Fig. 4-1 Method of Predicting Future Power and Energy Demand

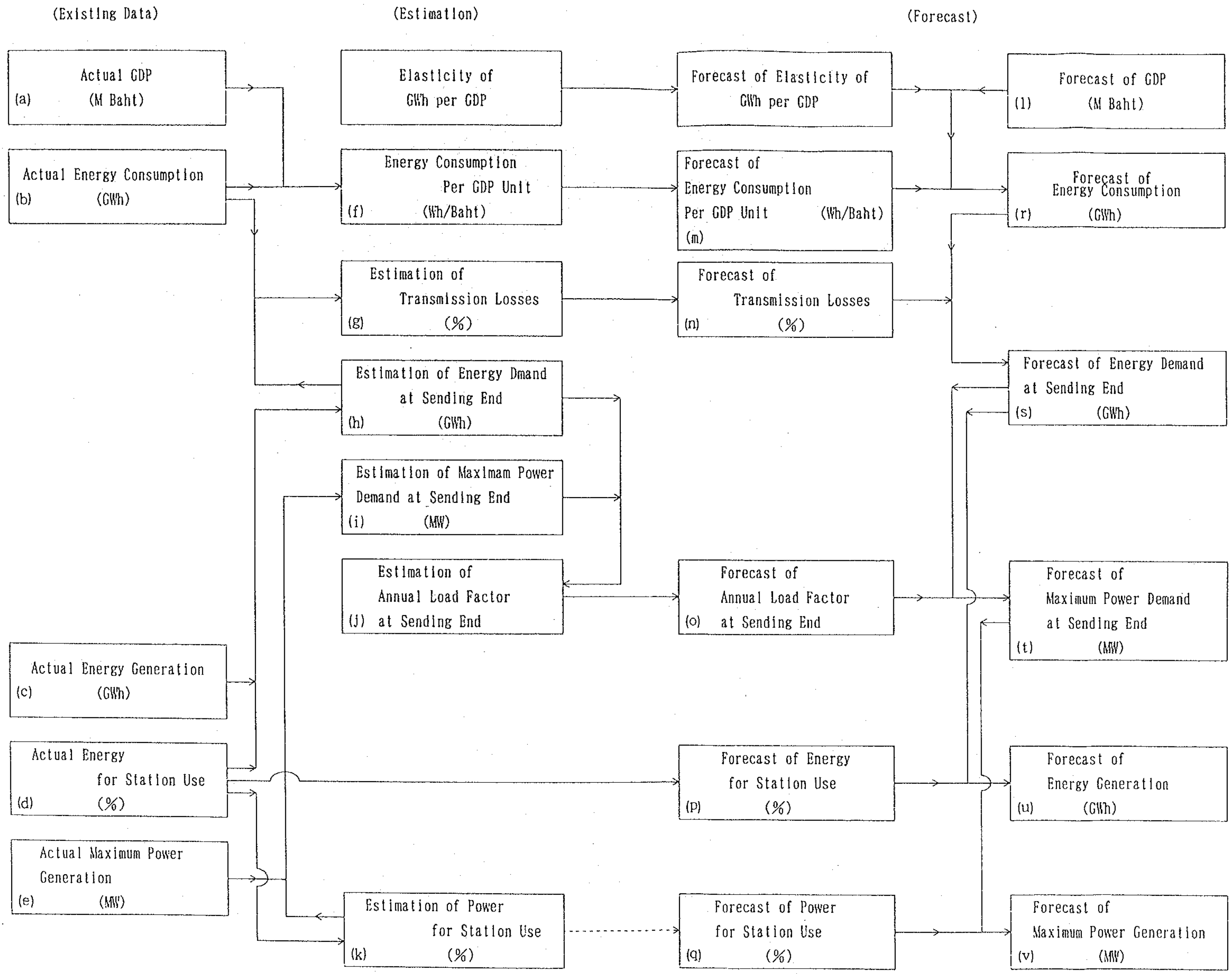


Fig. 4 - 2 Energy Demand at Generating End

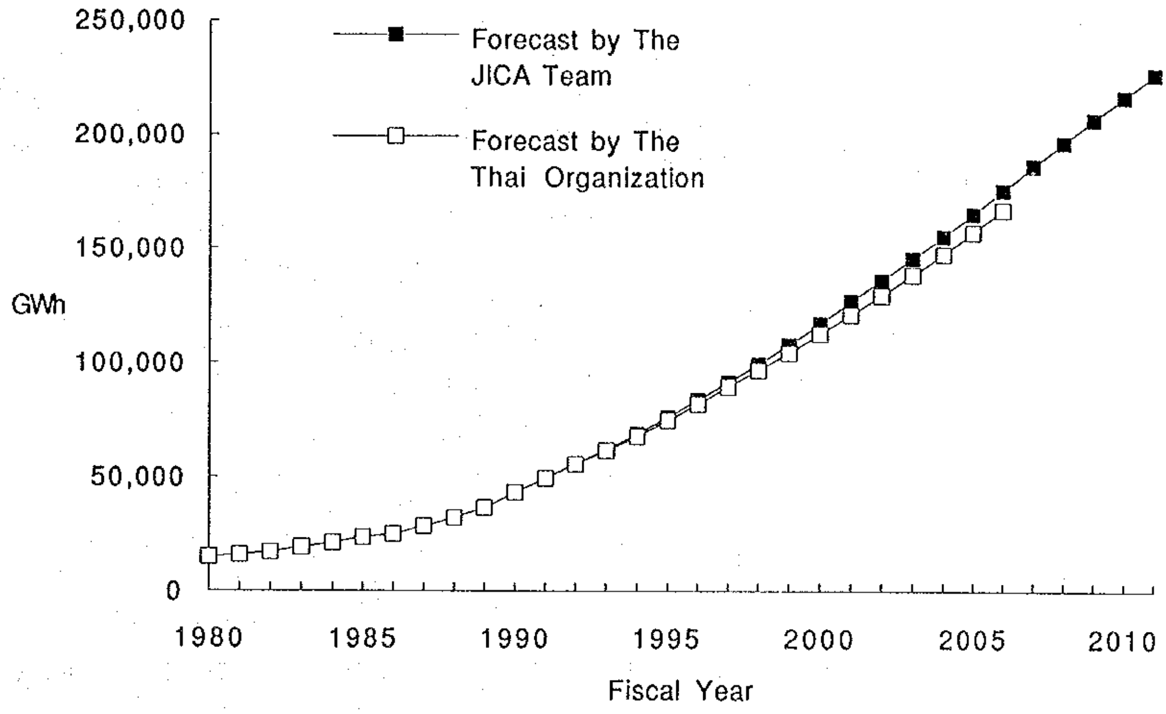


Fig. 4 - 3 Maximum Power Demand at Generating End

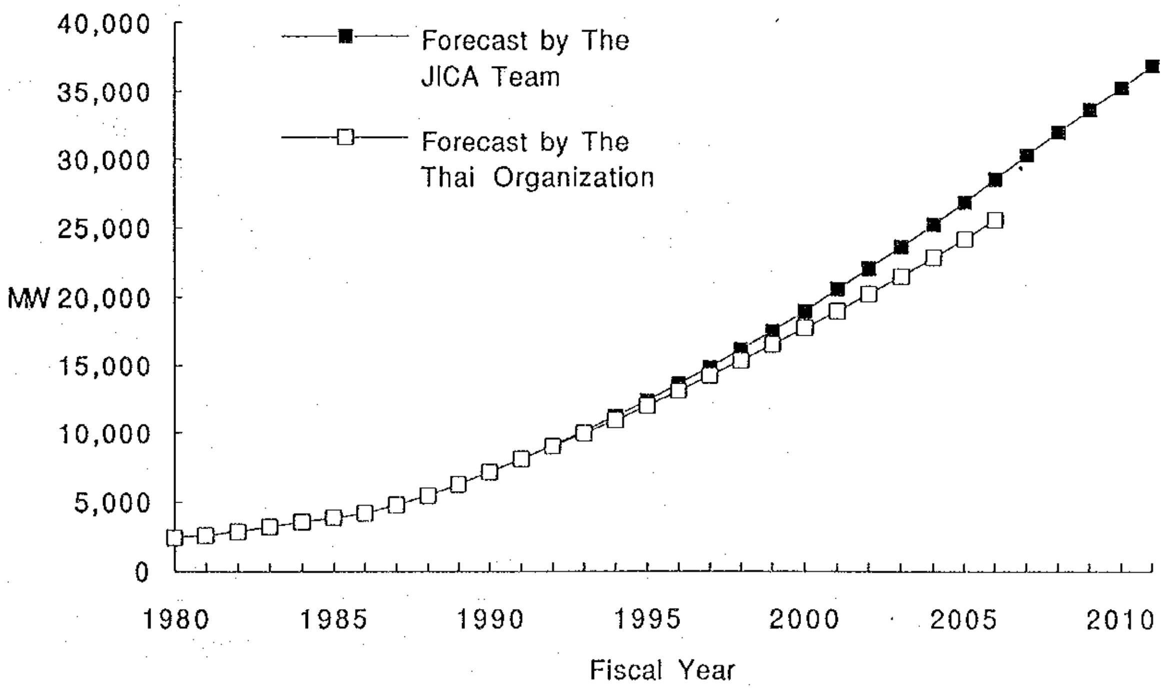


Fig. 4 - 4 Energy Demand by MEA

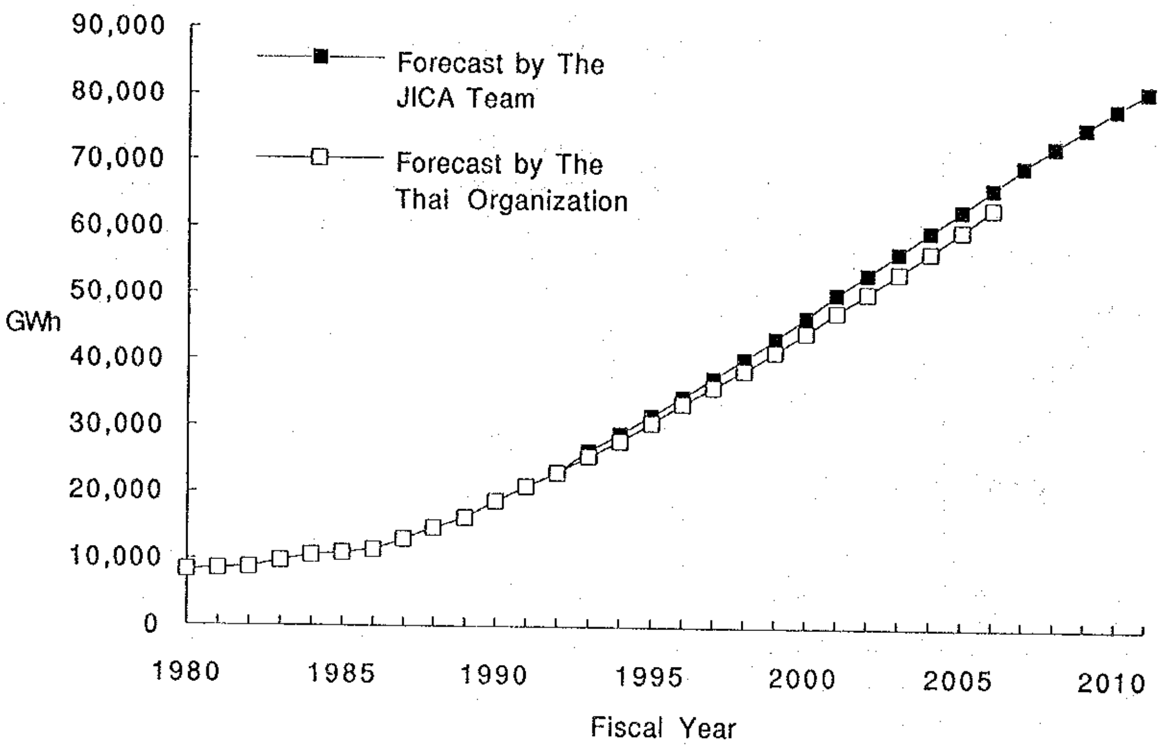
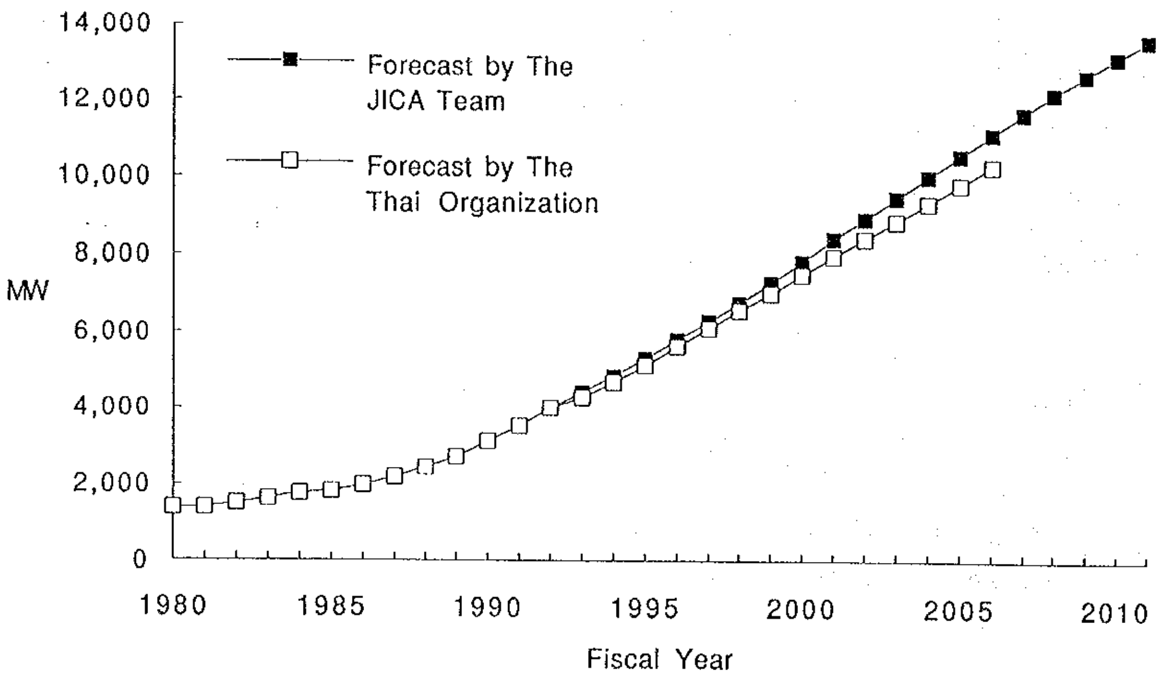


Fig. 4 - 5 Maximum Power Demand by MEA



CHAPTER 5

POWER SYSTEM PLANNING OF THE GREATER BANGKOK AREA

FOR A LONG FUTURE

CHAPTER 5 POWER SYSTEM PLANNING OF THE GREATER BANGKOK AREA FOR A LONG FUTURE

5.1 The Power System of Thailand - Present Situation

Fig. 5-1 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%).

5.1.1 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.

5.1.2 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.

A short of power in Region 1 is supplemented by means of interconnection of lines from Region 4 which has a great surplus power due to the recent extension of the Mae Moh power plant in addition to relatively low power demand.

Region 2 is also short of power as mentioned before. To meet its demand some of power must be sent from the neighboring regions, Region 1 and/or Region 4.

On the other hand, Region 3 is well balanced in power supply and demand, and so interchanging power with the other regions will not be needed in ordinal operation of the power system.

A typical power transmission among the regions is estimated by the JICA team in connection with the peaking time of fiscal 1991. That is shown on Fig. 5-2. Region 4 sends a total of 2,200 MW to Region 1 and Region 2, which receive 1,700 MW and 500 MW respectively.

5.2 Development of Power Sources for Future Need

As mentioned before, the total installed generating capacity of Thailand is 11,033 MW as of September 1992. It holds about 18% of reserve margin for the dependable capacity 10,634 MW which takes seasonal output variation of hydroelectric power plants and generation under full rated capacity of thermal power plants into account.

However, a great effort is required to make for continuous development of power sources to hold a sufficient power supply capability to cope with demand for power which is forecast to increase in future with a high growth rate.

Table 5-1 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.

Because of the concentrated effort to develop a combined cycle power plant in the lower part of central region and thermal power plants in the eastern seaboard area and on the western coast of the Gulf of Thailand, the total installed generating capacity in Region 1 will be rapidly increased reaching about 18,000 MW in fiscal 2006.

On the other hand, the peak demand in this region is forecast to be about 19,100 MW in the same year, if it is assumed to account for about 75% of the total demand of the country. As a result, there will be still a shortage of power supply of about 1,100 MW which must be offset by power sent from the other regions.

Bang Saphan in the western seaboard, the location of the proposed thermal power plant, is very remote from the Greater Bangkok Area and close to Region 3, even though it belongs to Region 1 geographically. The distance between the project site and Sai Noi substation of the Greater Bangkok Area is about 375 km.

In addition, EGAT is planning to develop nuclear power in the southern seaboard area in Region 3, mostly aiming to send power to the Greater Bangkok Area of Region 1.

It is supposed that the western seaboard and southern seaboard areas will become zones to generate great power after 2000. The transmission system must be able to send bulky amount of power from the above two seaboard areas over a long distance to the Greater Bangkok Area. Power system stability will be decisive and a lot of investment will be required to form the transmission system.

Environmental problems will accompany as a very important and serious matter to be solved for developing power sources and building the transmission system. It is conceivable that the transmission system possible to be built will be one of the crucial factors in decision of the scale of power sources.

Region 4 will increase its supply capability due to the continuous development of the lignite mines and thermal power to use lignite as fuel in the Mae Moh and Lampang areas. The surplus power of this region will be sent to Region 1 and Region 2.

The JICA team has estimated power transmission among the regions in 2006. Fig. 5-3 shows an example of this.

5.3 Approach to The Future Power Systems of The Greater Bangkok Area

5.3.1 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 4, 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.

5.3.2 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.

5.3.3 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.

It must, at all times, have enough generation available for service, and enough capacity for power transmission and distribution to assure continuous power supply and good voltage to every customer despite planned outages for inspection and maintenance, while at the same time it should be operated so as to realize the maximum economies.

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.

5.3.4 Approach to The Transmission Expansion Planning

The plan of reinforcement of the transmission system depends on power demand forecast for the area, location and scale of power sources which will be developed in future, possibility for acquisition of new locations for substations and new rights-of-way for transmission lines in the area,consideration to the environmental aspects and reliability criteria to be considered.

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.

It has been taken into account in the planned transmission system that the system should optimally sustain the voltage and hold a high reliability of power transmission with facilities of sufficient capacity with a view to realizing reduction of the frequency and duration of power outages.

Planning of future power systems has been implemented by the procedure shown in Fig. 5-4. 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.

After developing one or some network designs for the conditions and requirements to be considered in the above horizon year, we return to the present power system and move toward the horizon year system in chronological order to study the network growth.

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.

5.4 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.

The consequence of contingency generally takes the form of the outage of a certain amount of generation or of an entire power plant, the outage of a critical transmission line, the outage of a significant portion of substation or some combination of these outages of power facilities.

To define the power system reinforcements required, a compromise is generally sought between the quality of service and the cost of generation and transmission of electric power.

To assure against a very rare disturbance will involve too great an investment in power supply facilities, as compared to the resulting improvement in the quality of service.

The planning criteria which assume facility outages and are generally adopted to arrange the transmission expansion program vary from utility to utility depending on the state of load density of the area served and the degree of development of its power supply facilities.

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.

5.5 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 described in 5.3.3 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.

Facilities of larger capacity should be adopted. Some of the aged existing facilities will have to be replaced in consistency with this policy. It is recommendable to adopt transformer units of larger capacity and gas insulated switchgears (GIS) for substations, and bundle conductors for transmission lines.

(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.

5.6 Reliability Criteria and Overloading of Equipment

When a transmission system is planned on the basis of an (n-1) criterion, measures below are usually taken to avoid an interruption of power supply at the single contingency.

For example, more than two circuits are designed on a right-of-way to be operated in parallel with each other, or the transmission system is designed to form loops and more than two transformer banks are used in parallel.

However, from an economical point of view, at the single contingency the remaining facilities are generally allowed to be overloaded to some extent, though limited for short duration.

Fig. 5-5 shows an example of overload operation of a transmission line. Two circuits are operated in parallel, being initially loaded with 80% of its capacity each. When one circuit fails, the remaining circuit is loaded with 160% of its capacity for 10 minutes allowed.

The transmission power should be promptly decreased to 120% and in 20 minutes it should be reduced to the level of its capacity 100%.

Fig. 5-6 is an example of overload operation of a transformer in case three banks are used in parallel.

In the event of loss of either one transformer bank or generating unit connected with a lower voltage transmission system, each of the remaining banks which is initially loaded with 80% of its capacity can be overloaded with up to 150%. In 10 minutes, however, the load should be decreased to 120%, and then in 20 minutes it should be finally reduced to its capacity 100%.

Every electric power company in Japan has a standard of overloading operation for an individual transformer. Some of their standards are based on "A guide for operation of oil filled transformers" which has been issued by The Institute of Electrical Engineers of Japan (IEEJ).

The operation limit of equipment is normally determined from overloading capacity for a short duration, say 10-minute in Japan. This time duration is generally recognized as necessary to control load flows by system operation and to avoid stopping service of the remaining facilities due to overload.

5.7 Capacity of The Transmission Lines and Transformer Banks

The capacity of equipment at the planning stage depends on utility's way of thinking regarding overloading operation of equipment at the contingency. The equipment will be able to get out of the overloaded state by means of network switching, starting up and bearing a load on hot or spinning reserves and so forth.

In this study, the capacity of equipment is regarded as below, which will lead to a conservative design of transmission system.

If load flow is probable to exceed the following level in normal state, measures for reinforcement shall be taken to solve the problem.

(1) Transmission capacity of the overhead lines

a. Transmission capacity of the single-circuit line

Voltage kV	Conductor MCM ACSR	Transmission Capacity MVA
230	1 x 1272	429
	2 x 1272	858
	4 x 795	1,303
	4 x 1272	1,716
500	4 x 795	2,834
	4 x 1272	3,734

b. Transmission capacity of the double-circuit lines

In case of a loss of one circuit due to a fault, the other circuit should uninterruptedly send the same amount of power before the fault.

Therefore a double-circuit line should be treated as having the same capacity as a single-circuit line with the same conductor size.

c. Transmission capacity of the n circuits

Transmission capacity of the n circuits should be (n-1) times the capacity of a single-circuit line with the same conductor size.

(2) Transmission capacity of the underground lines

Underground lines will be used for sending power from substations on the present 230 kV ring to the substations which will be located in a densely populated area where rights-of-way for overhead transmission lines are not possible to be developed.

One circuit of underground cables and one transformer bank should form one unit and its transmission capacity should be determined from the transformer.

The scheme of this transmission system is shown on Fig.5-7.

Underground cables will also be used for the section of the transmission line placed in the vicinity of the airport where a structure to be installed is regulated by the height restriction.

The size and number of cables to be laid should be decided so as to have sufficient transmission capacity for load flows forecast in future.

(3) Maximum loading capacity of the transformer banks

In regard to transmission capacity of transformer banks, overloading operation of transformers should be taken into account in the event of a single contingency.

In this study, the maximum loading capacity and number of transformer banks are designed in principle according to the table below which refers to the guide issued by IEEJ. Following this, in the event of loss of one transformer bank, the remaining transformer banks could bear resulting overload for about 30 minutes.

We recommend, however, EGAT should study guides for operation of transformers in actual use in connection with the maximum loading to give normal life expectancy and according as the guides installation plan of transformers should be made.

Installed Capacity (MVA)	Maximum Loading (MVA)
200 x 2	250
200 x 3	480
200 x 4	690
200 x 5	900
200 x 6	1,100
250 x 2	320
250 x 3	600
300 x 2	380
300 x 3	720
300 x 4	1,040
300 x 5	1,350
600 x 2	760
600 x 3	1,440
600 x 4	2,080
600 x 5	2,700
750 x 2	950
750 x 3	1,800
750 x 4	2,580
750 x 5	3,370

A new substation should start with more than two transformer banks and an additional transformer bank should be installed when the integrated load flow of the paralleled transformer banks is probable to exceed the above maximum loading value.

5.8 The Present Power Supply Capability of The Greater Bangkok Area

The power supply capability of the Greater Bangkok Area is determined by the total capacity of the maximum loading of 230 kV transformers which supply power to the transmission systems of lower voltage level, namely 115 kV and 66 kV, of this area.

Table 5-2 shows the installed capacity and maximum loading of each substation in the area. Correlation between the installed capacity and maximum loading is as described in the previous section 5.7.

It is assumed in this table that when one transformer bank fails, remaining transformer banks can be loaded for a short term with 120% - 130% of the rated capacity until a prompt power flow control removes that overload situation.

In the Greater Bangkok Area, as of 1992, the total installed capacity and maximum loading of 230 kV transformers are 5,500 MVA and 4,100 MVA, respectively.

Supposing a power factor of transformer is 0.9, the power supply capability of this area is about 3690 MW as of 1992.

5.9 Image of the Transmission System in Future

The maximum power demand of MEA area was 3,993 MW in fiscal 1992. It is increasing at a high rate and forecast to be 7,472 MW in fiscal 2,000 and 10,264 MW in fiscal 2006. If an annual growth rate is assumed to be about 5% for farther years, the maximum power demand will exceed 13,000 MW in 2011.

EGAT has to urgently implement the development of power sources and the reinforcement of the transmission system to meet increasing demand.

Power required in the area is supplied by the power plants in this area, i.e. NORTH BANGKOK, SOUTH BANGKOK and BANG PAKONG, and the 500 kV and 230 kV network surrounding this area.

EGAT has a plan to build up 500 kV transmission system which links three substations, NONG CHOK, WANG NOI and SAI NOI outside the 230 kV transmission lines which encircle the Greater Bangkok Area. When this 500 kV link is completed, it will function to supply power to the Greater Bangkok Area together with the existing 230 kV transmission system and the power plants, i.e. SOUTH BANGKOK and BANG PAKONG, which are located in this area and its vicinity.

According to EGAT's power development plan, PDP 92-01(1), which was issued in September 1992, as shown in Table 5-3, the total capacity of power plants connected to 230 kV system of the Greater Bangkok Area will be 5,779 MW as of 2006. It is just about 56% of the forecasted peak demand of the MEA service area for the same year.

Supposing the power demand of the MEA service area after twenty years is a little less than 14,000 MW and power of 4,500 MW to 5,000 MW is supplied from the above power plants, the shortage of 9,000 MW to 9,500 MW must be supplemented by power generated in other areas.

It means that such a large amount of power must be sent through the 500 kV transmission network from the power sources to the Greater Bangkok Area and supplied by means of 500 kV/230 kV transformers at the 500 kV substations.

If a 500 kV substation comprises four transformer banks, 1,000 MVA each, the transmission system in and around the Greater Bangkok Area will need four 500 kV substations at least and eight rights-of-way for 230 kV transmission lines with a capacity 1,600 MW each to distribute the above power in this area.

In addition to the Nong Chok substation, EGAT is planning to build two 500 kV substations, SAI NOI and WANG NOI, on the outskirts of the metropolis.

Besides these three substations, however, another 500 kV substation should be installed in order to enhance a power supply capability from the west of the Greater Bangkok Area, and the Bangkok Noi substation is recommended to be strengthened by the introduction of 500 kV for this purpose.

Fig. 5-8 shows a preliminary image of the transmission system of the Grater Bangkok Area in future. The JICA team has developed this image to horizon-year power systems taking account of several factors and requirements peculiar to power system expansion of the area.

5.10 Main Points for Planning Horizon Year Transmission Systems

5.10.1 Expansion of the 500 kV System

Here are the matters the JICA team has especially paid attention to for planning the future transmission system of 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.

In full knowledge of these matters, the JICA team has examined measures for reinforcement of the transmission system. The plan of the future transmission system of high reliability has been made by introducing 500 kV voltage into the inside of the present 230 kV transmission line loops of the Greater Bangkok Area. The plan has been confirmed as reasonable by the power system analyses.

Besides the before-mentioned four substations, namely WANG NOI, NONG CHOK, SAI NOI and BANGKOK NOI, one or two 500 kV substations will be necessitated in the Greater Bangkok Area in future, if these substations have to supply some power to the substations located on the outside of the project area such as ANG THONG, SARABURI and so forth.

And also, to increase capability of supplying power to the center of Bangkok without obtaining new rights-of way, it will be indispensable to replace the existing line with a 500 kV line to introduce 500 kV system inside the project area.

Short-circuit currents in the transmission system of the Greater Bangkok Area will be effectively reduced by the introduction of 500 kV system and operation with the split of 230 kV system.

5.10.2 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 the Rangsit substation and North Bangkok substation, 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 (π) 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 230 kV line between the Nong Chok and On Nuch substations should be reinforced with a four-circuit line, the conductor of which will be 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 the 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 the Bang Pakong power station and the 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 the 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 populated areas

In order to increase power supply capability for densely populated areas, new 230 kV substations G, H, and J 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, A, BANG KAPI, SOUTH THONBURI and BANGKOK NOI by 230 kV underground cables.

The transmission system should adopt unit system in which the above substations 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 as shown on Fig. 5-7.

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.

5.10.3 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. 5-9 and 5-10 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 5-4 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.5-11 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 5-5 and 5-6 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. 5-12 shows the transmission systems of the Greater Bangkok Area at present and in horizon year.

Table 5 - 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	446	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 5 - 2 CAPACITY OF TRANSFORMER BANKS AT 230KV SUBSTATIONS IN THE GREATER BANGKOK AREA

As of 1992

Substation	Transformer Banks		
	Voltage (kV)	Installed Capacity (MVA)	Max. loading (MVA)
NORTH BANGKOK	230/72.5	1 x 200 3 x 33.3	135
BANG KAPI	230/69	3 x 200	480
BANGKOK NOI	230/69	2 x 200 6 x 33.3	480
SOUTH BANGKOK	230/72.5	4 x 200	690
	230/115	1 x 200	200
BANG PHLI	230/69	2 x 200	250
	230/115	2 x 200	250
LAT PHRAO	230/69	3 x 200	480
RANGSIT	230/72.5	3 x 200	480
	230/115	1 x 200 1 x 100	135
NONG CHOK	230/115	1 x 200	200
CHIDLOM	230/69	2 x 250	320
Total		5,500	4,100

Table 5 - 3 CAPACITY OF THE POWER SOURCES IN THE GREATER BANGKOK AREA

Power Plant	Existing (as of 1991) (MW)	Additional Installation (MW)	Retired (MW)	Total (as of 2006) (MW)
North Bangkok	237.5	0	237.5	0
South Bangkok	1330	335 (Combined Cycle Block 1) 600 (Combined Cycle Block 2)	0	2265
Bang Pakong	2276.6	198 (Combined Cycle Block 3-4 Steam) 2 x 600 (Thermal Units 3-4)	760.6	2914
Wang Noi	-	600 (Gas turbine)	-	600
Total	3844.1	2933	998.1	5779

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

Table 5 - 4 COMPARISON OF THREE-PHASE SHORT CIRCUIT CURRENTS OF THE 2011 YEAR SYSTEMS REGARDING POWER PLANT CONFIGURATION

230kV bus	Case 1 kA	Case 2 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 5 - 5 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 5 - 6 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
						500	4	500/230	5x750	3370	
BANGKOK NOI	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.

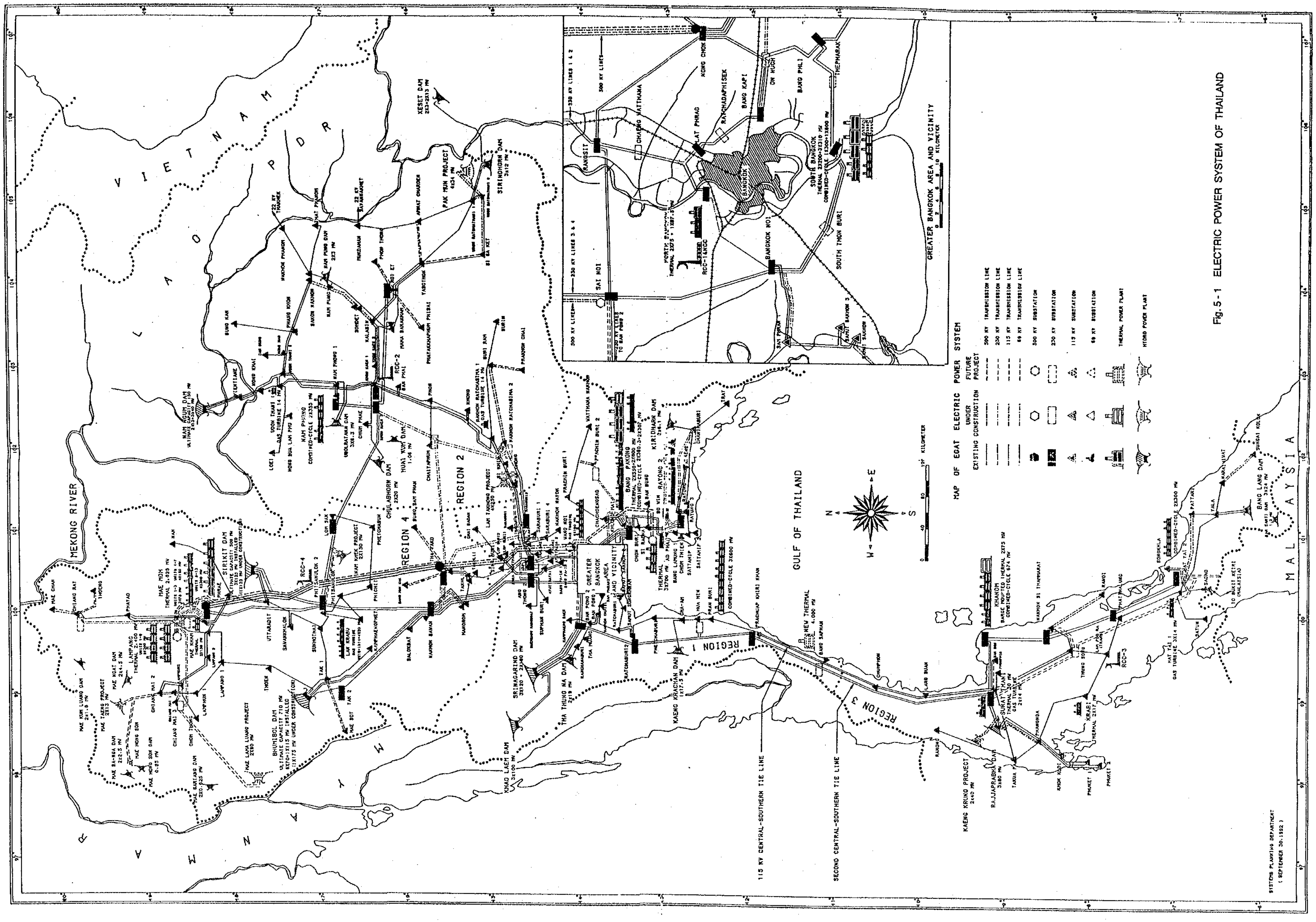


Fig.5-1 ELECTRIC POWER SYSTEM OF THAILAND

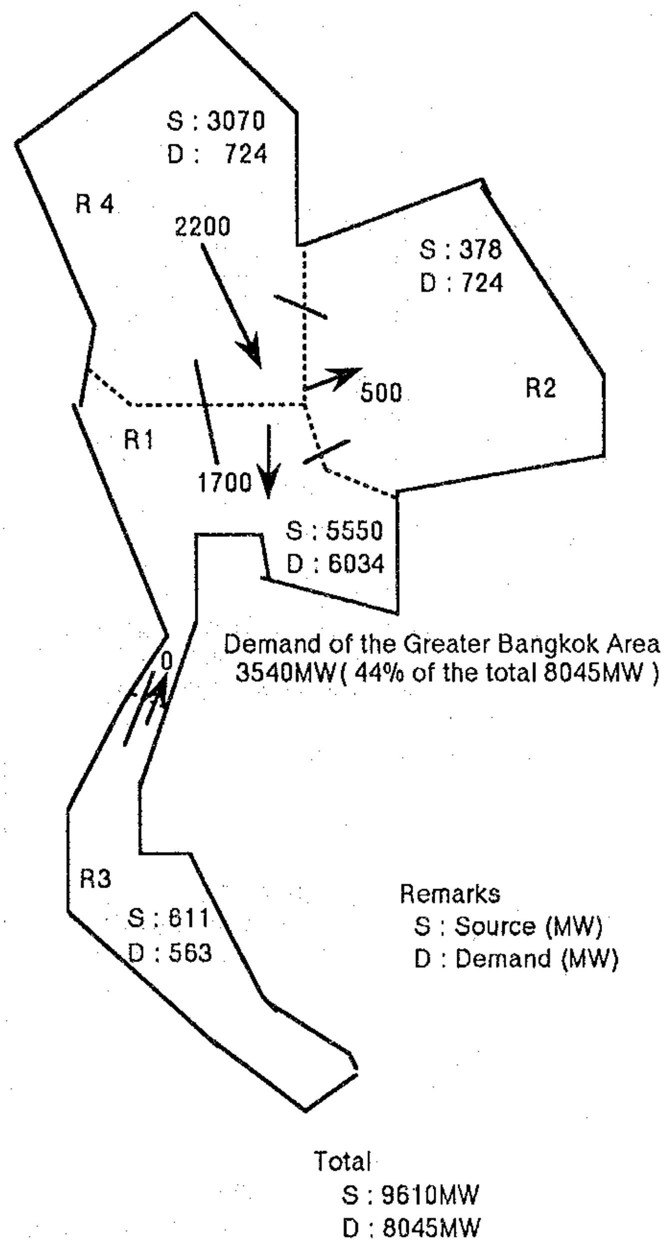


Fig. 5 - 2 ESTIMATED POWER TRANSMISSION AMONG REGIONS IN 1991

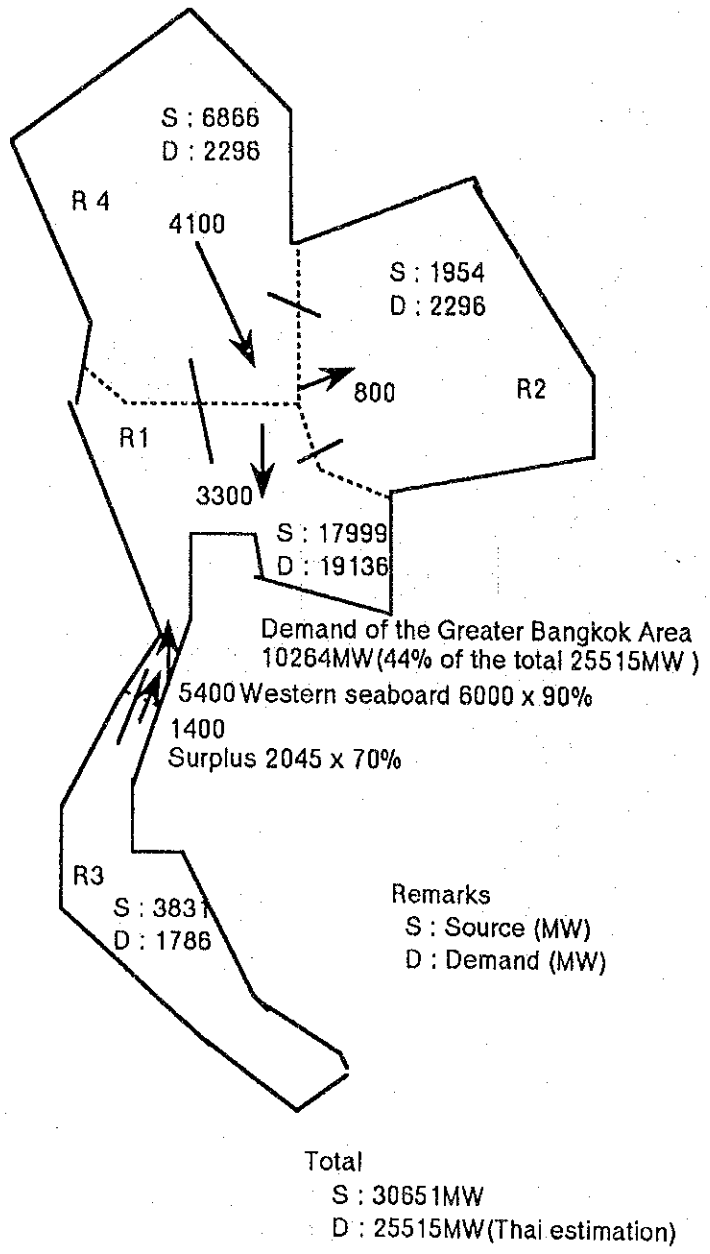
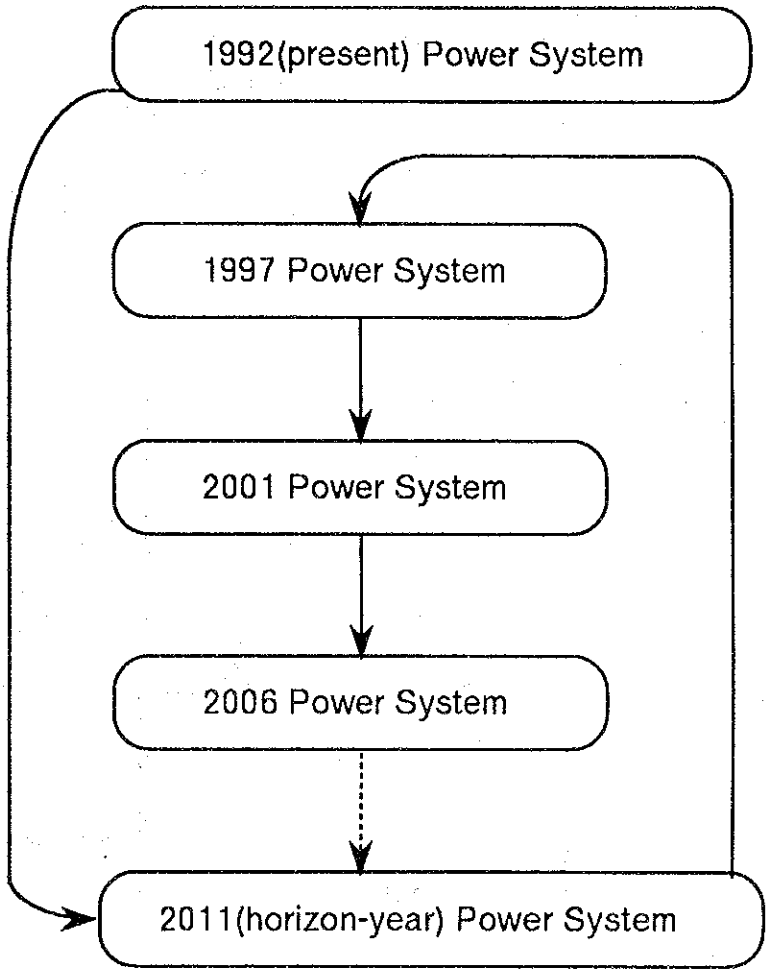


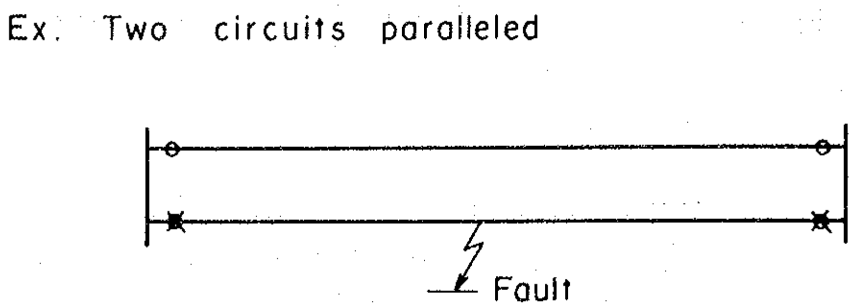
Fig. 5 - 3 ESTIMATED POWER TRANSMISSION AMONG REGIONS IN 2006

Fig. 5 - 4 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



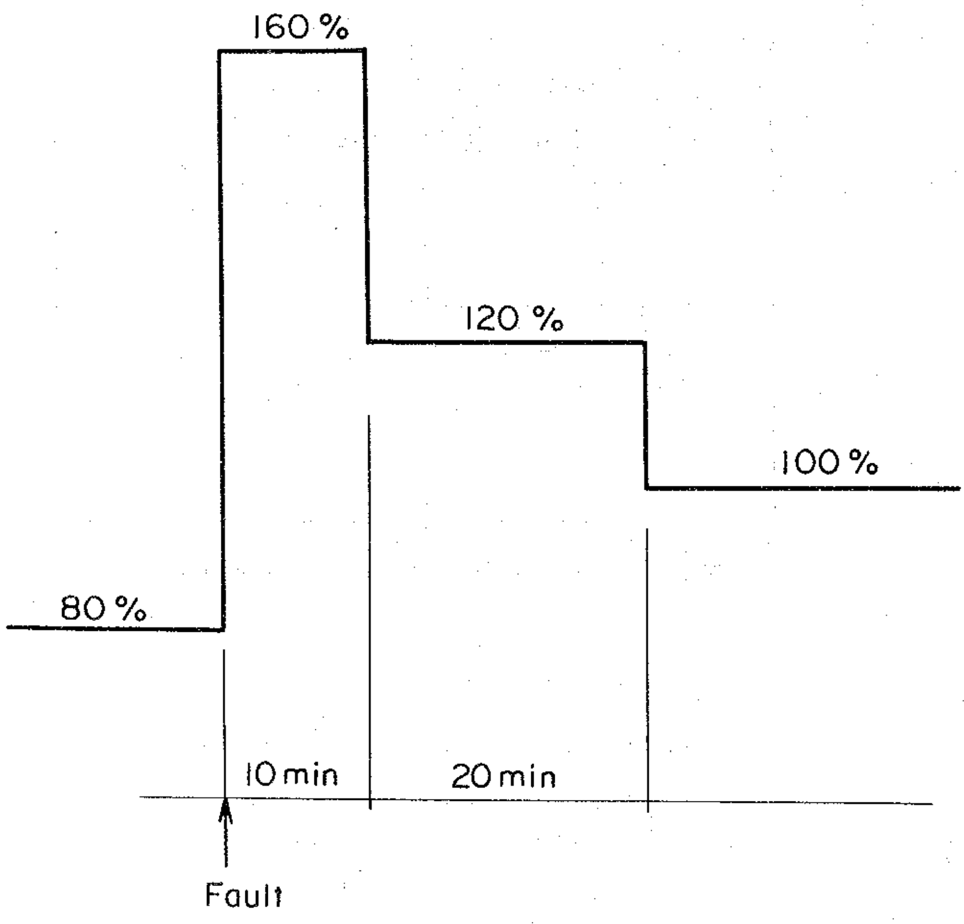
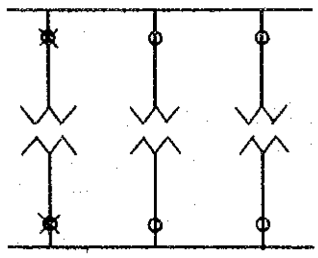


Fig. 5 - 5 EXAMPLE OF OVERLOAD OPERATION OF A TRANSMISSION LINE

Ex : Three banks paralleled



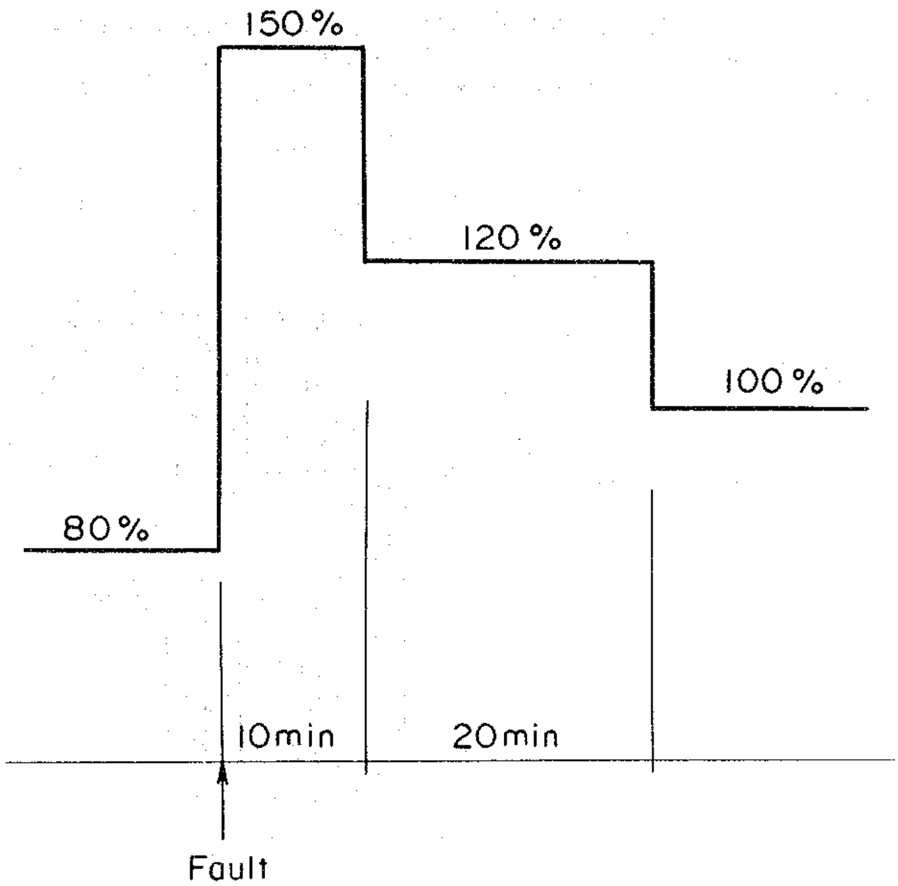
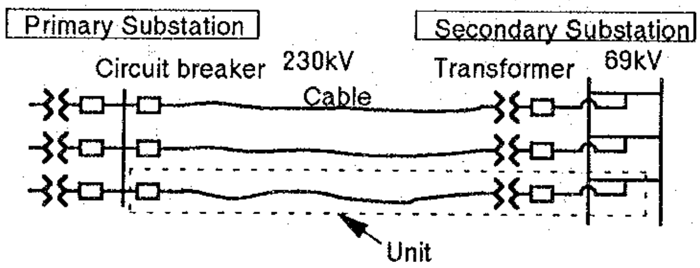


Fig. 5 - 6 EXAMPLE OF OVERLOAD OPERATION OF TRANSFORMER BANKS

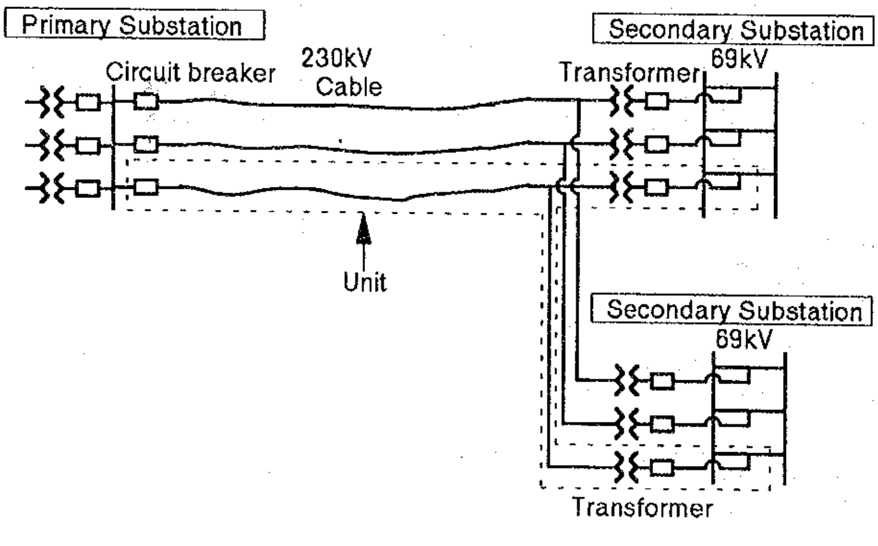
Fig. 5 - 7 Transmission System In The Densely Populated Area

(1) Single Unit System

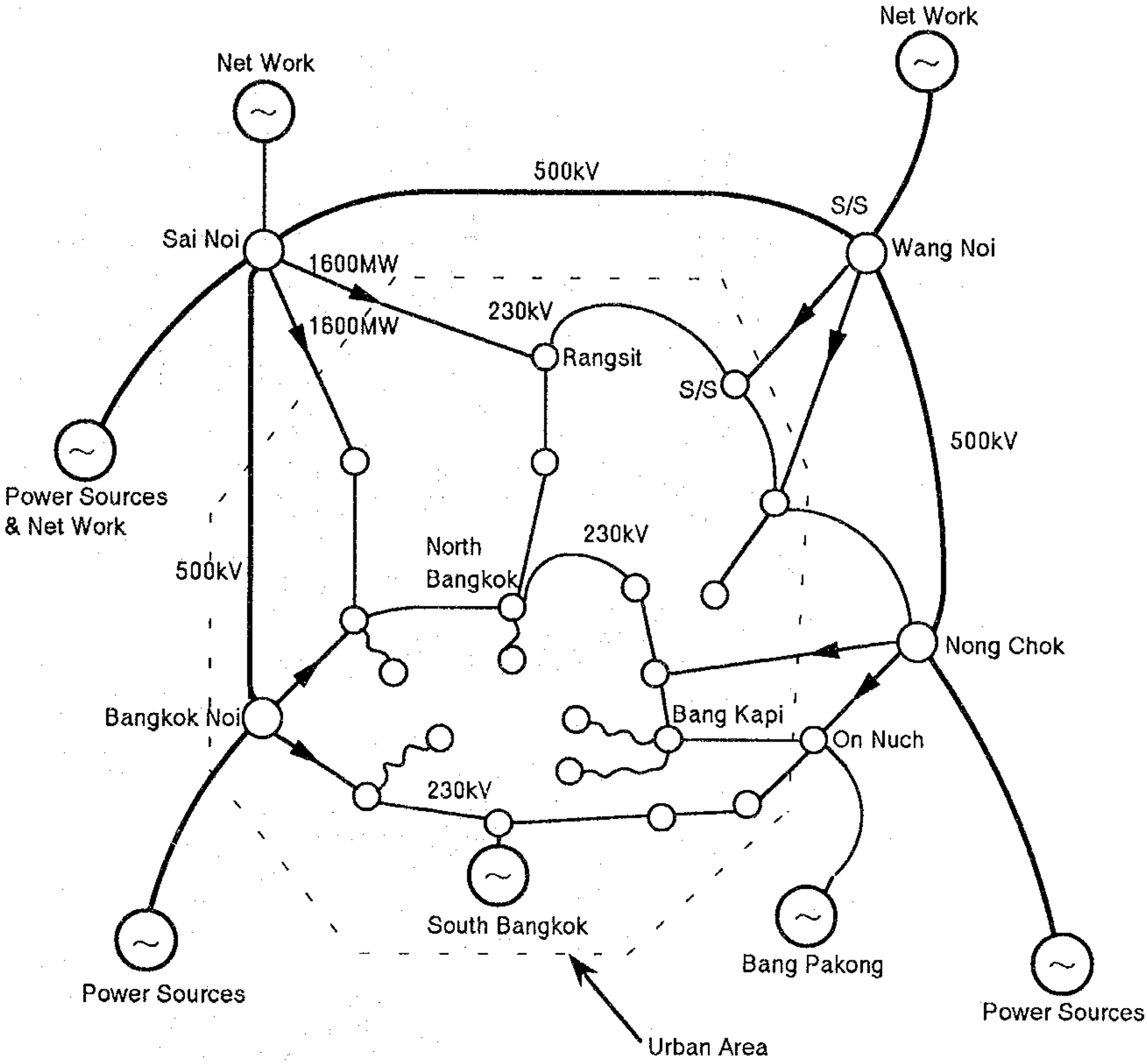


1. Load of the secondary substation should be restricted so as to supply power continuously even at a fault of one unit.
2. The system has high reliability due to its simplicity.

(2) Multi-terminal Unit System



1. The number of secondary substations which are comprised in a unit should bematch the capacity of the cable.
2. At a fault of a unit, transformers which belong in the fault unit stop operation simultaneously.
3. Load of the secondary substations should be restricted so that at a contingency the same amount of power as before the fault can be supplied continuously.

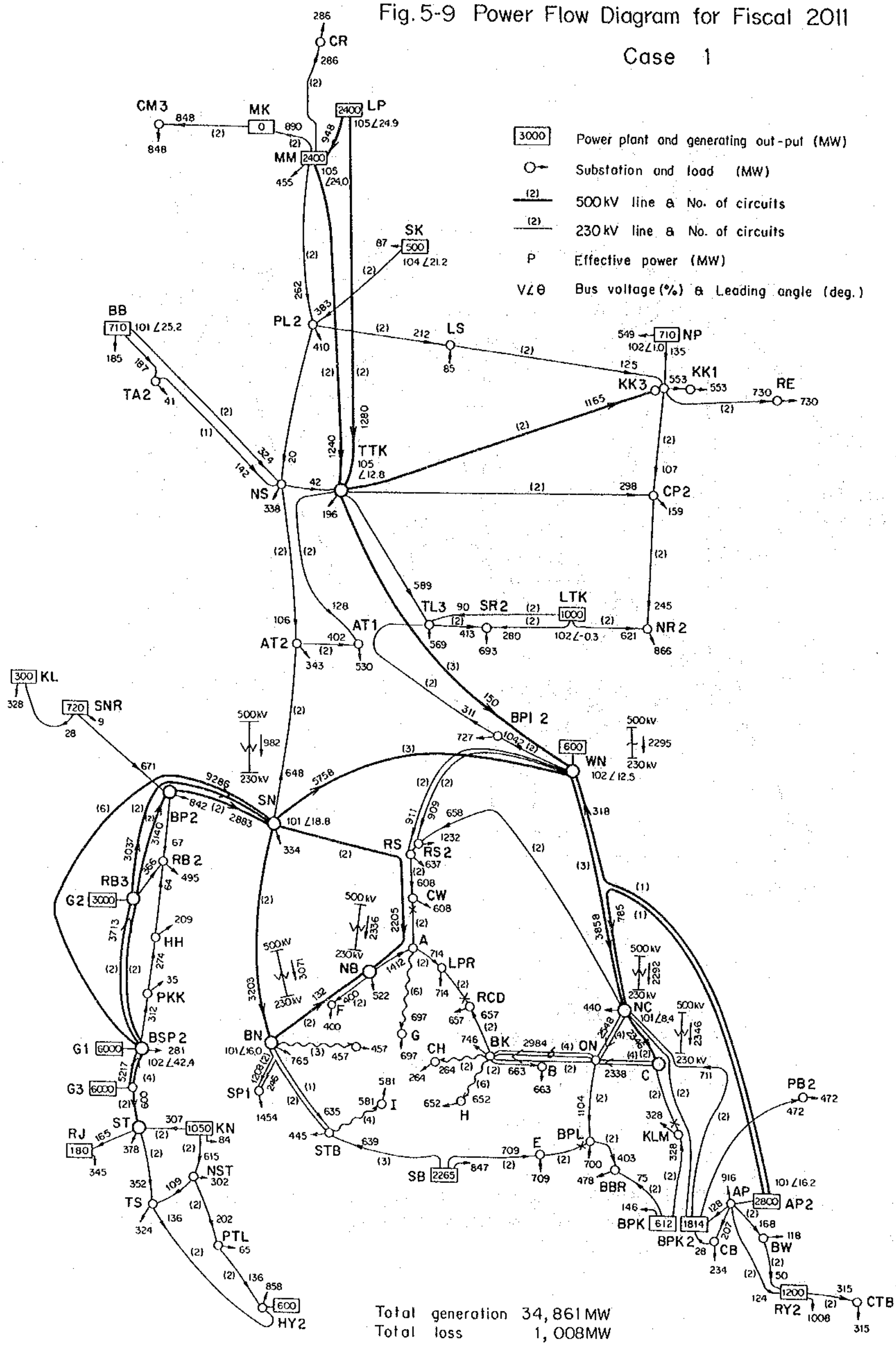


(1)	Power Demand	15,000 - 16,000MW
(2)	Supply From The 230kV System	4,000 - 5,000MW
(3)	Supply From The 500kV System = (1) - (2)	10,500 - 12,500MW

Fig. 5 - 8 PRELIMINARY IMAGE OF THE FUTURE TRANSMISSION SYSTEM OF THE GREATER BANGKOK AREA (AFTER 2011)

Fig. 5-9 Power Flow Diagram for Fiscal 2011

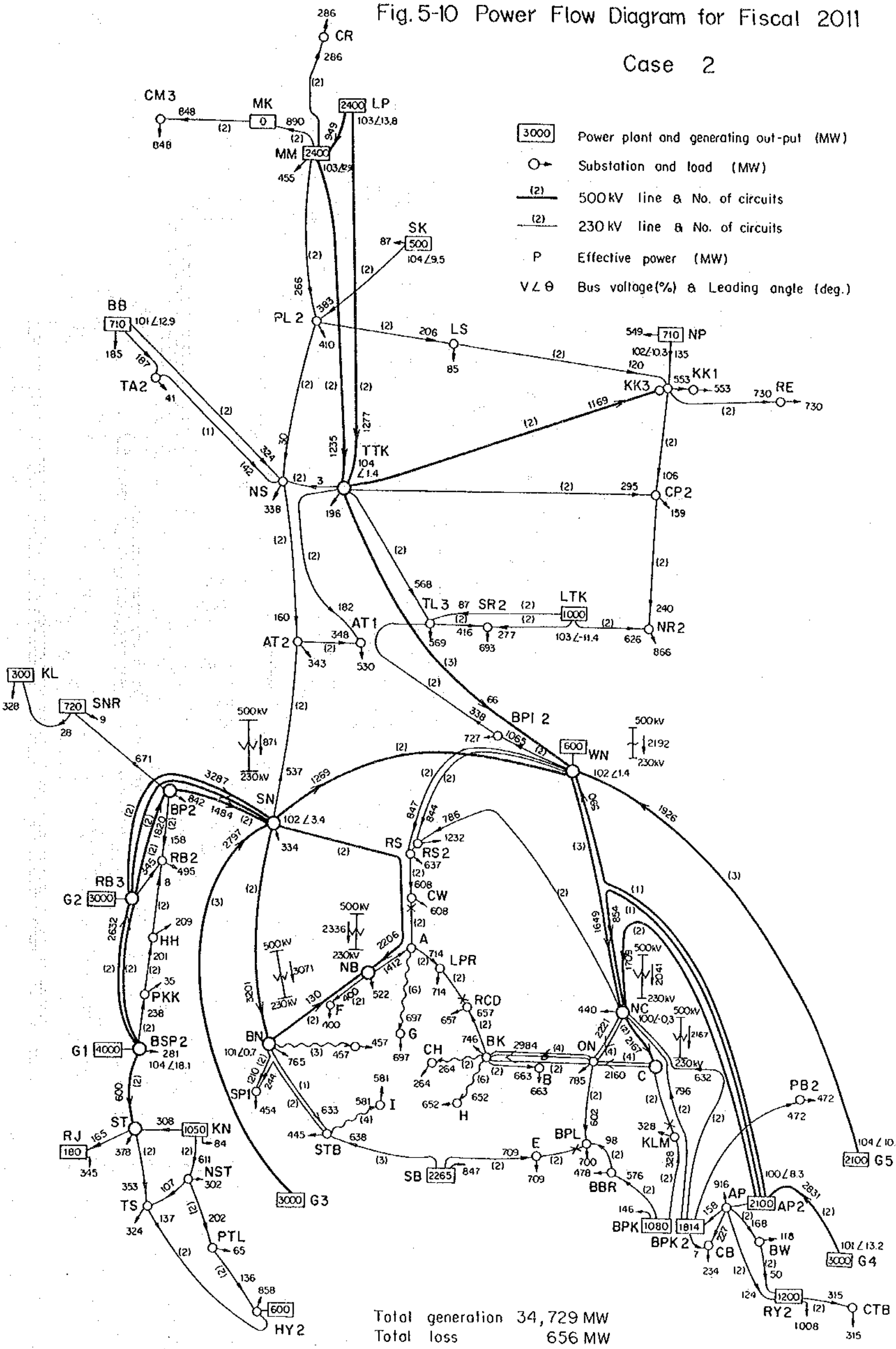
Case 1



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

Fig. 5-10 Power Flow Diagram for Fiscal 2011

Case 2



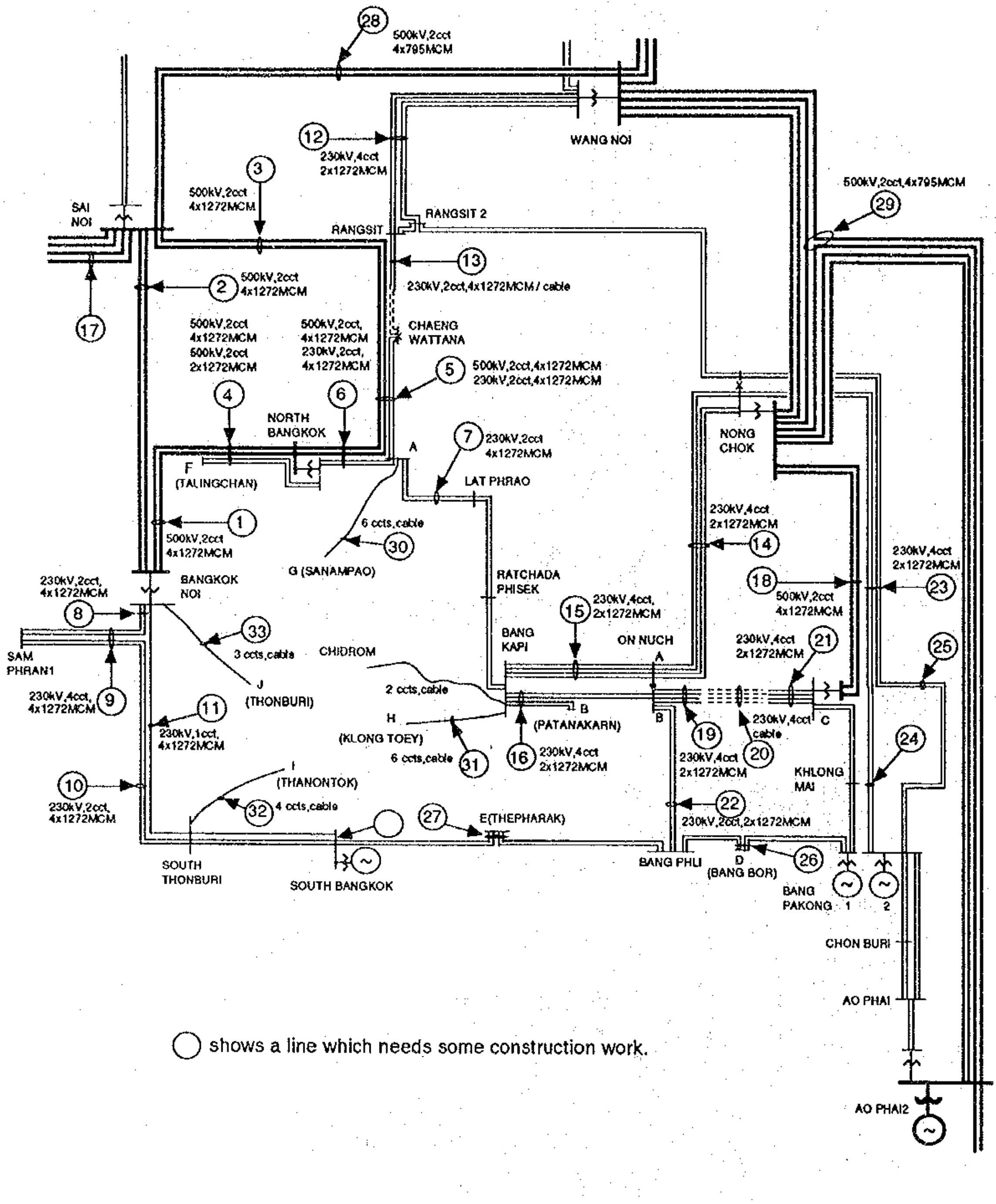
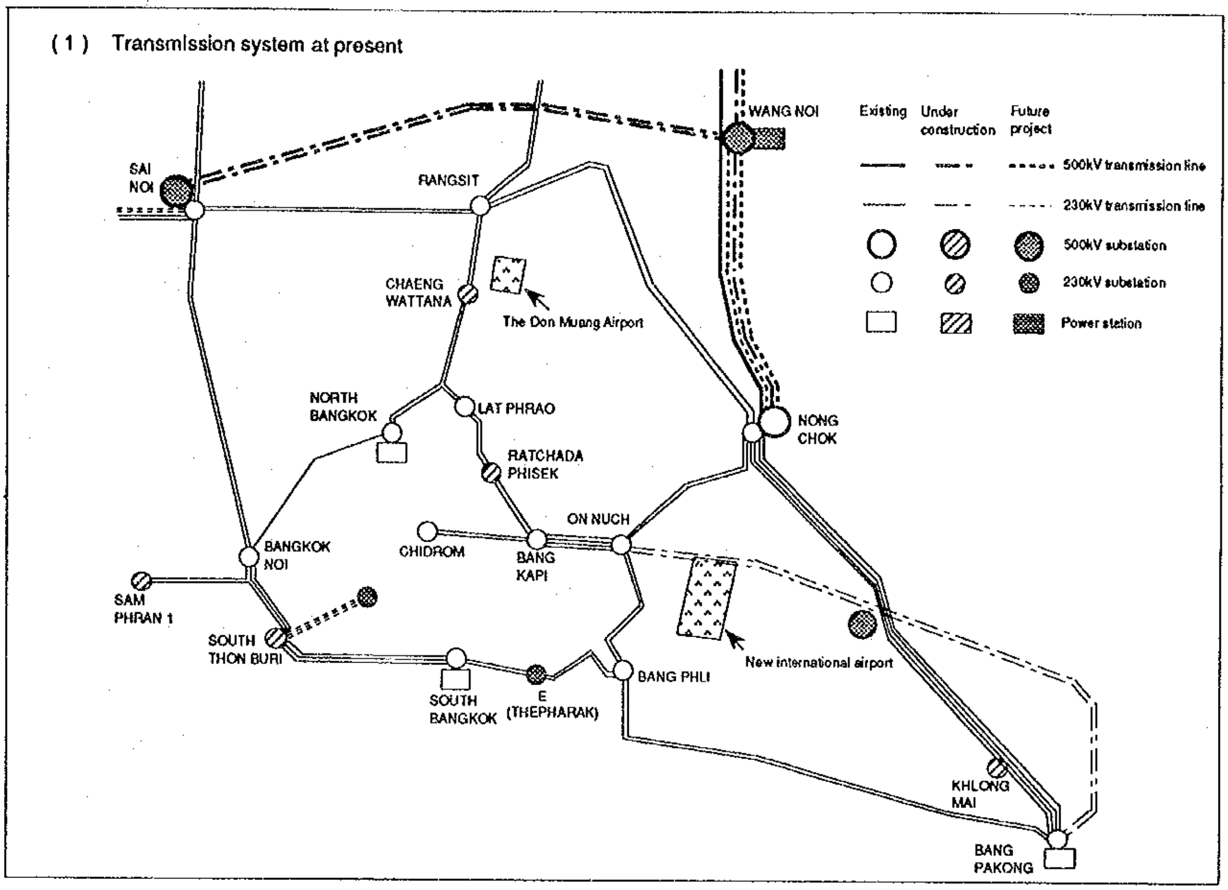


Fig. 5-11 TRANSMISSION SYSTEM OF THE GREATER BANGKOK AREA AFTER 2011



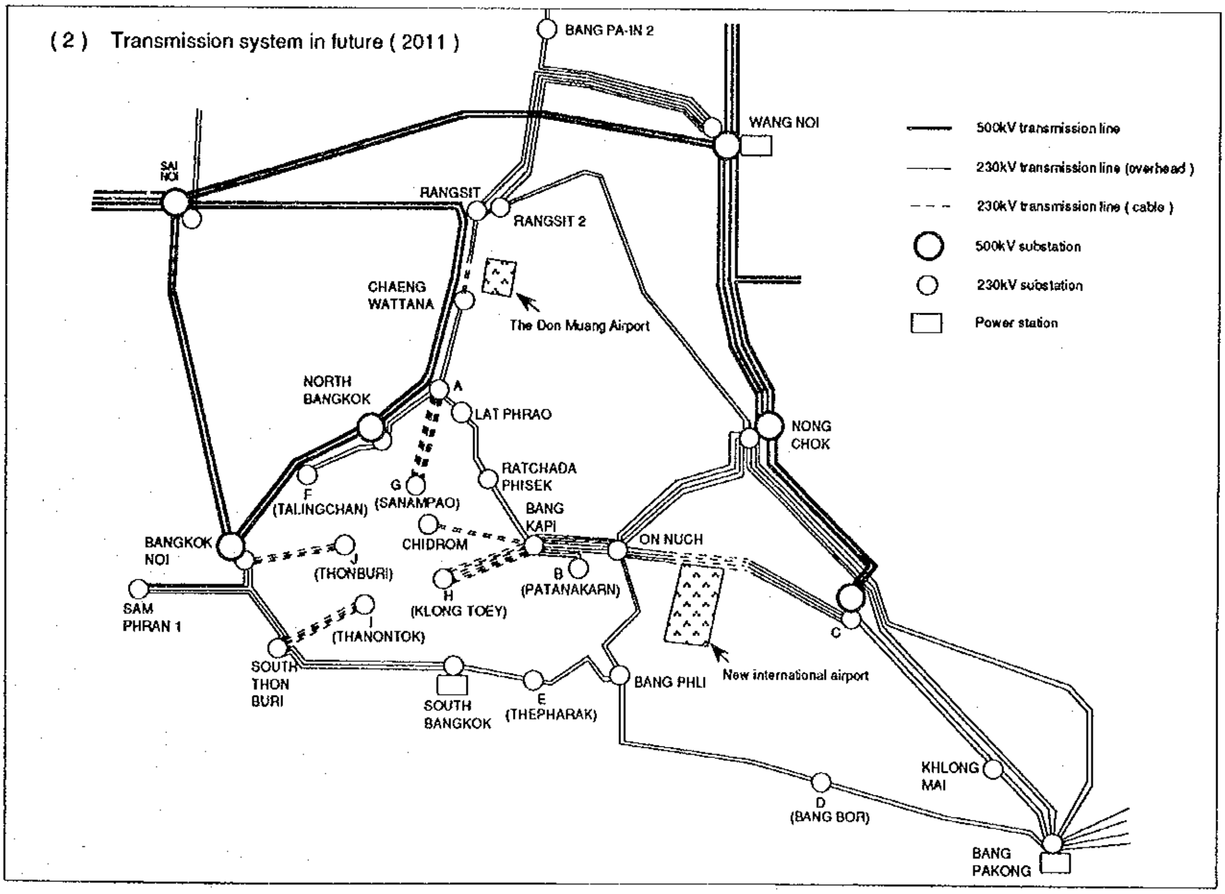


Fig. 5-12 TRANSMISSION SYSTEMS OF THE GREATER BANGKOK AREA AT PRESENT AND IN FUTURE

CHAPTER 6

POWER SYSTEM ANALYSIS

CHAPTER 6 POWER SYSTEM ANALYSIS

6.1 Conditions of Analysis

(1) Fiscal Year under Study

Year 1997, 2001, 2006, 2011

(2) Network System of Each Year under Study

Year 1997, 2001, 2006

The existing plans for expansion of the power system, which has been formulated by EGAT are reviewed and investigated. Investigations are focused on the capacity appraisal of transmission lines and transformers, and in reducing the short circuit current level, and maintaining power system stability.

Load flow, short circuit current and power stability analysis have to be carried out for the whole EGAT system in each studied year in order to identify the needs of transmission network expansions and reinforcements.

Year 1997	Fig.6-1-1	Single Line Diagram
	Fig.6-1-2	Impedance Map
Year 2001	Fig.6-1-3	Single Line Diagram and Impedance Map
Year 2006	Fig.6-1-4	Single Line Diagram and Impedance Map

Year 2011

The 2011's network system is assumed to be based on expanded 2006's network system. However, the power development will be required because of increasing power demands. According to latest EGAT's Power Development Plan (PDP 92-01), the new power plants from 2006 to 2011 are assumed that four units of nuclear power plant rated 1000MW each will be located in the southern part of Thailand, that is located at same site as Nuclear Unit 1-2.

(3) Load Forecast at each substation

Table 6-1-1 shows system peak load and MEA peak load of each substation in Thailand. This load forecast is formulated by EGAT. The load factor of system peak is 85% at each substation.

(4) Transmission System Planning Critera of EGAT

a) The steady state system voltage at any busbar in transmission system should be 98-105% of the nominal voltage under normal condition and 92-108% under contingency (emergency) condition.

b) The transmission system must be designed so that it will operate satisfactorily under both normal and contingency conditions. According to EGAT's practice, the single contingency (n-1) criterion is adopted, i.e. the system must be stable during and after the disturbances in the system resulting in the loss of one generating unit or one circuit of transmission line, as well as no loss of load is allowed.

c) The bulk power system can be maintained stable during and after most severity of following contingency:

A permanent three-phase fault on any generator or transmission circuit, with normal fault clearing and without reclosing.

d) Normal fault clearing time to be used shall be as follows:

500KV system : 4 cycles
230KV system : 5 cycles

e) Less probable, more severe disturbances, involving multiple contingencies; or the following unlikely contingencies are not evaluated.

Loss of an entire generating plant
Loss of all circuits on common right-of-way
Loss of one busbar section
Three-phase fault with delayed fault clearing

6.2 Year 1997

(1) Year 1997's Network System

Fig. 6-1-1 shows network system in year 1997.

The capacities of reactive power compensator (shunt reactor) for each 500kV transmission line installed at substations within the Greater Bangkok Area shows at following table.

Substation	Shunt Reactor	Transmission Line
NONG CHOK	40MVA 2units 75MVA 2units	NONG CHOK-SAI NOI 120.0km 2cct NONG CHOK-THA TAKO 208.0km 1cct NONG CHOK-THA TAKO 215.0km 1cct
SAI NOI	40MVA 2units	NONG CHOK-SAI NOI 120.0km 2cct

(2) Load Flow

Fig. 6-2-1 shows the load flow of 500kV and 230kV system in the case of system peak.

The results of load flow:

The busbar-voltage at each substation can be maintained within steady state voltage criteria (98 - 105%). The required capacities of reactive power compensator (shunt capacitor) at each substation in the Greater Bangkok Area are shown at Table 6-1-2, capacities of shunt capacitor in year 1997 are planned by EGAT.

No transmission line is overloaded under normal condition.

(3) Short Circuit Current

The short circuit current levels at all 500kV and 230kV busbars are less than 50kA that is the interrupting rating of 500kV and 230kV circuit breakers. Fig. 6-2-2 shows the short circuit current and short circuit capacity of the whole 500kV and 230kV system in Thailand.

(4) Load Flow under Contingency Condition

According to EGAT's transmission system planning criteria, under loss of one circuit of transmission lines or loss of one bank of 500kV/230kV transformers, no loss of load is allowed. So, load flow under contingency condition, i.e. loss of one bank of 500kV/230kV transformers or one circuit of transmission lines, should be checked that any transformers and any transmission lines can be maintained within allowable capacity.

Contingency Condition;

500kV transformer	:	Out-of service of one bank
transmission line	:	Out-of service of one circuit
		Thermal limit of conductors
		1x1272MCM ACSR 230KV 429MVA
		2X1272MCM ACSR 230KV 858MVA

Contingency Condition	Under Normal Condition	Under Contingency Condition
out-of service of one NONG CHOK 500kV/230kV transformers 600MVA 2-banks	296MW+j 63MVar (303MVA:50.5%) (per bank)	436MW+j87MVar (445MVA:74%)
out-of service of one SAI NOI 500kV/230kV transformers 600MVA 2-banks	450MW+j161MVar (478MVA:80%) (per bank)	643MW+j220MVar (680MVA:113%)
one circuit of 230kV NONG CHOK - ON NUCH double circuit is tripped 2x1272MCM ACSR 2cct	463 MW/cct	673 MW
one circuit of 230kV BANG KAPI - RATCHADA double circuit is tripped 2x1272MCM ACSR 2cct	421 MW/cct	764 MW
one circuit of 230kV BANGKOK NOI - SAI NOI double circuit is tripped 1x1272MCM ACSR 2cct	233 MW/cct	323 MW
one circuit of 230kV BANG PHLI -BANG PAKONG double circuit is tripped 2x1272MCM ACSR 2cct	435 MW/cct	619 MW

No trasmission line is overloaded under contingency condition.

The 500kV/230kV 600MVA transformer at Sai Noi substation is expected to be overloaded during one bank outage. In the case of system peak, remaining transformer is expected to be 113% overloading. Taking account of short-time overloading requirement upon transformer, 113% overloading (advanced loading is 80%) is allowed.

- In the case of 500kV/230kV 750MVA transformer at Sai Noi substation:

  Impedance of 750MVA transformer is adopted the same value as that of 600MVA transformer on the base of machine MVA, that is 13.06%.

  Fig. 6-2-3 shows the result of load flow and short circuit current in the Greater Bangkok Area. No transmission line is overloaded under normal condition. The short circuit current levels are less than 50kA at whole 500kV and 230kV bus in the case of 750MVA 2-bank transformers at SAI NOI substation.

Contingency Condition	Under Normal Condition	Under Contingency Condition
out-of service of one SAI NOI 500kV/230kV transformers 750MVA 2-banks	489MW+j174MVar (519MVA:69%) (per bank)	725MW+j245MVar (765MVA:102%)

- Taking account of load flow under contingency condition and increasing power demands in future, adopting 750MVA unit transformer at Sai Noi substation is recommended.

(5) System Stability

Generator constants are shown at Table 6-2-1.

AVR and GOV block and control constans are used EGAT's data.

The generators with PSS (Power System Stabilizer) are following:

REGION-3	BANG LANG		3x 24MW
	RAJJAPRABHA		3x 80MW
	KAENG KRUNG		2x 40MW
	KHANOM		2x 75MW + C.C. 674MW
REGION-4	MAE MOH	unit 4-7	4x150MW
		unit 8-13	6x300MW
	MAE KHAM		2x150MW
REGION-1	EASTERN		
	BANG PAKONG thermal		2x550MW + 2x600MW
REGION-1	WESTERN		
	SRINAGARIND unit 4-5		2x180MW
	KHAO LAEM		3x100MW
	LOWER CENTRAL C.C.		2x600MW

PSS-block and constants are used EGAT's data.

$$Pg \rightarrow -0.75\frac{5.0\,S(1+0.06S)(1+0.06S)}{(1+5.0S)(1+0.18S)(1+0.18S)} \rightarrow \text{to AVR}$$

Limiter: 0.1pu / -0.1pu

- The bulk power system can be maintained stable during and after 500KV transmission line contingency (three-phase fault with normal fault clearing).

Fig.6-2-4 shows the results of the system stability in the case of 500kV transmission line fault. Figures show relative rotor angles of typical generators in each region. The basis of angle is assumed Bang Pakong thermal generator.

CASE-No.	Fault Transmission Line (fault point)	Stability Result
97-TMM	MAE MOH - THA TAKO (MAE MOH)	stable
97-NTT	THA TAKO - NONG CHOK (THA TAKO)	stable
97-SNN	SAI NOI - NONG CHOK (NONG CHOK)	stable
97-SRR	SAI NOI - RATCHABURI 3 (RATCHABURI 3)	stable

Fig. 6-2-5 shows fluctuation of 230kV bus voltage at each substation in the Greater Bangkok Area during and after a permanent three-phase fault at Bang Pakong bus and one unit of Bang Pakong thermal plant (600MW) tripped with normal fault clearing. The steady state system voltage at any busbar in the Greater Bangkok Area can be maintained within voltage criteria (92~108%) under contingency condition.

6.3 Year 2001

(1) Year 2001's Network System

Fig. 6-1-3 shows single line diagram of 2001's network system.

The expansion plan in the Greater Bangkok Area from 1997 to 2001, which has been formulated by EGAT are following:

- 500kV transmission system

AO PHAI 2 - NONG CHOK	4x 795MCM ACSR 1cct 170km
AO PHAI 2 - SAI NOI	4x 795MCM ACSR 1cct 256km
BANG SAPHAN - RATCHABURI 3	4x1272MCM ACSR 2cct 275km

The capacities of reactive power compencator (shunt reactor) for each 500kV transmission line installed at substations in the Greater Bangkok Area shows at following table.

Substation	Shunt Reactor	Transmission Line
NONG CHOK	40MVA 75MVA 2units 55MVA	NONG CHOK-SAI NOI 120km 1cct NONG CHOK-THA TAKO 208km 1cct NONG CHOK-THA TAKO 215km 1cct NONG CHOK-AO PHAI 170km 1cct
SAI NOI	40MVA 95MVA	NONG CHOK-SAI NOI 120km 1cct SAI NOI-AO PHAI 256km 1cct

- 500kV/230kV transformer
  NONG CHOK 3x600MVA
  SAI NOI 4x600MVA

- 230kV transmission system

BANG KAPI - RATCHADAPHISEK	2x1272MCM ACSR 2cct (totally 4cct)
NONG CHOK - ON NUCH	2x1272MCM ACSR 2cct (totally 4cct)
RANGSIT - CHAENG WATTHANA	2x1272MCM ACSR 2cct
BANGKOK NOI - SAI NOI	2x1272MCM ACSR 2cct

(2) Load Flow

Fig. 6-3-1 shows load flow based on EGAT's expansion plan. Under normal condition, 500kV/230kV 600MVA transformer at Sai Noi substation (4-banks) are overloaded. Sai Noi substation requires 5-banks of 600MVA transformer in year 2001.

- Fig. 6-3-2 shows load flow in the case of 5-bank transformers at Sai Noi substation. The busbar voltage at each substation can be maintained within steady state voltage criteria (98-105%).

  The required capacities of reactive power compensators (shunt capacitor) at each substation in the Greater Bangkok Area are shown at table 6-1-2.

- No transmission line is overloaded under normal condition.

(3) Short Circuit Current

Fig. 6-3-3 shows the short circuit current and short circuit capacity of whole 500kV and 230kV system in the case of 5-bank transformers at Sai Noi substation. The short circuit currents at Nong Chok and On Nuch 230kV busbar exceed 50kA.

NONG CHOK 230KV busbar	56.9kA
ON NUCH 230KV busbar	55.1kA

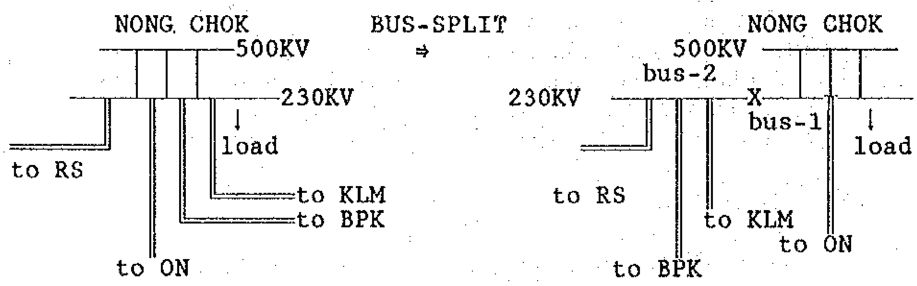
(4) Countermeasures for Reducing Short Circuit Current Level

In order to reduce the short circuit current levels at Nong Chok and On Nuch substation, it will be necessary to make reconfiguration of 230kV system in the Greater Bangkok Area.

Basically, maintaining EGAT's expansion plan in year 2001, following countermeasures can be taken for reducing short circuit currents levels.

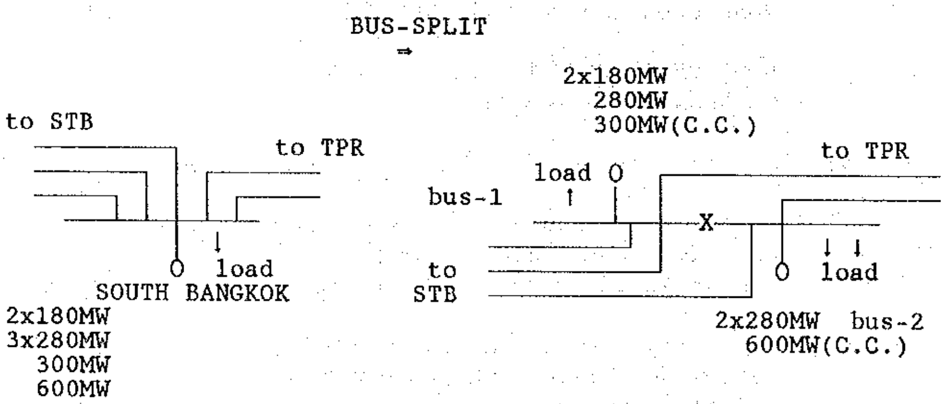
a) NONG CHOK 230kV BUS-SPLIT

The method of splitting 230kV busbar at Nong Chok substation is referred to EGAT's planning in year 2006. Nong Chok 230kV bus is split with quadruple circuit to On Nuch, three 500kV/230kV transformers and distribution transformers connected to bus 1; while double circuit to Rangsit, double circuit to Bang Pakong and double circuit to Khlong Mai connected to bus 2. The configuration of Nong Chok 230kV bus is shown at following figure.



b) SOUTH BANGKOK BUS-SPLIT

The method of splitting 230kV busbar at South Bangkok substation and power station is adopted EGAT's plan (referred to REPORT NO. 81200-3533 "TRANSMISSION SYSTEM FOR POWER PLANT PROJECT BLOCK 2 (600MW)"). The 230kV bus at South Bangkok substation is split with two circuits of triple circuit to South Thon Buri, one circuit of double circuit to Thepharak, thermal power plants (2x200MW and 310MW), combined cycle plant block-1 (300MW) and 69kV distribution transformers connected to bus 1; while one circuit of triple circuit to South Thon Buri, one circuit of double circuit to Thepharak, thermal power plants (2x310MW), combined cycle plant block-2 (600MW), 69kV and 115kV distribution transformers connected to bus 2. The configuration of South Bangkok 230kV bus is shown at following figure.



- The results of short circuit current levels which have been taken above mentioned countermeasures are summarized at following table.

	BASE-CASE	CASE-1	CASE-2	CASE-3
NONG CHOK	56.9 kA	56.9 kA		
BUS-1			41.4 kA	41.1 kA
BUS-2			36.1 kA	36.1 kA
ON NUCH	55.1 kA	55.0 kA	49.6 kA	49.6 kA
SAI NOI	49.9 kA	49.8 kA	49.8 kA	49.7 kA
SOUTH BANGKOK	49.8 kA		49.3 kA	
BUS-1		40.4 kA		40.1 kA
BUS-2		38.8 kA		38.5 kA

*countermeasures for reducing short circuit level

BASE-CASE : EGAT's plan
CASE-1 : SOUTH BANGKOK BUS-SPLIT CASE
CASE-2 : NONG CHOK 230KV BUS-SPLIT CASE
CASE-3 : SOUTH BANGKOK and NONG CHOK 230KV BUS-SPLIT CASE

- For reducing short circuit current level at Nong Chok 230kV busbar, splitting of Nong Chok 230kV bus by year 2001 is recommended, with quadruple circuit to On Nuch, three 500kV/230kV transformers and distrubution transformers connected to bus 1; while double circuit to Rangsit, double circuit to Bang Pakong and double circuit to Khlong Mai connected to bus 2.

  Fig. 6-3-4 shows the result of load flow and short circuit current in the case of splitting of both Nong Chok 230kV bus and South Bangkok bus. No transmission line is overloaded under normal condition.

(5) Load Flow under Contingency Condition

In the configuration (Fig. 6-3-4) for reducing short circuit current levels, load flow under contingency condition should be checked that any transformers and any transmission lines can be maintain within allowable capacity to prevent cascaded tripping during single circuit outage.

Contingency Condition

500kV transformer : Out-of service of one bank
transmission line : Out-of service of one circuit
Thermal limit of conductors
1x1272MCM ACSR 230kV 429MVA
2x1272MCM ACSR 230kV 858MVA
4x1272MCM ACSR 230kV 1716MVA

Contingency Condition	Load Flow under Normal Condition	Load Flow under Contingency Condition
out-of service of one 500kV/230kV SAI NOI transformer 750MVA 4-banks	639MW+j 78MVar (644MVA: 86%) (per bank)	795MW+j103MVar (802MVA: 107%) (per bank)
one circuit of 230kV BANGKOK NOI - SAI NOI double circuit is tripped 2x1272MCM 2cct	643.5MW+j84MVar (per cct)	933MW+j165MVar overload
one circuit of 230kV SAI NOI - RANGSIT double circuit is tripped 2x1272MCM 2cct	572MW+j83MVar (per cct)	840MW+j 83MVar critical load
one circuit of 230kV RANGSIT-CAENG WATTHANA double circuit is tripped 2x1272MCM 2cct	438.5MW+j68MVar (per cct)	783MW+j134MVar
one circuit of 230kV BANG PHLI - BANG PAKONG double circuit is tripped 2x1272MCM 2cct	439.6MW+j87MVar (per cct)	661MW+j135MVar
one circuit of 230kV ON NUCH - BANG PAKONG double circuit is tripped 2x1272MCM 2cct	486MW+j 70MVar (per cct)	656MW+j104MVar

- The 500kV/230kV transformers at Sai Noi substation are operated with overloading during one bank outage. Taking account of short-time overloading requirement upon transformers, 107% overloading (advanced loading is 86%) is allowable operation.

- This network system (Fig. 6-3-4) will pose 230kV Bangkok Noi - Sai Noi line (2x1272MCM ACSR conductor :858MVA) overloading problems during single circuit outage contingency (single circuit trip on Bangkok Noi - Sai Noi 230kV line).

(6) Transmission System Expansion Plan

- BANGKOK NOI - SAI NOI 29.6km

  According to EGAT's transmission system expansion plan, existing 230kV double circuit is modified from 1x1272MCM ACSR conductor per phase to 2x1272MCM ACSR conductor per phase upto year 2001. However, these conductors will cause overloading problem during single circuit outage in 2001's network system. Therefore, this section should be reinforced with 230kV four-circuit steel tower with 2x1272MCM ACSR conductor per phase or with 230kV double circuit steel tower with 4x1272MCM ACSR conductor per phase to save right-of way, or be augmentated with 500kV transmission line. From Chapter-5 this section should be augmentated with 500kV transmission line for a long future.

- Construction schedule related to augmentation of BANGKOK NOI - SAI NOI line designed with 500kV specification

  During construction for augmentation of Bangkok Noi - Sai Noi line designed with 500kV specification , existing 230kV double circuit will be removed. In the configuration under construction on Bangkok Noi - Sai Noi line section, routes to deliver power at Bangkok Noi substation are single circuit with 1x1272MCM ACSR conductor on North Bangkok - Bangkok Noi, and double circuit with 2x1272MCM ACSR conductor on Soutuh Thon Buri - Bangkok Noi. In decision of construction schedule, load flow analysis under construction should be carried out in each year and each construction schedule in order to check overloading problems.

a) Year 1997

When Bangkok Noi - Sai Noi line is constructed at first, Rangsit - Chaeng Watthana line (1x1272MCM ACSR 429MVA) is expected to be overloaded at system peak in year 1997. The construction of Rangsit - Chaeng Watthana line at first solves line overloading ploblems. However, construction of Rangsit - Chaeng Watthana line in year 1998 cause overloading on Bangkok Noi - Sai Noi line (1x1272MCM ACSR 429MVA).

Fig. 6-3-5 shows the result of load flow under construction of Rangsit - Chaeng Watthana line section in year 1997.

From Chapter-5, Rangsit - Chaeng Watthana line (8.0km) is reinforced with 500kV double circuit with 4x1272MCM ACSR conductor per phase and 230kV double circuit with 2x1272MCM ACSR conductor per phase in common steel tower. However, in the area controlled by regulation concerning height restriction of structures built around the airport, 230kV double circuit is constructed by underground cable. The double circuit designed with 500kV specification will be a portion of North Bangkok - Sai Noi 500kV transmission line and will be operated with 500kV after completion of North Bangkok - Sai Noi 500kV transmission line.

b) Year 1998

Fig. 6-3-6 shows the result of load flow under construction of Nong Chok - On Nuch line section in 1998's network system.

The Nong Chok - On Nuch line (16.8km) is expanded from 230kV double circuit to quadruple circuit with 2x1272MCM ACSR conductor per phase. The expansion plan of the 230kV Nong Chok - On Nuch line from 230kV double circuit to quadruple circuit is same as expansion plan formulated by EGAT. The short circuit current at Nong Chok 230kV bus will exceed 50kA at the commissioning dates (year 1999) of Ao Phai power plants, by this time Nong Chok 230kV bus should be split for reducing short circuit current at Nong Chok 230kV bus. Therefore, reinforcement of Nong Chok - On Nuch line is recommended prior to commissioning date of Ao

Phai power plants. According to EGAT PDP 92-01, 500kV lines link between Nong Chok, Sai Noi and Ao Phai have been proposed for commissioning in 1998. In this year, construction of Nong Chok - On Nuch 230kV four-circuit steel tower with 2x1272MCM ACSR conductor per phase and splitting of Nong Chok 230kV busbar are recommended.

The 1998's network system under construction of Nong Chok - On Nuch line is the weakest system configuration in recommended construction schedule. In this network, if one circuit of Bangkok Noi - Sai Noi double circuit will be occurred fault-tripping, the remaining circuit will be expected to be overloaded and be caused cascaded tripping. Following route tripping of Bangkok Noi - Sai Noi line, North Bangkok - Chaeng Watthana (1x1272MCM ACSR) and Lat Phrao - Chaeng Watthana (1x1272MCM ACSR) line will be expected to be overloaded. The control of loading as load shedding will be required to avoid system collapse in the Greater Bangkok Area.

c) Year 1999

Fig. 6-3-7 shows the result of load flow under construction of Bangkok Noi - Sai Noi line in 1999's network system.

The Bangkok Noi - Sai Noi line section is reinforced with 500kV designed double circuit with 4x1272MCM ACSR conductor per phase. After completion of construction, this line section is operated with 230kV at first.

d) Year 2000

Fig. 6-3-8 shows the result of power flow under construction of North Bangkok - Bangkok Noi line (18.4km) in 2000's network system.

From Chapter-5, in consideration of system reliability in the Greater Bangkok Area, the North Bangkok - Bangkok Noi line is recommended to be augmentated with 500kV double circuit with 4x1272MCM ACSR conductor per phase. After completion of construction, this line section is operated with 230kV for a while.

e) Year 2001

Fig.6-3-9 shows the result of load flow and short circuit current after above mentioned reinforcement in year 2001. No transmission line is overloaded under normal condition and no transmission has any problem to cause cascaded tripping during single circuit outage. And, short circuit current levels are less than 50kA at all 500kV and 230kV busbar.

Load flow under contingency condition

Contingency Condition : Out-of service of one bank
Out-of service of one circuit
Thermal limit of conductors
2x1272MCM ACSR 230kV 858MVA
4X1272MCM ACSR 230kV 1716MVA

Contingency Condition	Power Flow under Normal Condition	Power Flow under Contingency Condition
out of service of NONG CHOK 500kV/230kV 750MVA transformer 600MVA 2 banks 750MVA 1 bank	750MVA 571MW+j65MVar 600MVA 458MW+j55MVar (461MVA: 77%) (per bank)	600MVA 633MW + j 88MVar (639MVA:106.5%) (per bank)
out of service of SAI NOI 500kV/230kV transformer 750MVA 4 banks	640.7MW+j79MVar (646MVA: 86%) (per unit)	801MW + j106MVar (808MVA:108%) (per bank)
one circuit of 230kV SAI NOI - RANGSIT double circuit is tripped 2x1272MCM ACSR 2cct	555MW+j48MVar (per cct)	805MW +j 76MVar
one circuit of 230kV ON NUCH - BANG PAKONG double circuit is tripped 2x1272MCM ACSR 2cct	475.9MW+j64MVar (per cct)	649MW +j101MVar
one circuit of 230kV BANGKOK NOI - SAI NOI double circuit is tripped 4x1272MCM ACSR 2cct	663MW +j88MVar (per cct)	946MW+j168MVar

(7) System Stability

The generators with PSS are following:

REGION-3	BANG LANG	3x 24MW
	RAJJAPRABHA	3x 80MW
	KAENG KRUNG	2x 40MW
	KHANOM	2x 75MW + C.C. 674MW
	COMBINED CYCLE	1x300MW
REGION-4	MAE MOH unit 4- 7	4x150MW
	unit 8-13	6x300MW
	MAE KHAM	2x150MW
REGION-1	EASTERN	
	BANG PAKONG thermal	2x550MW + 2x600MW
	AO PHAI	3x700MW
REGION-1	WESTERN	
	SRINAGARIND unit 4-5	2x180MW
	KHAO LAEM	3x100MW
	LOWER CENTRAL C.C.	3x600MW
	NEW THERMAL unit 1-2	2x1000MW

- The bulk power system can be maintained stable during and after 500kV transmission line contingency (three-phase fault with normal fault clearing) in power system of EGAT's plan.

  Fig.6-3-10 shows the results of the system stability in the case of 500kV transmission line fault. Figures show relative rotor angles of typical generator in each region. The basis of angle is assumed Bang Pakong thermal generator.

CASE-No.	Fault Transmission Line (Fault Point)	Stability
01-MTM	MAE MOH - THA TAKO (MAE MOH)	stable
01-NTT	NONG CHOK - THA TAKO (THA TAKO)	stable
01-NSN	NONG CHOK - SAI NOI (SAI NOI)	stable
01-NAA	NONG CHOK - AO PHAI (AO PHAI)	stable
01-SAA	SAI NOI - AO PHAI (AO PHAI)	stable
01-SRR	SAI NOI - RATCHABURI 3 (RATCHABURI 3)	stable
01-RBB	RATCHABURI3 - BANG SAPHAN(BANG SAPHAN)	stable

6.4 Year 2006

(1) Year 2006's Network System

Fig. 6-1-4 shows single line diagram of 2006's network system. The transmission system expansion plan in the Greater Bangkok Area from 2001 to 2006, which has been formulated by EGAT are following:

- 500kV transmission system

NONG CHOK - WANG NOI	4x 795MCM ACSR	2cct	50km
	4x 795MCM ACSR	1cct	64km
SAI NOI - WANG NOI	4x 795MCM ACSR	2cct	56km
AO PHAI - WANG NOI	4x 795MCM ACSR	1cct	200km
BANG SAPHAN - SAI NOI	4x1272MCM ACSR	2cct	375km
BANG SAPHAN - BANGKOK NOI	4x1272MCM ACSR	2cct	350km

The capacities of reactive power compensator (shunt reactor) for each 500kV transmission line installed at substations in the Greater Bangkok Area shows at following table.

Substation	Shunt Reactor	Transmission Line
NONG CHOK	75MVA 2units 40MVA 55MVA	NONG CHOK-WANG NOI 50km 2cct NONG CHOK-WANG NOI 64km 1cct NONG CHOK-AO PHAI 170km 1cct
SAI NOI	40MVA 95MVA 100MVA 2units	SAI NOI-WANG NOI 56km 1cct SAI NOI-WANG NOI 56km 1cct SAI NOI-BANG SAPHAN 375km 2cct
BANGKOK NOI	100MVA 2units	BANGKOK NOI-BANG SAPHAN 350km 2cct
WANG NOI	75MVA	WANG NOI-THA TAKO 165km 1cct

- 500kV/230kV transformer

NONG CHOK	6x600MVA
SAI NOI	6x600MVA
BANGKOK NOI	4x600MVA
WANG NOI	2x600MVA

- 230kV transmission system

NORTH BANGKOK - LAT PHRAO	2x1272MCM ACSR 1cct
NORTH BANGKOK - BANGKOK NOI	2x1272MCM ACSR 2cct
NORTH BANGKOK - CHAENG WATTHANA	2x1272MCM ACSR 1cct
LAT PHRAO - CHAENG WATTANA	2x1272MCM ACSR 2cct
RANGSIT - CHAENG WATTHANA	2x1272MCM ACSR 4cct
RANGSIT - WANG NOI	2x1272MCM ACSR 2cct
BANG PHLI - ON NUCH	2x1272MCM ACSR 2cct

(2) Load Flow

Fig. 6-4-1 shows load flow of EGAT's expansion plan. The busbar voltage at each substation can be maintained within steady state voltage criteria (98-105%). The required capacities of reactive power compensator (shunt capacitor) at each substation in the Greater Bangkok Area are shown at Table 6-1-2.

No transmission line is overloaded under normal condition.

(3) Short Circuit Current

Fig. 6-4-2 shows the short circuit current and capacity of whole 500kV and 230kV system in the case of EGAT's expansion plan. The short circuit current levels at following 230KV busbar exceed 50kA.

NONG CHOK 230KV bus	56.4 KA
ON NUCH	57.8 KA
BANG KAPI	51.6 KA
BANG PHLI	51.1 KA
SOUTH BANGKOK	54.3 KA
SOUTH THON BURI	50.9 KA
BANGKOK NOI 230KV bus	54.0 KA

(4) Transmission System Expansion Plan

In order to reduce the short circuit current level less than 50kA, it is necessary to make reconfiguration of 230kV system in the Greater Bangkok Area. The year 2006's power system will be expanded from modified power system in year 2001 for reducing short circuit current and correcting overloading during single circuit outage. In addition to EGAT's transmission system expansion plan, upto 2001 following reinforcements and expansions will have been completed.

- RANGSIT - CAENG WATTHANA (8.0km)

  To be reinforced with 230kV double circuit with 4x1272MCM ACSR conductor per phase and 500kV double circuit with 4x1272MCM ACSR conductor per phase.

- NONG CHOK - ON NUCH (16.8km)

  To be reinforced with 230kV quadruple circuit with 2x1272MCM ACSR conductor per phase.

- BANGKOK NOI - SAI NOI (29.6km)

  To be reinforced with double circuit designed 500kV specification with 4x1272MCM ACSR conductor per phase.

- NORTH BANGKOK - BANGKOK NOI (18.4km)

  To be reinforced with double circuit designed 500kV specification with 4x1272MCM ACSR conductor per phase.

For reducing short circuit current, Nong Chok 230kV bus and South Bangkok bus are split.

As a result of discussion with EGAT, it will be difficult to get new right-of-way from Bang Saphan to Bangkok Noi. So, transmission system expansion plans to deliver power from new thermal and nuclear generating plants are adopted EGAT's PDP 92-01, that is following:

New Thermal Switchyard - Sai Noi
500kV 4x1272MCM ACSR 4cct 375km (commissioning date 2001)

New Thermal Switchyard - Sai Noi
500kV 4x1272MCM ACSR 2cct 375km (commissioning date 2004)

Nuclear Switchyard - New Thermal Switchyard
500kV 4x1272MCM ACSR 2cct 125km (commissioning date 2005)

The power system configuration above-mentioned transmission system relevant to new thermal and nuclear plants is shown as following.

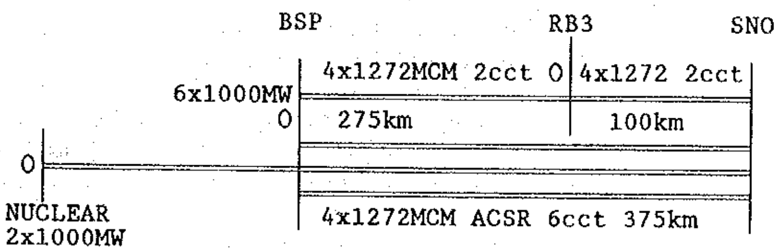


Fig. 6-4-3 shows the result of load flow and short circuit current in 2006's power system expanded with above-mentioned expansion plan in addition to EGAT's transmission system expansion plan from 2001's power system.

Sai Noi - Rangsit 230kV-line (2x1272MCM ACSR conductor) is overloaded during normal condition. And even though Sai Noi 230kV-bus is split by the EGAT's method, the short circuit current at Sai Noi 230kV bus exceeds 50kA. Scheduled outage on North Bangkok - Chaeng Watthana 230kV line and Lat Phrao - Chaeng Watthana 230kV line is expected to correct Sai NOi - Rangsit 230kV line overload and to reduce short circuit current at Sai Noi 230kV bus less than 50kA. However, another overloading problems is expected, for example, Bangkok Noi - Sai Noi 230kV line overloading problem under contingency condition. Essentially, Sai Noi - Rangsit line should be expanded from 230kV double circuit 2x1272MCM ACSR conductor per phase to 230kV double circuit 4x1272MCM ACSR conductor per phase or 500kV double circuit 4x1272MCM ACSR conductor per phase. Taking account of future demand increase at Rangsit and Chaeng Watthana substation, the augmentation as 500kV substation is recommended. But, Rangsit substation has no space for augmentation with 500kV, so using right-of-way on Sai Noi - Rangsit - Chaeng Watthana - North Bangkok, construction of Sai Noi - North Bangkok 500kV double circuit with 4x1272MCM ACSR conductor per phase is recommended.

(5) Transmission System Construction Schedule

For avoiding overloading problems during construction of transmission line, power flow and short circuit current analysis have to be carried out at each construction schedule year.

a) Year 2001

Fig. 6-4-4 shows the result of load flow under construction of North Bangkok - Lat Phrao - Chaeng Watthana line section in 2001's power system.

According to Chapter-5 "long future plan" a new substation "A" is constructed at location between North Bangkok and Lat Phrao.

The North Bangkok - new substation "A" line section (4.4km) is rebuilt with 500kV designed double circuit and 230kV double circuit steel tower with 4x1272MCM ACSR conductor per phase, respectively.

The Lat Phrao - new substation "A" line section (2.7km) is reinforced with 230kV double circuit steel tower with 4x1272MCM ACSR conductor per phase.

The Chaeng Watthana - new substation "A" line section (7.1km) is rebuilt with 500kV designed double circuit and 230kV double circuit with 4x1272MCM ACSR codnductor per phase, respectively.

b) Year 2002

Fig. 6-4-5 shows the result of load flow under construction of North Bangkok - Lat Phrao - Chaeng Watthana in 2002's network system.

Fig. 6-4-6 shows the result of load flow under construction of Rangsit - Wang Noi and Bangkok Noi - Sam Phran 1 line section in 2002's power system.

The Sai Noi - Rangsit line is modified from tap to Rangsit to via Rangsit due to the augmentation of North Bangkok - Sai Noi with 500kV double circuit. The Rangsit - Wang Noi line needs more double circuit to correct the overloading of Rangsit - Wang Noi line after completion of North Bangkok - Sai Noi 500kV transmission line. Taking account of reliability of feeding to Rangsit substation,the Rangsit - Wang Noi line should be expanded before construction of Sai Noi - Rangsit line.

The Rangsit - Wang Noi line section (49.9km) is expanded with double circuit steel tower with 2x1272MCM ACSR conductor per phase in parallel with existing right-of-way.

According to EGAS's PDP 92-01, Wang Noi substation will be terminated to 230kV Bang Pa-In 2 - Rangsit lines on Wang Noi gas turbine project (600MW for proposed commissioning in 1966). On this project, Wang Noi - Rangsit will be expanded with 230kV double-circuit steel towers with 2x1272MCM ACSR conductor per phase. In order to save right-of-way, construction of four-circuit steel towers for Wang Noi - Rangsit transmission lines is recommended on this project and in year 2002, double circuit with 2x1272MCM ACSR conductor per phase will be strung at four-circuit steel towers.

The Bangkok Noi - Sam Phran 1 line section (11.7km) is reinforced with quadruple circuit steel tower with 4x1272MCM ACSR conductor conductor per phase. At this time existing double circuit steel towers have to be removed, therefore Sam Phran 1 substation has no 230kV feeder line. Before removal of existing 230kV double circuit steel towers, the South Thon Buri - Sam Phran 1 transmission line has to be constructed and operated by temporary route from branched point on South Thon Buri - Bangkok Noi line to Sam Phran 1.

If 230kV network system in region-3 will be expanded and Sam Phran 1 substation will be integrated in region-3 230kV network system, existing South Thon Buri - Sam Phran 1 - Bangkok Noi line sections (2x1272MCM ACSR conductor) have sufficient thermal capacity throughout year 2011.

c) Year 2003

Fig. 6-4-7 shows the result of load flow under construction of Rangsit - Wang Noi and Bangkok Noi - Sam Phran 1 line section in 2003's power system in the case of operation of Bangkok Noi - Sai Noi with 230KV. The short circuit current at Sai Noi 230kV bus exceeds 50kA. Splitting of Sai Noi 230kV bus can reduce short circuit current less than 50kA, but 500kV/230kV transformer banks will increase from 4 banks to 6 banks taking account of contingency condition overloading problem (one bank is tripped). The boost of Bangkok Noi substation with 500kV is recommended and Bangkok Noi - Sai Noi transmission line should be operated with 500kV in year 2003. Fig. 6-4-8 shows the result of load flow and short circuit current under construction of Rangsit - Wang Noi and Bangkok Noi - Sam Phran 1 in the case of boost of Bangkok Noi substation with 500kV. However, the Lat Phrao - Ratchadaphisek line is put into scheduled outage due to reducing short circuit current at On Nuch less than 50kA.

The requrired capacity of 500kV/230kV transformer banks at each substation is following:

NONG CHOK substation	600MVA 2 banks and 750MVA 2 banks
SAI NOI substation	750MVA 3 banks
BANGKOK NOI substation	750MVA 4 banks
WANG NOI substation	600MVA 3 banks

d) Year 2004

Fig. 6-4-9 shows the result of load flow under construction of Sai Noi - Rangsit line section and South Thon Buri - Sam Phran 1 - Bangkok Noi line section in 2004's power system.

The Sai Noi - Rangsit line section (24.5km) is expanded with 500KV designed double circuit with 4x1272MCM ACSR conductor per phase, after copmletion of construction this line section will be operated as the North Bangkok - Sai Noi 500kV double circuit (36km) via Rangsit, Chaeng Watthana and new substation "A".

The South Thon Buri - Sam Phran 1 (19.8km) is reinforced from single circuit 2x1272MCM ACSR conductor per phase to double circuit with 4x1272MCM ACSR conductor per phase. The temporary route from branched point to Sam Phran 1 is removed and double circuits are strung at four circuit steel tower. The line section from branched point to South Thon Buri is rebuilt with double circuit steel tower with 4x1272MCM ACSR conductor per phase.

The South Thon Buri - Bangkok Noi line section (8.1km) is modified from double circuit with 2x1272MCM ACSR per phase to single circuit with 4x1272MCM ACSR conductor per phase.

e) Year 2005

Fig. 6-4-10 shows the result of load flow under construction of South Thon Buri - Sam Phran 1 - Bangkok Noi and Bang Phli - On Nuch line section in 2005's power system.

The Bang Phli - On Nuch line (10.5km) is modified from 230kV double circuit steel tower with 1x1272MCM ACSR per phase to 2x1272MCM ACSR conductor per phase.

Fig. 6-4-11 shows the result of load flow and short circuit current under construction of Bang Phli - On Nuch line in 2005's power system.

In order to reduce the short circuit current, the boost of North Bangkok substation with 500kV is recommended and North Bangkok - Bangkok Noi (18.4km) and North Bangkok - Sai Noi (36km) transmission lines are operated with 500kV. The requrired capacity of 500kV/230kV transformer banks at each substation is following:

NONG CHOK substation	600MVA 2 banks and 750MVA 2banks
SAI NOI substation	750MVA 3 banks
BANGKOK NOI substation	750MVA 4 banks
NORTH BANGKOK substation	750MVA 3 banks
WANG NOI substation	600MVA 3 banks

f) Year 2006

Fig.6-4-12 shows the result of load flow in 2006's power system after above mentioned reinforcements and expansions.

The South Bangkok - Thepharak transmissiom lines are put into scheduled outage without South Bangkok bus-split and either the Lat Phrao - Ratchadaphisek (Fig. 6-4-12) or Chaeng Watthana -new substation "A" (Fig. 6-4-13) transmission lines are put into scheduled outage due to reducing short circuit current.

The requried capacity of 500KV/230KV transformer banks at each substation is as following:

NONG CHOK substatio	600MVA 2 banks and 750MVA 2 banks
SAI NOI substation	750MVA 3 or 2 banks
BANGKOK NOI substation	750MVA 4 banks
NORTH BANGKOK substation	750MVA 4 banks
WANG NOI substation	600MVA 3 banks

No transmission line is overloaded under normal condition and contingency condition.

The bus-voltage at each substation can be maintained within steady state criteria (98 - 105%). The required capacities of reactive power compensator (shunt capacity) at each substation in the Greater Bangkok Area shows at Table 6-1-2.

Because of boost at Bangkok Noi and North Bangkok substation with 500KV, bus-voltage at each substation is improved.

(6) System Stability

The generators with PSS are following:

REGION-3	BANG LANG		3x 24MW
	RAJJAPRABHA		3x 80MW
	KAENG KRUNG		2x 40MW
	KHANOM		2x 75MW + C.C. 674MW
	COMBINED CYCLE		2x300MW
REGION-4	MAE MOH	unit 4- 7	4x150MW
		unit 8-13	6x300MW
	LAMPANG		8x300MW
	MAE KHAM		2x150MW
REGION-1	EASTERN		
	BANG PAKONG thermal		2x550MW + 2x600MW
	AO PHAI		2x700MW
REGION-1	WESTERN		
	SRINAGARIND unit 4-5		2x180MW
	KHAO LAEM		3x100MW
	LOWER CENTRAL C.C.		3x600MW
	NEW THERMAL unit 1-6		6x1000MW
	NUCLEAR unit 1-2		2x1000MW

- The bulk power system can be maintained stable during and after 500kV transmission line contingency (three-phase fault with normal fault clearing) in power system of EGAT's plan.

  Fig.6-4-14 shows the results of the system stability in the case of 500kV transmission line fault.
  Figures show relative rotor angles of typical generators in each region.

CASE-No.	Fault Transmission Line (fault point)	Stability
06-MTM	MAE MOH - THA TAKO (MAE MOH)	stable
06-MLL	MAE MOH - LAMPANG (LAMPANG)	stable
06-TLL	THA TAKO - LAMPAMG (LAMPANG)	stable
06-TWT	THA TAKO - WANG NOI (THA TAKO)	stable
06-NWW	NONG CHOK - WANG NOI (WANG NOI)	stable
06-WAA	WANG NOI - AO PHAI (AO PHAI)	stable
06-NAA	NONG CHOK - AO PHAI (AO PHAI)	stable
06-NSS	NONG CHOK - SAI NOI (SAI NOI)	stable
06-SRR	SAI NOI - RATCHABURI 3 (RATCHABURI 3)	stable
06-SBB	SAI NOI - BANG SAPHAN (BANG SAPHAN)	stable
06-RBB	RATCHABURI 3- BANG SAPHAN(BANG SAPHAN)	stable
06-BNN	NUCLEAR - BANG SAPHAN(BANG SAPHAN)	stable

Fig. 6-4-15 shows the comparision of system stability between EGAT's transmission system expansion plan and power system augmentated North Bangkok and Bangkok Noi with 500kV. The fault condition is a permanent three-phase fault on Sai Noi - Bang Saphan 500kV transmission line at Bang Saphan with normal fault clearing without reclosing.

The reconfiguration of transmission system in the Greater Bangkok Area has little influence on system stability.

Fig. 6-4-16 shows fluctuation of 230kV bus voltage at each substation in the Greater Bangkok Area during and after a permanent three-phase fault at Bang Pakong bus and one unit of thermal generator (600MW) tripped with normal fault clearing. The steady state system voltage at any busbar can be maintained within voltage criteria (92 - 108%) under contingency condition.

EGAT's PDP (power development plan and transmission expansion plan) and recommended construction schedule from year 1997 to year 2006 for transmission system and 500kV substation in the Greater Bangkok Area are shown at Table 6-4-1.

6.5 Year 2011

(1) Power Development Plan

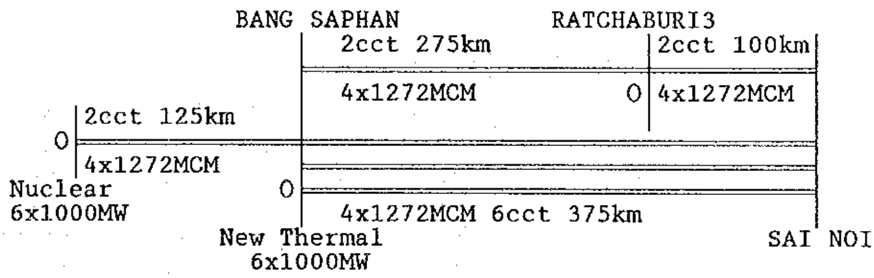
According to latest EGAT's PDP 92-01, power development planning from 2006 to 2011 will be assumed Nuclear Unit 3 - 6 (4x1000MW).

		Proposed Commissioning Date
Nuclear Unit 3	1x1000MW	January 2007
Nuclear Unit 4	1x1000MW	July 2007
Nuclear Unit 5	1x1000MW	January 2008
Nuclear Unit 6	1x1000MW	July 2008

In this study, new power development projects will be assumed above mentioned power sources which will be located in the same site as nuclear unit 1-2, that is at the southern part of Thailand.

According to latest EGAT's PDP, following 500kV transmission lines relevant to Nuclear project will be constructed upto 2006.

New Thermal Switchyard - Sai Noi
4x1272MCM ACSR 6cct 375km
Nuclear Switchyard - New Thermal Switchyard
4x1272MCM ACSR 2cct 125km



- Nuclear Switchyard - New Thermal Switchyard (Bang Saphan)

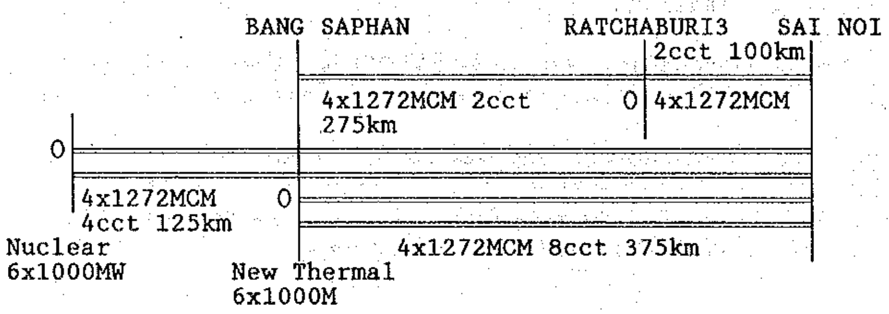
  In final nuclear-unit commissioning date, 5700MW (6x1000MW-6x50MW : 50MW station service) in full output of nuclear generating units should be transmitted on nuclear switchyard - new thermal switchyard 500kV double circuit transmission line. The thermal limit of 500kV 4x1272MCM ACSR transmission line is 3730MVA per circuit, so in the case of single circuit outage the remaining circuit is expected to be overloaded. Untill commissioning date of nulear unit-4, nuclear switchyard - new thermal switchyard (Bang Saphan) 500kV transmission line should be expanded with four circuits.

• New Thermal(Bang Saphan) - Sai Noi

According to latest EGAT's PDP, upto 2006 this section will be expanded with six circuits. The comparision of transient stability study between six circuit and eight circuit Sai Noi - Bang Saphan line for a fault at Bang Saphan on Sai Noi - Bang Saphan 500kV line are shown at Fig.6-5-1. The condition of load flow is selected the severest case.

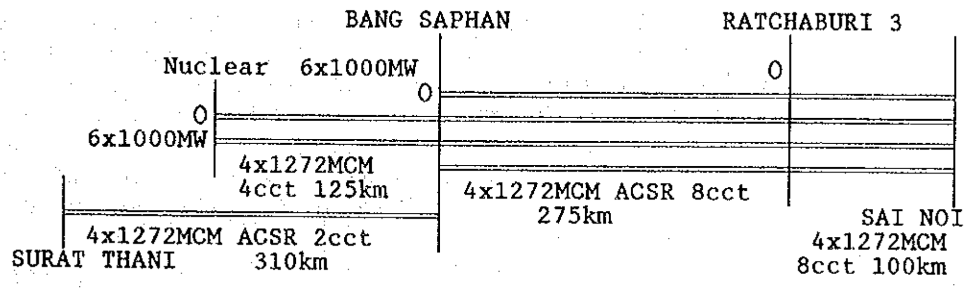
New Thermal 6x(1000-50)MW = 5700MW
Nuclear 6x(1000-50)MW = 5700MW

The six circuit system is transiently unstable. On the other hand, the eight circuit system is transiently stable. Therefore, until the commitioning date of final nuclear unit Bang Saphan - Sai Noi 500kV transmission line should be constructed one more double circuit, totally expanded with eight circuits.



• New Thermal (BANG SAPHAN) - Ratchaburi 3 - Sai Noi

Fig. 6-5-2 shows the result of power stability in the case of tap to Ratchaburi 3 of Sai Noi - Bang Saphan 500kV transmission lines. From the result of transient stability study, for maintaining stable during and after a permanent three-phase fault on Bang Saphan - Ratchaburi 3 500kV transmission line with normal fault clearing and without reclosing, Bang Saphan - Ratchaburi 3 500kV lines are required 10 circuits. In the case of 8-circuits on Bang Saphan - Ratchaburi 3 transmission, the performance of power stability is enhanced by interconnection between region-1 and region-3 strongly. Fig. 6-5-3 shows the result of power stability interconnected between Bang Saphan and Surat Thani (310km) with 500kV transmission line.



(2) Year 2011's network system and load flow

In addition to EGAT's expansion plan by year 2006, following modifications, reinforcements and expansions in the Greater Bangkok Area have been completed by year 2006 for reducing short circuit current and correcting overloading ploblems under normal and contingency condition.

- 500kV transmission line
  BANGKOK NOI - SAI NOI (29.6km) 500kV 4x1272MCM ACSR 2cct
  NORTH BANGKOK - SAI NOI (36km) 500kV 4x1272MCM ACSR 2cct
  NORTH BANGKOK - BANGKOK NOI (18.4km) 500kV 4x1272MCM ACSR 2cct

- 230kV transmission line
  RANGSIT - CHAENG WATTHANA(10km) 4x1272MCM ACSR 2cct
  NORTH BANGKOK - A S/S (4.4km) 4x1272MCM ACSR 2cct
  LAT PHRAO - A S/S (2.7km) 4x1272MCM ACSR 2cct
  CHAENG WATTHANAN - A S/S (7.1km) 4x1272MCM ACSR 2cct
  RANGSIT - WANG NOI (49.9km) 2x1272MCM ACSR 4cct
  BANGKOK NOI - SAM PHRAN 1 (11.7km) 4x1272MCM ACSR 2cct
  SOUTH THON BURI - SAM PHRAN 1 (19.8km) 4x1272MCM ACSR 2cct
  SOUTH THON BURI - BANGKOK NOI (8.1km) 4x1272MCM ACSR 1cct

Fig. 6-5-4 shows the results of load flow and short circuit current in 2011's network system expanded from 2006's network system based on EGAT's load forecast (Table 6-1-1). The short circuit current levels at whole 230kV and 500kV bus in the Greater Bangkok Area are less than 50kA. However, North Bangkok - new substation "A" 230kV double circuit with 4x1272MCM ACSR conductor (conductor thermal limit : 1716MVA) per phase is expected to be overloaded under single circuit tripped.

Contingency Condition	Load Flow under Normal Condition	Load Flow under Contingency Condition
single circuit of 230kV North Bangkok - "A" double circuit is tripped	1086.4MW-j123.8MVar (per cct)	2073.7MW-j190.7MVar overload

The load flow on Bangkok Noi - Sai Noi 500kV transmission line and North Bangkok - new substation "A" 230kV transmission line are restricted by thermal limit of conductors (4x1272MCM ACSR) under contingency condition, that are 3730MVA and 1716MVA, respectively. In order to control load flow on Bangkok Noi - Sai Noi 500kV transmission line and North Bangkok - new substation "A" 230kV transmission line, sectionalizing of 230kV nertwork system in the Greater Bangkok Area is recommended. The South Bangkok - Thepharak line is put into scheduled outage due to control load flow on the Bangkok Noi - Sai Noi 500kV transmission line, while the Rangsit - Chaeng Watthana line and Lat Phrao - Ratchadaphisek line (Fig. 6-5-5), or Chaeng Watthana - new substation "A" line and Bang Kapi - Ratchadaphisek line (Fig. 6-5-6) are put into scheduled outage due to control load flow on the North Bangkok - new substation "A" 230kV transmission line.

The 2011's network system in the case of more increasing demand than EGAT's load forecast is described in detail in Chapter-5.

Table 6-1-1 load forecast at each substation

Load Forecast of Greater Bangkok Area

substation	node	1997			2001			2006			2011		
		(MVA)	sys-peak	MEA peak	(MVA)	sys-peak	MEA peak	(MVA)	sys-peak	MEA peak	(MVA)	sys-peak	MEA peak
69KV													
North Bangkok	1601	2x200	284.040	299.820	2x200	280.689	296.283	3x200	352.385	371.962	3x200	421.213	444.613
	1611	200	141.803	149.681	2x200	280.689	296.283	3x200	352.385	371.962	3x200	421.213	444.613
			425.843	449.501		561.378	592.566		704.770	743.924		842.425	889.227
Lat Phrao	1602	2x200	259.948	274.390	2x200	211.966	223.742	2x200	235.473	248.555	2x200	281.466	297.102
	1612	2x200	259.948	274.390	2x200	211.966	223.742	2x200	235.473	248.555	2x200	281.466	297.102
	1622		0.000	0.000	200	105.988	111.876	2x200	235.473	248.555	2x200	281.466	297.102
			519.896	548.779		529.920	559.360		706.419	745.665		844.397	891.307
Bang Kapi	1603	2x200	243.609	257.143	3x200	351.148	370.656	3x200	425.843	449.501	4x200	509.019	537.297
	1613	2x200	243.609	257.143	3x200	351.148	370.656	3x200	425.843	449.501	4x200	509.019	537.297
			487.218	514.286		702.296	741.312		851.686	899.002		1018.037	1074.595
Bang Phli	1604	2x200	355.938	375.712	3x200	376.569	397.489	3x200	438.554	462.918	4x200	524.212	553.335
South Bangkok	1605	2x200	261.157	275.666	2x200	314.668	332.150	2x200	292.153	308.384	3x200	349.216	368.617
	1615	200	130.578	137.832	200	157.338	166.079	2x200	292.153	308.384	3x200	349.216	368.617
	1625	200	130.578	137.832	200	157.338	166.079	2x200	292.153	308.384	3x200	349.216	368.617
			522.313	551.330		629.344	664.308		876.459	925.151		1047.649	1105.851
South Thon Bu	1506	2x200	178.966	188.909	2x200	194.840	205.664	2x200	214.713	226.641	2x200	256.651	270.909
	1616	2x200	178.966	188.909	2x200	194.840	205.664	2x200	214.713	226.641	2x200	256.651	270.909
	1626		0.000	0.000	200	97.420	102.832	2x200	214.713	226.641	2x200	256.651	270.909
			357.932	377.817		487.100	514.161		644.139	679.925		769.952	812.727
Bangkok Noi	1607	2x200	174.166	183.842	2x200	224.142	236.594	2x200	288.480	304.507	3x200	344.826	363.983
	1617	2x200	174.166	183.842	2x200	224.142	236.594	2x200	288.480	304.507	3x200	344.826	363.983
			348.332	367.684		448.284	473.189		576.960	609.013		689.652	727.966
Rangsit	1609	2x200	255.880	270.096	2x200	276.268	291.616	3x200	345.683	364.888	3x200	413.202	436.157
	1619	2x200	255.880	270.096	2x200	276.268	291.616	3x200	345.683	364.888	3x200	413.202	436.157
			511.760	540.191		552.536	583.232		691.366	729.775		826.403	872.315
Ratchadaphise	1634	300	304.652	321.577	2x300	493.357	520.766	2x300	332.310	350.772	2x300	397.217	419.284
	1644		0.000	0.000		0.000	0.000	2x300	332.310	350.772	2x300	397.217	419.284
			304.652	321.577		493.357	520.766		664.620	701.543		794.433	838.569
Thepharak	1636	300	81.775	86.318	300	115.810	122.244	300	153.160	161.669	300	183.075	193.246
Chidlom	1830		329.960	348.291		343.860	362.963		390.650	412.353		466.952	492.893
Satu Pradit	1833		508.140	536.370		629.540	664.514		756.280	798.296		903.996	954.218
			4753.759	5017.857		5869.994	6196.105		7455.063	7869.233		8911.184	9406.249
115KV													
Bang Phli	1704	2x200	227.462	240.099	2x200	237.187	250.364	2x200	229.795	242.561	2x200	274.678	289.938
	1714	200	113.731	120.049	200	118.594	125.183	2x200	229.795	242.561	2x200	274.678	289.938
			341.193	360.148		355.781	375.547		459.590	485.123		549.357	579.877
South Bangkok	1705	2x200	170.154	179.607	2x200	231.495	244.356	2x200	194.796	205.618	2x200	232.843	245.779
	1715		0.000	0.000		0.000	0.000	200	97.398	102.809	200	116.422	122.890
			170.154	179.607		231.495	244.356		292.194	308.427		349.265	368.669
Bangkok Noi	1707	200	20.114	21.231	200	35.548	37.523	200	55.569	58.656	200	66.423	70.113
Sai Noi	1708	200	38.400	40.533	200	62.778	66.266	200	87.997	92.886	200	105.185	111.028
Rangsit	1709	2x200	253.209	267.276	2x200	330.249	348.596	2x200	326.355	344.486	3x200	390.099	411.771
	1719	200	126.415	133.438	200	164.871	174.031	2x200	326.355	344.486	3x200	390.099	411.771
			379.624	400.714		495.120	522.627		652.710	688.972		780.197	823.541
Nong Chok	1710	2x200	182.585	192.729	2x200	186.443	196.801	2x200	272.289	287.416	3x200	325.472	343.554
Chaeng Wattha	1735	2x300	190.255	200.825	2x300	491.188	518.476	4x300	666.139	703.147	4x300	796.249	840.485
Thepharak	1736	300	81.780	86.323	300	115.810	122.244	300	153.160	161.669	300	183.075	193.246
On Nuch	1741		0.000	0.000	2x200	192.849	203.563	2x200	288.000	304.000	3x200	344.252	363.377
			1404.105	1482.111		2167.012	2287.402		2927.648	3090.295		3499.475	3693.891
			6157.864	6499.968		8037.006	8483.506		10382.711	10959.528		12410.659	13100.140
		Average Growth Rate				97-01(%)	6.880		01-06(%)	5.260		06-11(%)	3.630

Table 6-1-1 load forecast at each substation (cont.)

Load Forecast of Region-2

substation	node	1997			2001			2006			2011		
		non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak
Nam Phung	2603	3.720	3.534	2.046	4.800	4.560	2.640	6.160	5.852	3.388	7.610	7.230	4.186
Pak Chong	2701	41.830	39.738	23.007	55.850	53.058	30.718	75.270	71.506	41.399	97.220	92.359	53.471
Sikhui	2702	41.510	39.434	22.831	55.740	52.953	30.657	77.770	73.881	42.774	104.950	99.703	57.723
Nakhon Rat2	2703	127.520	121.144	70.136	189.720	180.234	104.346	241.930	229.834	133.062	290.540	276.013	159.797
Nakhon Rat1	2704	61.320	58.254	33.726	75.850	72.057	41.718	95.880	91.086	52.734	118.340	112.423	65.087
Buri Ram	2705	14.940	14.193	8.217	19.020	18.069	10.461	23.820	22.629	13.101	28.480	27.056	15.664
Surin	2706	55.880	53.086	30.734	70.940	67.393	39.017	90.420	85.899	49.731	110.550	105.023	60.803
Phon	2707	29.390	27.921	16.165	37.510	35.634	20.631	47.740	45.353	26.257	58.540	55.613	32.197
Chaiyaphum	2708	47.600	45.220	26.180	62.510	59.384	34.381	81.380	77.311	44.759	100.760	95.722	55.418
Khon Kaen-1	2710	56.890	54.046	31.290	71.340	67.773	39.237	90.970	86.422	50.034	113.000	107.350	62.150
Khon Kaen-2	2711	30.770	29.231	16.924	38.580	36.651	21.219	49.200	46.740	27.060	61.100	58.045	33.605
Maha Sarakha	2712	30.990	29.440	17.045	40.160	38.152	22.088	53.450	50.778	29.398	69.060	65.607	37.983
Yasothon	2713	31.230	29.668	17.177	40.650	38.618	22.358	52.980	50.331	29.139	66.180	62.871	36.399
Kalasin	2714	30.930	29.383	17.012	40.260	38.247	22.143	53.800	51.110	29.590	69.730	66.244	38.352
Roi Et	2715	44.750	42.512	24.613	57.820	54.929	31.801	74.400	70.680	40.920	91.590	87.011	50.375
Si Sa Ket	2716	58.930	55.984	32.412	75.970	72.172	41.784	96.860	92.017	53.273	119.060	113.107	65.483
Ubon Ratcha1	2717	46.150	43.842	25.383	59.760	56.772	32.868	76.830	72.989	42.257	94.370	89.652	51.904
Ubon Ratcha2	2718	32.960	31.312	18.128	42.680	40.546	23.474	54.880	52.136	30.184	67.400	64.030	37.070
Sirindhorn	2720	8.780	8.341	4.829	11.040	10.488	6.072	13.680	12.996	7.524	16.210	15.400	8.916
Amnat Charoe	2721	18.750	17.813	10.313	24.360	23.142	13.398	31.660	30.077	17.413	39.480	37.506	21.714
Mukdahan	2722	24.660	23.427	13.563	30.980	29.431	17.039	39.170	37.212	21.544	47.880	45.486	26.334
Chulabhorn	2723	0.200	0.190	0.110	0.280	0.266	0.154	0.380	0.361	0.209	0.480	0.456	0.264
Chum Phae	2724	39.950	37.953	21.973	50.950	48.403	28.023	65.460	62.187	36.003	81.350	77.282	44.743
Udon Thani1	2726	33.580	31.901	18.469	41.550	39.473	22.853	51.710	49.125	28.441	62.620	59.489	34.441
Udon Thani2	2727	28.310	26.894	15.571	35.040	33.288	19.272	43.600	41.420	23.980	52.770	50.132	29.024
Phang Khon	2728	21.640	20.558	11.902	27.310	25.944	15.021	34.220	32.509	18.821	41.280	39.216	22.704
Bung Kan	2729	14.410	13.689	7.926	18.230	17.319	10.027	22.810	21.670	12.546	27.390	26.021	15.065
Sakhon Nakho	2730	30.870	29.327	16.979	38.760	36.822	21.318	48.340	45.923	26.587	58.160	55.252	31.988
Nong Bua Lam	2731	22.940	21.793	12.617	28.810	27.370	15.846	36.240	34.428	19.932	44.100	41.895	24.255
Loei	2732	37.030	35.179	20.367	46.910	44.564	25.801	59.530	56.554	32.742	73.020	69.369	40.161
Nong Khai	2733	32.880	31.236	18.084	41.390	39.320	22.765	52.110	49.505	28.661	63.410	60.239	34.876
Khong	2736	32.650	31.018	17.958	38.020	36.119	20.911	45.450	43.178	24.998	53.770	51.082	29.574
Phayakkhaphu	2737	38.450	36.528	21.148	49.110	46.655	27.011	62.640	59.508	34.452	76.670	72.837	42.169
Nam Phong	2738	75.640	71.858	41.602	87.920	83.524	48.356	102.800	97.660	56.540	117.650	111.768	64.708
Ban Phai	2739	24.980	23.731	13.739	31.890	30.296	17.540	40.580	38.551	22.319	49.750	47.262	27.363
Prakhon Chai	2745	32.810	31.170	18.046	41.770	39.682	22.974	52.310	49.695	28.771	63.030	59.878	34.667
Nong Han	2746	26.850	25.508	14.768	33.390	31.720	18.365	41.630	39.549	22.897	50.280	47.766	27.654
Ban Dung	2747	8.500	8.075	4.675	8.500	8.075	4.675	8.500	8.075	4.675	8.500	8.075	4.675
Phon Thong	2748	19.620	18.639	10.791	25.570	24.292	14.064	33.340	31.673	18.337	41.610	39.530	22.886
Nakhon Phano	2751	21.390	20.321	11.765	27.330	25.963	15.032	34.720	32.984	19.096	42.400	40.280	23.320
Somdet	2752	24.990	23.740	13.745	32.800	31.160	18.040	42.000	39.900	23.100	51.200	48.640	28.160
That Phanom	2750	12.060	11.457	6.633	15.780	14.991	8.679	20.640	19.608	11.352	25.750	24.463	14.163
		1419.250	1348.288	780.588	1826.850	1735.508	1004.768	2327.260	2210.897	1279.993	2857.240	2714.378	1571.482
		Average	Growth	Rate		97-01(%)	6.515		01-06(%)	4.961		06-11(%)	4.189

Table 6-1-1 load forecast at each substation (cont.)

Load Forecast of Region-3

substation	node	1997			2001			2006			2011		
		non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak
Chumphon	3701	55.070	52.317	38.549	73.790	70.101	51.653	96.820	91.979	67.774	119.390	113.420	83.573
Lang Suan	3702	15.530	14.753	10.871	20.810	19.769	14.567	27.310	25.944	19.117	33.680	31.996	23.576
Phunphin	3704	63.240	60.078	44.268	83.970	79.771	58.779	111.500	105.925	78.050	141.150	134.093	98.805
Rajjaprabha	3705	2.940	2.793	2.058	3.930	3.734	2.751	5.400	5.130	3.780	7.210	6.850	5.047
Ranong	3706	48.770	46.332	34.139	66.650	63.318	46.655	89.540	85.063	62.678	112.960	107.312	79.072
Takua Pa	3707	9.630	9.149	6.741	13.030	12.378	9.121	18.210	17.300	12.747	24.440	23.218	17.108
Phangnga	3708	12.500	11.875	8.750	16.860	16.017	11.802	23.350	22.183	16.345	31.000	29.450	21.700
Phuket-1	3709	60.330	57.314	42.231	81.920	77.824	57.344	111.310	105.745	77.917	143.550	136.373	100.485
Phuket-2	3710	63.800	60.610	44.660	86.640	82.308	60.648	117.730	111.843	82.411	151.870	144.277	106.309
Krabi	3711	24.890	23.646	17.423	33.700	32.015	23.590	45.720	43.434	32.004	59.450	56.478	41.615
Lam Poo Ra	3712	61.930	58.833	43.351	79.770	75.782	55.839	103.930	98.734	72.751	131.570	124.991	92.099
Thung Song	3713	84.360	80.142	59.052	98.140	93.233	68.698	115.160	109.402	80.612	132.750	126.113	92.925
Nakhon Si Th	3714	87.730	83.344	61.411	117.950	112.053	82.565	159.480	151.506	111.636	206.370	196.052	144.459
Khanom	3716	33.050	31.397	23.135	45.440	43.168	31.808	63.410	60.239	44.387	83.870	79.677	58.709
Phatthalung	3717	31.440	29.868	22.008	40.310	38.295	28.217	52.220	49.609	36.554	65.160	61.902	45.612
Hat Yai 1	3719	74.770	71.032	52.339	98.210	93.300	68.747	130.510	123.984	91.357	166.110	157.805	116.277
Hat Yai 2	3720	56.640	53.808	39.648	74.390	70.671	52.073	98.860	93.917	69.202	125.840	119.548	88.088
Songkhla	3721	69.690	66.206	48.783	92.880	88.236	65.016	124.260	118.047	86.982	158.420	150.499	110.894
Satun	3722	21.990	20.890	15.393	28.480	27.056	19.936	37.620	35.739	26.334	47.830	45.439	33.481
Yala	3723	38.910	36.964	27.237	50.790	48.250	35.553	68.880	65.436	48.216	87.990	83.590	61.593
Narathiwat	3724	13.950	13.253	9.765	18.010	17.110	12.607	23.780	22.591	16.646	30.210	28.700	21.147
Pattani	3725	56.490	53.666	39.543	72.740	69.103	50.918	95.380	90.611	66.766	120.400	114.380	84.280
Bang Lang	3726	7.420	7.049	5.194	9.850	9.358	6.895	13.550	12.873	9.485	17.960	17.062	12.572
Sadao	3728	17.700	16.815	12.390	24.190	22.981	16.933	34.310	32.595	24.017	46.650	44.317	32.655
Ban Don	3731	29.100	27.645	20.370	38.260	36.347	26.782	51.170	48.612	35.819	65.720	62.434	46.004
Sungai Kolok	3734	25.900	24.605	18.130	33.440	31.768	23.408	44.160	41.952	30.912	56.140	53.333	39.298
Kaeng Krung	3735	5.130	4.874	3.591	6.810	6.469	4.767	9.040	8.588	6.328	11.430	10.859	8.001
Ranot	3736	41.830	39.738	29.261	55.890	53.096	39.123	75.000	71.250	52.500	96.040	91.238	67.228
		1114.730	1058.994	780.311	1466.850	1393.508	1026.795	1947.610	1850.230	1363.327	2475.160	2351.402	1732.612
		Average	Growth	Rate		97-01(%)	7.104		01-06(%)	5.834		06-11(%)	4.911

Table 6-1-1 load forecast at each substation (cont.)

Load Forecast of Region-4

substation	node	1997			2001			2006			2011		
		non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak
Takhli-1	4625	13.000	12.350	8.450	13.000	12.350	8.450	13.000	12.350	8.450	13.000	12.350	8.450
Sam Ngao	4701	2.000	1.900	1.300	2.550	2.423	1.658	3.290	3.125	2.139	4.110	3.905	2.672
Tak-1	4702	22.160	20.824	14.404	28.760	27.018	18.694	37.300	35.036	24.245	46.490	44.166	30.219
Mae Sot	4703	15.720	14.934	10.218	20.400	19.380	13.260	26.460	25.137	17.199	33.000	31.350	21.450
Kamphangphet	4704	32.470	30.847	21.106	44.420	42.199	28.873	62.290	59.176	40.489	83.640	79.458	54.366
Sukhothai	4705	23.080	21.926	15.002	30.280	28.766	19.682	39.810	37.820	25.877	50.090	47.586	32.559
Phitsanulok2	4706	29.570	28.092	19.221	38.780	36.841	25.207	52.540	49.913	34.151	68.930	65.484	44.805
Phitsanulok1	4707	42.170	40.062	27.411	55.700	52.915	36.205	76.790	72.951	49.914	102.690	97.555	66.749
Phichit	4708	33.350	31.683	21.678	45.680	43.396	29.692	66.020	62.719	42.913	92.380	87.761	60.047
Phetchabun	4709	45.090	42.836	29.309	56.520	53.694	36.738	71.850	68.258	46.703	88.180	83.771	57.317
Lom Sak	4710	18.390	17.471	11.954	23.150	21.992	15.048	29.460	27.987	19.149	36.230	34.418	23.550
Sirikit	4711	3.550	3.372	2.308	4.830	4.589	3.140	6.820	6.479	4.433	9.280	8.816	6.032
Uttaradit	4712	34.980	33.231	22.737	45.800	43.510	29.770	60.730	57.693	39.475	77.360	73.492	50.284
Phrae	4713	47.740	45.353	31.031	62.520	59.394	40.638	84.060	79.857	54.639	108.720	103.284	70.668
Nan	4714	32.730	31.093	21.275	43.800	41.610	28.470	60.610	57.579	39.397	80.670	76.637	52.436
Phayao	4717	55.920	53.124	36.348	72.060	68.457	46.839	93.130	88.473	60.535	116.110	110.304	75.472
Chiang Rai	4718	81.470	77.396	52.956	103.880	98.686	67.522	131.850	125.258	85.703	160.830	152.789	104.540
Lampang-2	4719	36.870	35.027	23.966	47.900	45.505	31.135	62.050	58.948	40.332	77.260	73.397	50.219
Lamphun-2	4720	92.090	87.486	59.859	120.640	114.608	78.416	149.270	141.807	97.026	178.040	169.138	115.726
Chom Thong	4721	26.240	24.928	17.056	34.060	32.357	22.139	44.160	41.952	28.704	55.110	52.354	35.822
Chiang Mai-3	4722	177.420	168.549	115.323	225.690	214.406	146.699	288.260	273.847	187.369	356.620	338.789	231.803
Chiang Mai-2	4723	51.780	49.191	33.657	67.500	64.125	43.875	87.480	83.106	56.862	108.790	103.351	70.714
Sawan Khalok	4726	32.600	30.970	21.190	42.730	40.593	27.775	56.380	53.561	36.647	71.320	67.754	46.358
Lan Krabu	4730	11.610	11.029	7.547	15.350	14.583	9.978	20.010	19.010	13.007	24.610	23.379	15.997
Thoen	4731	8.750	8.313	5.688	11.250	10.688	7.313	14.320	13.604	9.308	17.480	16.606	11.362
Lampang-1	4732	38.880	36.936	25.272	50.510	47.985	32.832	65.440	62.168	42.536	81.480	77.406	52.962
Lamphun-1	4733	20.020	19.019	13.013	25.660	24.377	16.679	32.820	31.179	21.333	40.440	38.418	26.286
Chiang Mai-1	4734	51.780	49.191	33.657	67.500	64.125	43.875	87.480	83.106	56.862	108.810	103.370	70.727
Nakhon Sawan	4741	74.270	70.557	48.276	96.400	91.580	62.660	127.370	121.002	82.791	162.000	153.900	105.300
Manorom	4743	54.900	52.155	35.685	73.660	69.977	47.879	99.810	94.819	64.877	128.830	122.389	83.740
Takhli-2	4744	15.690	14.905	10.199	20.500	19.475	13.325	27.530	26.154	17.895	35.750	33.963	23.238
Tha Tako	4748	8.250	7.837	5.363	10.710	10.175	6.962	14.150	13.442	9.198	17.970	17.071	11.681
Salokbat	4751	19.900	18.905	12.935	26.450	25.127	17.193	35.930	34.134	23.355	46.920	44.574	30.498
Bang Mun Nak	4752	36.090	34.286	23.459	48.250	45.838	31.363	67.070	63.716	43.595	90.230	85.719	58.650
Thoeng	4754	25.560	24.282	16.614	32.710	31.075	21.262	41.780	39.691	27.157	51.430	48.859	33.430
Mae Chan	4755	37.290	35.426	24.239	47.600	45.220	30.940	60.540	57.513	39.351	74.180	70.471	48.217
Tak-2	4802	40.240	38.228	26.156	40.320	38.304	26.208	40.420	38.399	26.273	40.520	38.494	26.338
		1393.620	1311.361	597.403	1797.520	1694.990	1159.938	2338.280	2208.617	1511.432	2939.500	2780.175	1902.225
		Average	Growth	Rate		97-01	5.222		01-06 (%)	5.401		06-11 (%)	4.683

Table 6-1-1 load forecast at each substation (cont.)

Load Forecast of Region-1 Central Area

substation	node	1997			2001			2006			2011		
		non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak
Ayutthaya-2	5604	17.620	16.739	14.096	22.810	21.670	18.248	29.670	28.187	23.736	36.990	35.141	29.592
Phachi(VOA)	5605	2.500	2.375	2.000	2.500	2.375	2.000	2.500	2.375	2.000	2.500	2.375	2.000
Angthong-1	5701	41.940	39.843	33.552	57.550	54.672	46.040	58.270	55.357	46.616	58.940	55.993	47.152
Thalan-1	5703	93.950	89.253	75.160	100.890	95.846	80.712	111.220	105.659	88.976	123.510	117.335	98.808
Thalan-2	5704	48.000	45.600	38.400	48.000	45.600	38.400	48.000	45.600	38.400	48.000	45.600	38.400
Saraburi-2	5705	481.000	456.950	384.800	509.490	484.016	407.592	560.440	532.418	448.352	583.680	554.496	466.944
Saraburi-3	5706	109.200	103.740	87.360	109.200	103.740	87.360	109.200	103.740	87.360	109.200	103.740	87.360
Saraburi-4	5707	58.230	55.318	46.584	67.960	64.562	54.368	81.800	77.710	65.440	97.040	92.188	77.632
Saraburi-1	5708	53.340	50.673	42.672	70.500	66.975	56.400	95.290	90.526	76.232	123.730	117.544	98.984
Singburi	5709	51.970	49.372	41.576	61.430	58.359	49.144	73.740	70.053	58.992	86.690	82.355	69.352
Lop Buri-1	5710	37.940	36.043	30.352	47.060	44.707	37.648	59.440	56.468	47.552	73.030	69.379	58.424
Angthong-2	5711	31.480	29.906	25.184	40.870	38.826	32.696	52.850	50.207	42.280	64.800	61.560	51.840
Lop Buri-2	5712	30.810	29.269	24.648	38.900	36.955	31.120	49.870	47.376	39.896	61.930	58.833	49.544
Phraphutthab	5713	28.230	26.819	22.584	35.310	33.545	28.248	45.900	43.605	36.720	58.480	55.556	46.784
Chaibadan	5714	12.910	12.265	10.328	17.360	16.492	13.888	24.100	22.895	19.280	32.100	30.495	25.680
Doembang Nan	5715	22.870	21.727	18.296	28.680	27.246	22.944	35.710	33.925	28.568	42.420	40.299	33.936
Ayutthaya-1	5716	37.130	35.274	29.704	48.060	45.657	38.448	62.510	59.384	50.008	77.950	74.053	62.360
Bang Pa In-1	5717	62.790	59.650	50.232	87.730	83.344	70.184	120.140	114.133	96.112	151.460	143.887	121.168
Suphan Buri	5719	34.510	32.784	27.608	43.280	41.116	34.624	53.890	51.195	43.112	63.980	60.781	51.184
Nakhon Nayok	5724	19.220	18.259	15.376	25.110	23.854	20.088	33.060	31.407	26.448	41.440	39.368	33.152
Thalan-3	5726	234.800	223.060	187.840	294.980	280.231	235.984	332.000	315.400	265.600	348.100	330.695	278.480
Bang Pa In-2	5727	318.440	302.518	254.752	433.590	411.910	346.872	513.680	487.996	410.944	575.430	546.658	460.344
Rangsit-69		271.880			353.150			460.690			577.400		
Rangsit-115		309.830			401.850			523.270			654.310		
		2410.590	1737.436	1463.104	2946.260	2081.697	1753.008	3537.240	2425.616	2042.624	4093.110	2718.330	2289.120
		Average	Growth	Rate		97-01(%)	5.145		01-06(%)	3.724		06-11(%)	2.962

Table 6-1-1 load forecast at each substation (cont.)

Load Forecast of Region-1 Eastern Area

substation	node	1997			2001			2006			2011		
		non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak
Chachoengsao	6702	67.680	64.296	54.144	87.060	82.707	69.648	114.470	108.747	91.576	145.840	138.548	116.672
Prachin Buri	6703	26.530	25.204	21.224	34.110	32.405	27.288	43.610	41.430	34.888	52.890	50.246	42.312
Watthana Nak	6704	36.790	34.951	29.432	45.550	43.272	36.440	57.690	54.805	46.152	71.040	67.488	56.832
Chon Buri	6706	58.970	56.021	47.176	78.390	74.471	62.712	107.420	102.049	85.936	141.400	134.330	113.120
Si Racha	6707	34.600	32.870	27.680	43.480	41.306	34.784	56.730	53.893	45.384	72.370	68.752	57.896
Ban Bung	6708	47.440	45.068	37.952	62.660	59.527	50.128	84.130	79.923	67.304	109.070	103.616	87.256
Ao Phai	6709	232.950	221.302	186.360	284.180	269.971	227.344	338.300	321.385	270.640	387.320	367.954	309.856
Bang Lamung	6710	100.700	95.665	80.560	133.940	127.243	107.152	179.130	170.174	143.304	230.040	218.538	184.032
Sattahip-1	6711	10.000	9.500	8.000	10.000	9.500	8.000	10.000	9.500	8.000	10.000	9.500	8.000
Sattahip-2	6712	29.800	28.310	23.840	39.100	37.145	31.280	52.660	50.027	42.128	68.180	64.771	54.544
Rayon-3	6713	30.680	29.146	24.544	41.320	39.254	33.056	49.940	47.443	39.952	52.960	50.312	42.368
Rayon-1	6715	79.230	75.269	63.384	92.000	87.400	73.600	109.500	104.025	87.600	129.360	122.892	103.488
Klaeng	6716	48.080	45.676	38.464	64.380	61.161	51.504	87.500	83.125	70.000	114.140	108.433	91.312
Chanthaburi	6717	88.990	84.541	71.192	120.930	114.884	96.744	165.960	157.662	132.768	218.240	207.328	174.592
Trat	6718	40.690	38.655	32.552	54.000	51.300	43.200	73.770	70.081	59.016	96.820	91.979	77.456
Chom Thien	6722	51.890	49.296	41.512	67.170	63.811	53.736	87.940	83.543	70.352	111.320	105.754	89.056
Prachin Buri	6730	75.480	71.706	60.384	155.110	147.355	124.088	255.280	242.516	204.224	348.220	330.809	278.576
Bo Win	6734	27.500	26.125	22.000	64.300	61.085	51.440	101.600	96.520	81.280	117.840	111.948	94.272
Khlong Mai	6740	167.070	158.717	133.656	226.250	214.938	181.000	280.550	266.523	224.440	328.300	311.885	262.640
Rayon-2	6714	551.030	372.428	313.624	620.340	438.273	369.072	670.530	476.453	401.224	711.710	505.714	425.864
		1806.100	1564.745	1317.680	2324.270	2057.007	1732.216	2926.710	2619.824	2206.168	3517.060	3170.796	2670.144
		Average	Growth	Rate		97-01(%)	6.509		01-06(%)	4.717		06-11(%)	3.743

Load Forecast of Region-1 Western Area

substation	node	1997			2001			2006			2011		
		non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak	non-coin	sys-peak	MEA peak
Sam Phran-1	7702	321.260	305.197	257.008	414.510	393.785	331.608	536.590	509.761	429.272	665.610	632.329	532.488
Samut Sakhon	7703	110.270	104.756	88.216	143.810	136.620	115.048	185.410	176.140	148.328	226.300	214.985	181.040
Samut Sakhon	7704	94.280	89.566	75.424	136.270	129.457	109.016	180.960	171.912	144.768	221.520	210.444	177.216
Samut Songkh	7705	40.600	38.570	32.480	54.580	51.851	43.664	77.240	73.378	61.792	106.190	100.881	84.952
Nakhon Chais	7706	61.850	58.758	49.480	79.800	75.810	63.840	103.300	98.135	82.640	128.100	121.695	102.480
Banpong-1	7707	41.240	39.178	32.992	53.110	50.454	42.488	69.210	65.750	55.368	86.900	82.555	69.520
Banpong-2	7708	178.010	169.110	142.408	229.530	218.053	183.624	300.070	285.066	240.056	378.110	359.205	302.488
Kamphaeng Sa	7709	37.910	36.015	30.328	49.700	47.215	39.760	65.640	62.358	52.512	83.020	78.869	66.416
Tha Muang	7710	45.420	43.149	36.336	50.460	47.937	40.368	55.780	52.991	44.624	59.900	56.905	47.920
Kanchanaburi	7711	55.710	52.925	44.568	71.410	67.839	57.128	89.660	85.177	71.728	105.990	100.690	84.792
Srinagarind	7713	0.830	0.789	0.664	1.100	1.045	0.880	1.440	1.368	1.152	1.750	1.662	1.400
Ratchaburi-1	7714	31.400	29.830	25.120	40.150	38.143	32.120	52.070	49.466	41.656	65.650	62.368	52.520
Ratchaburi-2	7715	99.260	94.297	79.408	132.420	125.799	105.936	177.390	168.520	141.912	227.620	216.239	182.096
Phetchaburi	7716	48.410	45.989	38.728	62.370	59.251	49.896	79.080	75.126	63.264	95.990	91.190	76.792
Cha Am	7717	44.870	42.626	35.896	56.450	53.628	45.160	72.390	68.771	57.912	90.240	85.728	72.192
Pranburi	7719	20.380	19.361	16.304	26.800	25.460	21.440	35.300	33.535	28.240	44.710	42.475	35.768
Prachuap Khi	7720	15.980	15.181	12.784	20.960	19.912	16.768	27.750	26.362	22.200	35.300	33.535	28.240
Khao Laem	7724	6.260	5.947	5.008	6.620	6.289	5.296	6.970	6.621	5.576	7.230	6.869	5.784
Sam Phran-2	7727	69.140	65.683	55.312	89.210	84.749	71.368	115.480	109.706	92.384	143.250	136.088	114.600
Hua Hin	7728	33.540	31.863	26.832	44.090	41.886	35.272	58.330	55.414	46.664	74.170	70.462	59.336
Bang Saphan	7729	103.760	98.572	83.008	144.600	137.370	115.680	152.580	144.951	122.064	161.470	153.397	129.176
Samut Sakhon	7730	99.360	94.392	79.488	127.570	121.191	102.056	162.570	154.442	130.056	197.020	187.169	157.616
		1559.740	1481.753	1247.792	2035.520	1933.744	1628.416	2605.210	2474.949	2084.168	3206.040	3045.738	2564.832
		Average	Growth	Rate		97-01(%)	6.882		01-06(%)	5.059		06-11(%)	4.238

Table 6-1-2
total capacity of reactive power compensator (shunt capacitor) at each substation in the Greater Bangkok Area and vicinity area

SUBSTATION	NODE CODE	BUS VOLTAGE	TOTAL CAPACITY OF SHUNT CAPACITOR (MVA)				
			EGAT's plan			this study	
			1997	2001	2006		2011
NORTH BANGKOK	1801	230KV	0.00	0.00	300.00	300.00	360.00
	1601	69KV	90.00	120.00	150.00	120.00	210.00
	1611	69KV	63.06	120.00	150.00	120.00	210.00
LAT PHRAO	1802	230KV	0.00	120.00	240.00	210.00	360.00
	1602	69KV	97.80	120.00	120.00	90.00	150.00
	1612	69KV	99.19	120.00	120.00	90.00	150.00
	1622	69KV	--	60.00	120.00	90.00	150.00
BANG KAPI	1803	230KV	132.25	120.00	240.00	240.00	300.00
	1603	69KV	132.25	150.00	180.00	210.00	210.00
	1613	69KV	99.19	150.00	180.00	210.00	210.00
BANG PHLI	1804	230KV	132.25	120.00	300.00	150.00	360.00
	1704	115KV	66.13	120.00	90.00	90.00	90.00
	1714	115KV	33.06	60.00	90.00	90.00	90.00
	1604	69KV	130.93	150.00	150.00	150.00	180.00
SOUTH BANGKOK	1805	230KV	132.25	240.00	300.00	270.00	300.00
	1705	115KV	66.12	120.00	60.00	60.00	60.00
	1715	115KV	--	--	30.00	30.00	30.00
	1605	69KV	93.07	150.00	150.00	120.00	150.00
	1615	69KV	66.13	90.00	150.00	120.00	150.00
	1625	69KV	66.13	90.00	120.00	120.00	150.00
SOUTH THON BURI	1806	230KV	132.25	240.00	300.00	300.00	360.00
	1606	69KV	99.19	60.00	90.00	90.00	150.00
	1616	69KV	66.13	60.00	90.00	90.00	150.00
	1626	69KV	--	30.00	90.00	90.00	150.00
BANGKOK NOI	1807	230KV	132.25	180.00	240.00	240.00	300.00
	1707	115KV	0.00	0.00	0.00	0.00	0.00
	1607	69KV	66.13	120.00	120.00	120.00	180.00
	1617	69KV	66.13	120.00	120.00	120.00	180.00
SAI NOI	1808	230KV	0.00	180.00	240.00	210.00	240.00
	1828	230KV	--	--	0.00	--	--
	1708	115KV	--	0.00	0.00	0.00	0.00
RANGSIT	1809	230KV	132.25	120.00	240.00	240.00	300.00
	1709	115KV	99.19	120.00	150.00	150.00	180.00
	1719	115KV	66.13	90.00	150.00	150.00	180.00
	1609	69KV	131.59	120.00	150.00	150.00	210.00
	1619	69KV	66.13	120.00	150.00	150.00	210.00
NONG CHOK	1810	230KV	198.38	240.00	240.00	240.00	240.00
	1820	230KV	--	--	0.00	0.00	0.00
	1710	115KV	66.13	90.00	90.00	60.00	90.00
ON NUCH	1811	230KV	0.00	0.00	0.00	0.00	0.00
	1741	115KV	--	90.00	120.00	90.00	120.00
RATCHADAPHISEK	1834	230KV	0.00	0.00	0.00	0.00	120.00
	1634	69KV	99.19	240.00	120.00	120.00	240.00
	1644	69KV	--	--	120.00	120.00	240.00
CHAENG WATTHANA	1835	230KV	0.00	0.00	0.00	0.00	120.00
	1735	115KV	132.25	180.00	240.00	210.00	360.00
THEPARAK	1836	230KV	0.00	0.00	0.00	0.00	0.00
	1736	115KV	33.06	30.00	60.00	60.00	60.00
	1636	69KV	33.06	30.00	60.00	60.00	60.00
ANGTON 1	5801	230KV	66.13	120.00	120.00	120.00	150.00
ANGTON 2	5802	230KV	132.25	120.00	120.00	120.00	210.00
SARABURI 2	5803	230KV	132.25	120.00	180.00	180.00	210.00
BANG PA-IN 2	5804	230KV	66.13	60.00	120.00	120.00	150.00
THALAN 3	5805	230KV	132.25	120.00	180.00	180.00	210.00
BAN PONG 2	7801	230KV	0.00	0.00	0.00	0.00	0.00
RATCHABURI 2	7802	230KV	0.00	120.00	120.00	120.00	120.00
SAM PHRAN 1	7816	230KV	0.00	0.00	120.00	180.00	240.00

Table 6-2-1 generator constants

generator	UNIT	MVA	H sec.	Xd %	Xd' %	Xd'' %	Xq %	Xq' %	Xq'' %	Xl %	Tdo' sec.	Tdo'' sec.	Tqo' sec.	Tqo'' sec.
REGION-1														
NORTH BANGKOK	2	96	1.9277	196.7	18.3	11	194.5	25.8	11	9.8	6	0.05	1.5	0.05
		105	1.7624	196.7	17.4	10.4	194.5	24.7	11	8.7	6	0.05	1.5	0.05
SOUTH BANGKOK	2	250	3.2688	215.2	38.1	26.5	211.8	55	26.5	22.3	5.7	0.05	1.5	0.05
	3	415	3.1273	204	42.3	27.6	201.8	60.6	27.6	22	6.5	0.05	1.5	0.05
C.C.-1(GT)	2	119.3	8.4	168	26	18	161	32	18	10	5.5	0.04	1.5	0.08
C.C.-1(ST)		135.5	3.2	166	26	18	159	56.5	18	14	5	0.04	1.5	0.07
C.C.-2(GT)	2	238.52	8.4	168	26	18	161	32	18	10	5.5	0.04	1.5	0.08
C.C.-2(ST)		271.06	3.2	166	26	18	159	56.5	18	14	5	0.04	1.5	0.07
RESION-2														
CHULABHDRN	2	22.5	3.0002	118	26	21	77		21	16	5.3	0.06		0.1
SIRINDHORN	3	14	2.6828	84.2	40.8	30.8	64		30.8	15.6	4.9	0.06		0.1
UBOLRATANA	3	10.5	2.1767	110	23	18	65		18	14	5	0.06		0.1
NAM PUNG	2	3.5	3.5248	120	32.9	22	70		22	16	8	0.03		0.25
NAM NGUM	2	17.5	1.9313	120	35	28.5	70		28.5	21	5	0.06		0.1
	3	50	2.878	110	33.3	21.9	65		21.9	14	5	0.06		0.1
NAM PHONG C.C.-1,2(GT)	4	133.6	7.6281	168	19.5	16	161	32	16	10	5.5	0.04	1.5	0.08
C.C.-1,2(ST)	2	142.4	5.3383	166	19.1	15.6	159	56.5	15.6	14	5	0.04	1.5	0.07
PAK MUN	4	36	1.3327	99	29	22	62		22	19	5.3	0.06		0.1
LAM TAKHONG	4	278	6.8624	106	29.4	18.9	60		18.9	12	7.4	0.05		0.1
REGION-3														
BANG LANG	3	28.2	5.8628	110	27.8	17.4	65		17.4	13	5	0.06		0.1
RAJJAPRABHA	3	89	3.3169	102	28.8	19.5	65		19.5	12	7.4	0.07		0.1
KAENG KRUNG	2	47	2.8252	110	31	21	68		21	20	6.5	0.06		0.1
KHANON C.C (GT)	4	132	8.4	168	26	18	161	32	18	10	5.5	0.04	1.5	0.08
C.C. (ST)		266	3.2	166	32.2	23	159	56.5	23	14	5	0.04	1.5	0.07
M.T		88.3	3.08	218.6	31.8	24.6	207.7	41.3	24.6	18.6	6	0.05	1.5	0.05
M.T.		88.3	3.08	180	22.2	17	170	30	14.6	17	6	0.05	1.5	0.05
R-3 C.C. C.C.-1,2(GT)	4	119.26	8.4	168	26	18	161	32	18	10	5.5	0.04	1.5	0.08
C.C.-1,2(ST)	2	135.53	3.2	166	26	18	159	56.5	18	14	5	0.04	1.5	0.07
SURAT THANI		42	3.9138	201.3	20.6	13.1	190.7	29	13.1	8.5	6	0.05	1.5	0.05
REGION-4														
BHUMIBOL unit 1-6	6	73.7	2.8046	100.6	33.9	21.8	65.6		21.8	16.4	6	0.05		0.1
unit-7		121.8	3.7999	120.2	30.4	20	71		20	15.3	7.8	0.05		0.15
unit-8		186.7	6.8624	106	34	23	65		23	12	7.4	0.05		0.1
SIRIKIT	4	132	7.4941	101	27.8	22.2	60		22.2	17	9.3	0.05		0.15
MAE TAENG	2	15.3	2.8	107	28	21	66		21	16	5.4	0.05		0.1
NAM KHEK	2	166.7	6.8624	106	32	22	65		22	12	7.4	0.05		0.1
LAN KRABU	3	20.8	7.6769	200	20	14	190	26	14	8	6	0.05	1.5	0.05
	4	32	6.3073	180	20.2	11.5	178	26.3	11.5	9	6	0.05	1.5	0.05
MAE MOH 2	3	83.3	3.0143	186.5	22.1	15.7	183.1	31.7	15.7	11.4	6	0.05	1.5	0.05
MAE MOH 3	4	167	2.7641	159	23.6	17.4	152	30.7	17.4	16	5.85	0.05	1.5	0.05
	6	333.3	4.5934	198	26.9	19.5	180	30	19.5	10	8.37	0.05	1.5	0.05
LAMPANG	8	333.3	4.5934	198	26.9	19.5	180	30	19.5	10	8.37	0.05	1.5	0.05
MAE LAMA LUANG	2	90	3.55	102	28.8	19.5	65		19.5	12	7.4	0.07		0.1
MAE KHAM	2	167	2.7641	159	23.6	17.4	152	30.7	17.4	16	5.85	0.05	1.5	0.05
R-1 CENTRAL														
WANG NOI	6	119.3	6.72	168	26	18	161	32	18	10	5.5	0.04	1.5	0.08
R-1 EASTERN														
BANG PAKONG thermal	2	680	2.5707	208.5	28.5	22.9	205.2	40.6	22.9	22	6.5	0.05	1.5	0.05
thermal	2	706	2.6474	210	27.5	21.2	202	49	21.2	16	5	0.04	1.5	0.06
C.C. (GT)	8	80	6.5957	221.6	18.5	12.9	219.4	23.8	12.9	9	8	0.05	2	0.05
C.C. (ST)	2	162	3.0171	225	21.2	15.1	213.7	27.3	15.1	9	6	0.05	1.5	0.05
C.C. (GT)	4	128.6	8.4	168	23.2	16.5	161	32	16.5	10	5.5	0.04	1.5	0.08
C.C. (ST)	2	145	3.2	166	23.4	15.7	159	56.5	15.7	14	5	0.04	1.5	0.07
AO PHAI	3	850	3.5707	210	32.6	21.2	202	49	21.2	16	5	0.04	1.5	0.06
KIRIDHARN	2	7.8	0.9877	110	34.7	28.3	65		28.3	14	5	0.06		0.1
RAYONG C.C.1-4(GT)	8	119.3	8.4	168	26	18	161	32	18	10	5.5	0.04	1.5	0.08
C.C.1-4(ST)	4	135.5	3.2	166	26	18	159	56.5	18	14	5	0.04	1.5	0.07
R-1 WESTERN														
SRINAGARIND	3	150	3.3905	110	29	22.7	65		22.7	19	5	0.06		0.1
	2	200	6.8624	106	29.4	18.9	60		18.9	12	7.4	0.05		0.1
THA THUNG NA	2	20.5	3.0814	140	41.5	32.7	80		32.7	25	5	0.06		0.1
KHAO LAEM	3	111.1	4	120	33	17.6	70		17.6	13	5	0.06		0.1
KAENG KRACHAN		21.2	3.6048	114	32.6	21.3	70		21.3	16	4.5	0.06		0.1
LOWER CENTRAL C.C.1-3(GT)	6	238.52	8.4	168	26	18	161	32	18	10	5.5	0.04	1.5	0.08
C.C.1-3(ST)	3	271.06	3.2	166	26	18	159	56.5	18	14	5	0.04	1.5	0.07
NEW THERMAL	6	1200	3.5	210	33	22	202	49	22	16	5	0.04	1.5	0.06
NUCLEAR	6	1200	3.5	210	33	22	202	49	22	16	5	0.04	1.5	0.06