- ation | Total | Accumlated (A) | Interest | Principal | Total | Accumlated (B) | (A)/(B) |
| 1994 | | | | | | | | | |
| 1995 | | | | | | | | | |
| 1996 | | | | | | | | | |
| 1997 | | | | | | | | | |
| 1998 | -24,374 | 17,730 | -6,644 | -6,644 | 36,538 | 16,361 | 52,899 | 52,899 | -0.13 |
| 1999 | -8,409 | 17,730 | 9,321 | 2,676 | 35,003 | 17,896 | 52,899 | 105,798 | 0.03 |
| 2000 | -572 | 17,730 | 17,158 | 19,834 | 33,324 | 19,575 | 52,899 | 158,697 | 0.12 |
| 2001 | 51,113 | 17,730 | 68,843 | 88,677 | 31,484 | 21,415 | 52,899 | 211,596 | 0.42 |
| 2002 | 71,447 | 29,776 | 101,223 | 189,900 | 56,068 | 33,635 | 89,703 | 301,299 | 0.63 |
| 2003 | 121,693 | 29,776 | 151,469 | 341,370 | 52,941 | 36,759 | 89,700 | 390,999 | 0.87 |
| 2004 | 184,392 | 29,776 | 214,168 | 555,538 | 49,523 | 40,178 | 89,701 | 480,700 | 1.16 |
| 2005 | 261,074 | 29,776 | 290,850 | 846,388 | 45,782 | 43,919 | 89,701 | 570,401 | 1.48 |
| 2006 | 354,883 | 29,776 | 384,659 | 1,231,047 | 41,690 | 48,012 | 89,702 | 660,103 | 1.86 |
| 2007 | 442,825 | 44,522 | 487,347 | 1,718,394 | 69,849 | 65,328 | 135,177 | 795,280 | 2.16 |
| 2008 | 569,479 | 44,522 | 614,001 | 2,332,395 | 63,783 | 42,088 | 105,871 | 901,151 | 2.59 |
| 2009 | 714,549 | 44,522 | 759,071 | 3,091,465 | 60,078 | 45,792 | 105,870 | 1,007,021 | 3.07 |
| 2010 | 879,495 | 44,522 | 924,017 | 4,015,482 | 56,042 | 49,828 | 105,870 | 1,112,891 | 3.61 |
| 2011 | 1,064,761 | 44,522 | 1,109,283 | 5,124,765 | 51,650 | 54,222 | 105,872 | 1,218,763 | 4.20 |
| 2012 | 1,084,821 | 69,472 | 1,154,293 | 6,279,059 | 101,171 | 68,826 | 169,997 | 1,388,760 | 4.52 |
| 2013 | 1,142,536 | 69,472 | 1,212,008 | 7,491,066 | 95,142 | 74,855 | 169,997 | 1,558,757 | 4.81 |
| 2014 | 1,203,136 | 69,472 | 1,272,608 | 8,763,675 | 88,576 | 81,421 | 169,997 | 1,728,754 | 5.07 |
| 2015 | 1,266,767 | 69,472 | 1,336,239 | 10,099,914 | 81,427 | 88,570 | 169,997 | 1,898,751 | 5.32 |
| 2016 | 1,333,579 | 69,472 | 1,403,051 | 11,502,964 | 73,645 | 96,354 | 169,999 | 2,068,750 | 5.56 |
| 2017 | 1,403,731 | 69,472 | 1,473,203 | 12,976,168 | 65,169 | 86,803 | 151,972 | 2,220,722 | 5.84 |
| 2018 | 1,477,391 | 69,472 | 1,546,863 | 14,523,031 | 57,740 | 70,639 | 128,379 | 2,349,101 | 6.18 |
| 2019 | 1,554,735 | 69,472 | 1,624,207 | 16,147,238 | 51,558 | 76,823 | 128,381 | 2,477,482 | 6.52 |
| 2020 | 1,635,945 | 69,472 | 1,705,417 | 17,852,654 | 44,825 | 83,554 | 128,379 | 2,605,861 | 6.85 |
| Total | 16,784,996 | 1,067,658 | 17,852,654 | | 1,343,008 | 1,262,853 | 2,605,861 | | |

# CHAPTER 8 FUTURE STUDIES

It is necessary to continue the following studies for implementing the project in accordance with the feasibility study on Bulk Power Supply Project for the Greater Bangkok Area:

(1) Study on the land acquisition for the transmission lines and substations to be installed in accordance with the feasibility study.

(2) Economic comparison study on the design of substation and transmission line taking environmental aspects into consideration.

(3) Review on the feasibility study in case that circumstances be changed.

(4) Study for obtaining governmental authorization of the actual implementation of the Project, such as environmental assessment of the Project.

(5) Study on the detailed design of the Project, including studies such as optimization of the transmission line design whether the overhead transmission line should be employed or underground cable.

(6) Study on the detailed implementation schedule.

(7) Study on the arrangement of the budget.

(8) Study on the procurement arrangement of the services and materials.

# CHAPTER 9 TECHNOLOGY TRANSFER

(1) OJT During Implementation of Field Investigation

At the time of presentation of the Inception Report, discussions shall be held on the features and problems of this Project in sufficient detail. During this process, technology shall be transferred to the counterpart concerning what kind of works are required in solving problems in each area, and what techniques are used in conducting such works.

In the presentation of Interim Report and Draft Final Report, each content of reports shall be presented by the personnel in direct charge of the subject, and technology transfer shall be implemented concerning not only the problems and their solutions related to this Project, but on the general subject of transmission line and substation development plan for the Kingdom of Thailand through exchange of questions and answers between the participants of the presentation meetings.

(2) Training of Counterpart in Japan

In the training in Japan, emphasis shall be placed on the design of transmission line and substation facilities and power system analysis methodologies which are closely related to the content of this Feasibility Study.

The power system analysis computer code possessed by EPDC shall be used in the training of power system analysis.

As EPDC has experiences on projects which are similar to this Study, a comprehensive technology transfer, including on-site training, shall be conducted based on EPDC's experiences on the problems and critical issues in power system planning.

a) Training on Transmission Line and Substation Expansion Plan of Greater Bangkok Area

Training programs shall be formulated and applied on the following subjects.

i) Power System Analysis

- Power flow calculation
- Short circuit capacity calculation
- Power system stability calculation

ii) Transmission Line and Substation Designs

- Design of urban type substations
- Transmission line tower structural calculation
- Insulation coordination and power line design

b) On-Site Training

EPDC has Nishi-Tokyo Substation at Machida City of Tokyo Metropolitan District. This substation is located inside the metropolitan area. A construction work for expansion of transmission line capacity is under way to convert a section of Tadami Trunk Line, which connects Shin-Nitta Substation of Tokyo Electric Power Company to Kita-Kumagaya Substation of the same company from the existing 275 kV, double circuit design to a line having two, 500 kV circuits and two, 275 kV circuits. This substation facility and the transmission line reinforcement project is similar to the Bulk Power Supply Project for the Greater Bangkok Area.

Therefore, it should be very effective in giving the trainees to grasp a comprehensive picture of the Bulk Power Supply Project for the Greater Bangkok Area if the training is given by pointing out the features and problems of planning, design, construction and expansion of Nishi-Tokyo Substation and the design and construction plan of Tadami Trunk Line Reinforcement Project, and their implication on the Project of Thailand.

As the training will be given not only by class room studies but through on-site observation of technical problems, the time period of training in Japan shall be appropriately planned.

JICA