2. Power Development Plan

2. Power Development Plan

2.1. Power Demand Forecast

2.1.1. Census and Economic Related Index

(1) Population and Population Distribution Data

Full scale population census in Cambodia over the country has not been carried out until very recently from 1962. In 1998, with the technical and financial assistance from the United Nations Population Fund (UNFPA), the census over the country has been conducted. In 1980, the Government then, People's Republic of Kampuchea, conducted the population census. However, it is not considered as the official/correct census data, as it was aimed to control by the administration then. Besides, in 1994, the National Institute of Statistics (NIS) established with the advice of UNFPA, carried out surveys on the 5,578 representative families and forecasted the numbers of population. Similarly, in 1996, NIS compiled the statistical data estimated from the sample of 20,000 families.

As explained above, there is less statistical data on the population. However, the census data in the past including the 1998 census are presented below.

Table 2.1-1 Data on Population Census

Surveyed Year	Type of Survey	Total Population (person)	Remarks
1962	Population census	5,728,771	Official census
1980	Rough population census	6,589,954	Administrative control data
1994	Socio-economic survey	9,870,000	Forecast from the survey data of the 5,578 sample families
1996	Population census	10,702,329	Forecast from the survey data of the 20,000 sample families
1998	Full scale population census	11,437,656	Full scale survey

(Source : General Population Census of Cambodia 1998, Provisional Population Total & Final Census Results Data Sheet, National Institute of Statistics, Ministry of Planning)

From the above, population increase between 1994 and 1998 are calculated to be approx. 4.1% for 1994 - 1996 and approx. 3.4% for 1996 - 1998, though the accuracy of data involve some issues.

Further, the Cambodian Government is forecasting the population and its increase rate as follows.

	Population (million person)	Population Increase
Year 2000	11.7	3.0 %
Year 2005	13.5	2.8 %
Year 2010	15.4	2.6 %
Year 2015	17.8	2.4 %

Table 2.1-2 shows the number and density of the population by each region extracted from the 1998 census.

Table 2.1-2 Number and Density of Population by Each Region (Year 1998)

Region	Population (person)	Percentage vs. Total Population (%)	Population Density (person/km^2)
Banteay Meanchey	577,772	5.05	87
Battambang	793,129	6.93	68
Kampong Cham	1,608,914	14.07	164
Kampong Chhnang	417,693	3.65	76
Kampong Speu	598,882	5.24	85
Kampong Thom	569,060	4.98	41
Kampot	528,405	4.62	108
Kandal	1,075,125	9.40	301
Koh Kong	132,106	1.16	12
Kratie	263,175	2.30	24
Mondul Kiri	32,407	0.28	2
Phnom Penh	999,804	8.74	3,448
Preach Vihear	119,261	1.04	9
Prey Veng	946,042	8.27	194
Pursat	360,445	3.15	28
Ratanak Kiri	94,243	0.82	9
Siem Reap	696,164	6.09	68
Sihanoukville	155,690	1.36	179
Stung Treng	81,074	0.71	7
Svay Rieng	478,252	4.18	161
Takeo	790,868	6.91	222
Otdar Mean Chey	68,279	0.60	11
Krong Kaeb	28,660	0.25	85
Krong Pailin	22,906	0.20	29
Total	**11,437,656**	**100.00**	**(Average) 64**

(2) Economic Index

Actual and forecast value of GDP, economic growth rate and other indices are shown on Table 2.1-3.

Table 2.1-3 Actual and Forecast on GDP and Other Indices

Year	1995 Actual	1996 Actual	1997 Actual	1998 Forecast	1999 Forecast	2000 Forecast	2001 Forecast	2002 Forecast
GDP (Billion Riel)	7200	8250	9100	10900	11900	13000	14300	15760
GDP (Million $, Converted at market price)	2923	3122	3033	2868	3132	3421	3763	4147
Average Exchange Rate Riel/$	2560	2720	3400	3800	3800	3800	3800	3800
Actual GDP Growth Rate (%)	7.6	7.0	1.0	1.0	4.0	5.5	6.1	6.3
Consumer price increase rate (%)	3.5	9.0	9.0	12.6	4.0	4.0	4.0	4.0

(Source : National Bank of Cambodia and Economic Unit Ministry of Economy and Finance)

GDP in Cambodia has been steadily increasing at the rate more than 7% from 1992 to 1996. However, the GDP increase in 1997 and 1998 stayed at the low level because of the political change. As the political situation now becomes stable, it is expected that the GDP will steadilty increase again at the rate of 4 to 6 %.

Actual and forecast on GDP composition and growth rates by each category are shown on Table 2.1-4.

Table 2.1-4 Actual and Forecast on GDP Composition and Growth Rates by Each Category

Year	1995 Actual	1996 Actual	1997 Actual	1998 Forecast	1999 Forecast	2000 Forecast	2001 Forecast	2002 Forecast
Agriculture								
GDP Comp. (%)	43.5	42.3	42.7	41.9	40.9	40.0	39.4	38.7
GDP Growth (%)	6.4	3.4	1.2	0.4	2.5	3.3	4.6	4.7
Industry								
GDP Comp. (%)	16.6	18.3	17.4	18.2	18.2	19.4	19.8	20.3
GDP Growth (%)	10.1	18.2	-2.9	4.0	5.3	12.0	8.7	8.9
Commercial								
GDP Comp. (%)	39.9	39.4	39.9	40.1	40.9	40.6	40.8	41.0
GDP Growth (%)	8.0	7.3	2.5	0.3	4.9	4.8	6.2	6.6

Industry occupies a small composition rate, however, it is forecasted to show high value in the future.

2.1.2. Power Demand Forecast

(1) Actual Records of the Power Demand in Cambodia

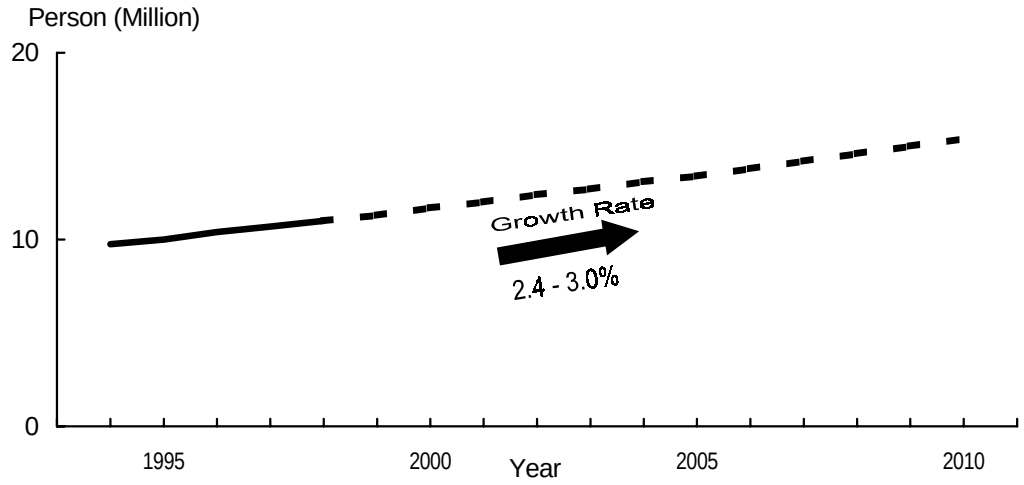
Peak power demand in Cambodia reached 387 GWh in energy generation, and 97 MW in generation output availability, respectively in 1999. Table 2.1-5 shows a trend of power demand after 1993. As shown in Table 2.1-5, the power demand has been steadily increasing after 1995. Increase of power demand is influenced, on macro basis, by the increase of population, GDP, etc. Trends of population growth rate and GDP growth rate are shown in Fig.2.1-1 and Fig.2.1-2, respectively.

Daily load curve and yearly load curve are shown in Fig.2.1-3 and Fig.2.1-4, respectively. Peak time in the daily load curve is observed at around 21:00. Fluctuation of the yearly load curve is not so large.

Table 2.1-5 Energy Generation and Generation Availability of EDC System

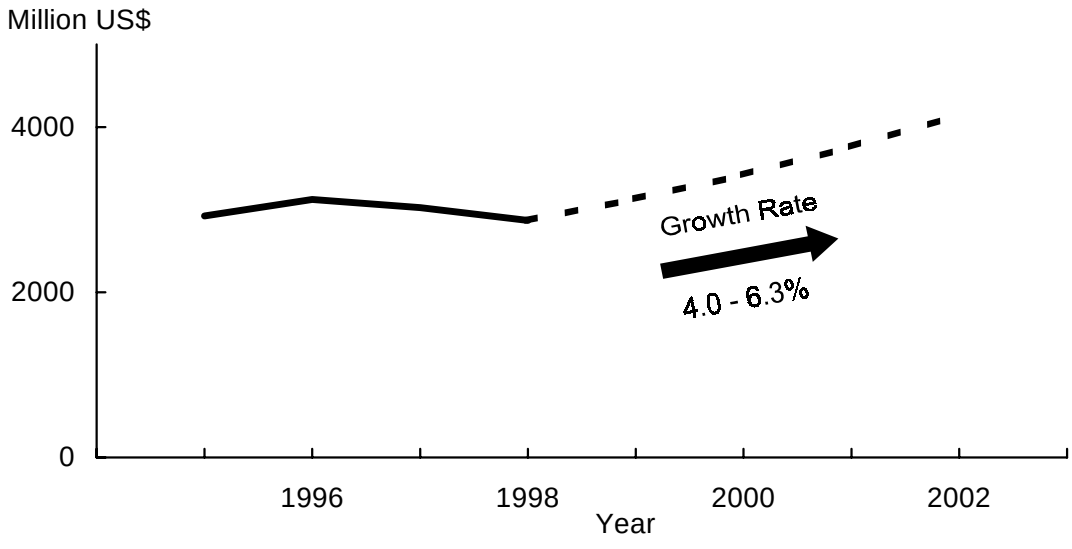
Year	Energy Generation (GWh)	Generation Availability (MW)
1993	146.37	41.65
1994	149.73	37.79
1995	189.00	43.49
1996	244.99	83.93
1997	310.26	88.78
1998	367.45	79.38
1999	386.77	97.26

(Source : EDC)



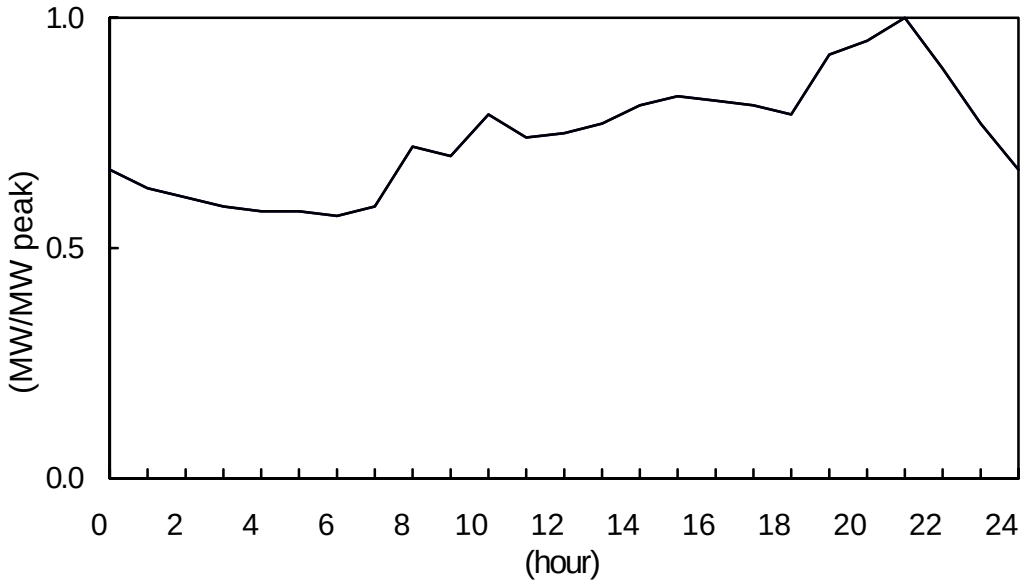
(Source : EDC)

Fig.2.1-1 Population of Cambodia



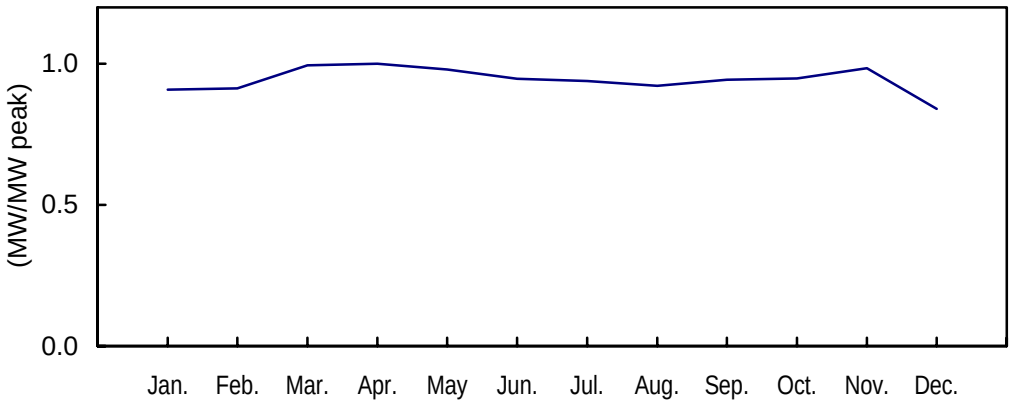
(Source : Ministry of Planning)

Fig.2.1-2 GDP of Cambodia



(Source : EDC)

Fig.2.1-3 Daily Load Curve (June 24, 2000)



(Source : EDC)

Fig.2.1-4 Yearly Load Curve (1999)

(2) Power Demand Forecast of the Cambodia Power Sector Strategy

According to the Cambodia Power Sector Strategy, it is forecasted that the peak demand will increase to 746 MW and the generated power will increase to 2,634 GWh in 2016. The average annual growth rates of those are 12% and 9.4%, respectively. This demand forecast is based on the Power Transmission Master Plan & Rural Electrification Strategy by the World Bank.

The demand forecast was carried out, in the following manner;

(a) Determination of the representative areas,
(b) Demand forecast of each representative area,
(c) Demand forecast of the other areas using the data of the representative area which has similar economic features,
(d) Summation of each area demand.

Forecasted peak demand and generation of each area, based on the above, are shown in Tables 2.1-6 and Table 2.1-7. Besides, Fig.2.1-5 and Fig.2.1-6 show the trends of peak demand and power generation forecasted until 2016 in whole Cambodia. The demand forecasts in high case and low case are included in each figure. The following conditions are adopted in high case and low case, respectively.

- High Case 30% lower power tariff and 1% increase of GDP growth
- Low Case 30% higher power tariff and 1% decrease of GDP growth

Table 2.1-6 Forecasted Peak Demand (MW)

- by IBRD -

Year	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**
Banteay Meanchey	5.9	8.0	10.0	12.0	14.5	17.3	20	24	26
Battambang	5.7	8.6	12.0	15.0	18.5	22.4	27	31	33
Kampong Cham	7.8	10.5	13.0	15.2	17.9	20.5	23	26	29
Kampong Chhnang	1.6	2.2	2.8	3.4	4.0	4.7	5	6	7
Kampong Speu	2.0	2.9	3.8	4.7	5.9	7.2	9	12	16
Kampong Thom	2.4	3.4	4.5	5.3	6.4	7.5	9	10	11
Kampot	4.8	8.1	10.1	13.9	16.3	18.9	25	28	33
Kandal	3.9	5.5	6.7	7.9	9.2	10.6	12	13	15
Koh Kong	0.9	1.2	1.4	1.7	2.0	2.3	3	3	4
Kratie	3.2	4.4	5.7	6.8	8.0	9.4	11	12	14
Mondul Kiri	0.2	0.3	0.4	0.5	0.6	0.7	1	1	1
Phnom Penh	93	131	170	207	256	304	356	418	484
Preach Vihear	0.5	0.7	1.0	1.1	1.4	1.6	2	2	2
Prey Veng	3.0	4.4	5.5	6.6	7.8	9.0	10	11	13
Pursat	2.3	3.2	4.2	5.0	5.9	6.9	8	9	11
Ratanak Kiri	1.1	1.3	1.5	1.7	1.9	2.2	2	3	3
Siem Reap	4.2	5.6	7.1	8.4	10.0	11.5	13	15	17
Sihanoukville	3.4	4.1	4.8	5.5	6.3	7.3	8	10	11
Stung Treng	0.5	0.7	0.9	1.1	1.3	1.5	2	2	2
Svay Rieng	1.6	2.2	2.8	3.2	3.9	4.4	5	6	6
Takeo	2.4	3.4	4.2	4.9	5.8	6.7	8	8	9
TOTAL	**150**	**212**	**273**	**331**	**404**	**477**	**558**	**651**	**746**

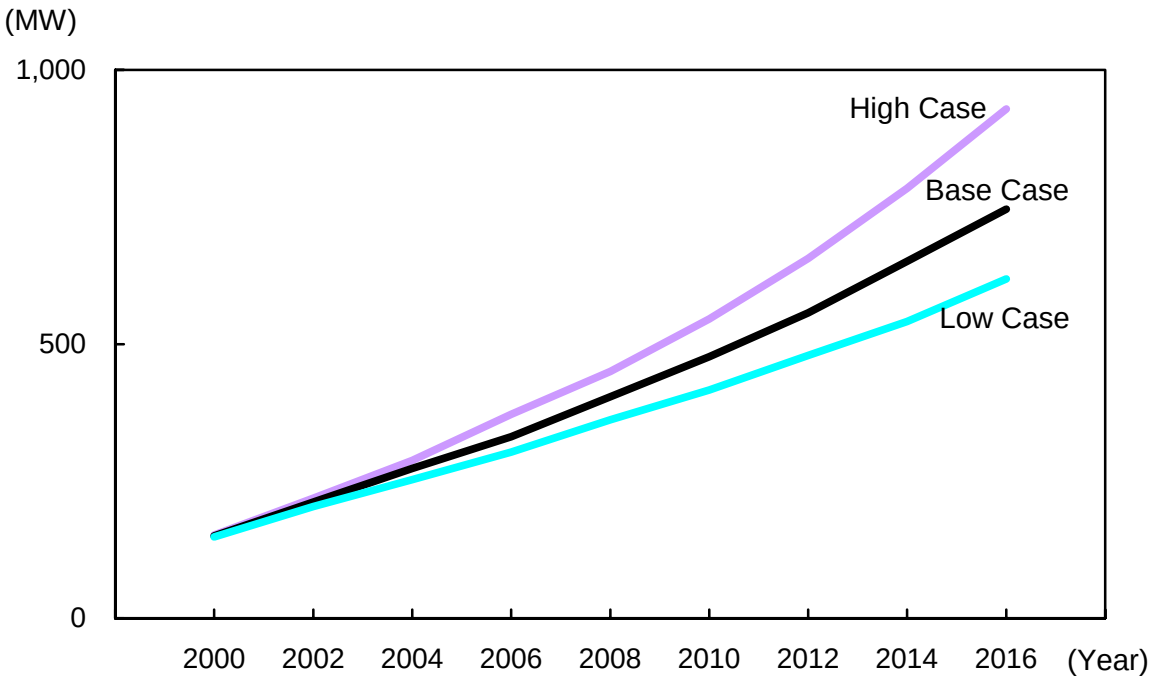
(Source : EDC)

Table 2.1-7 Forecasted Energy Generation (GWh)

- by IBRD -

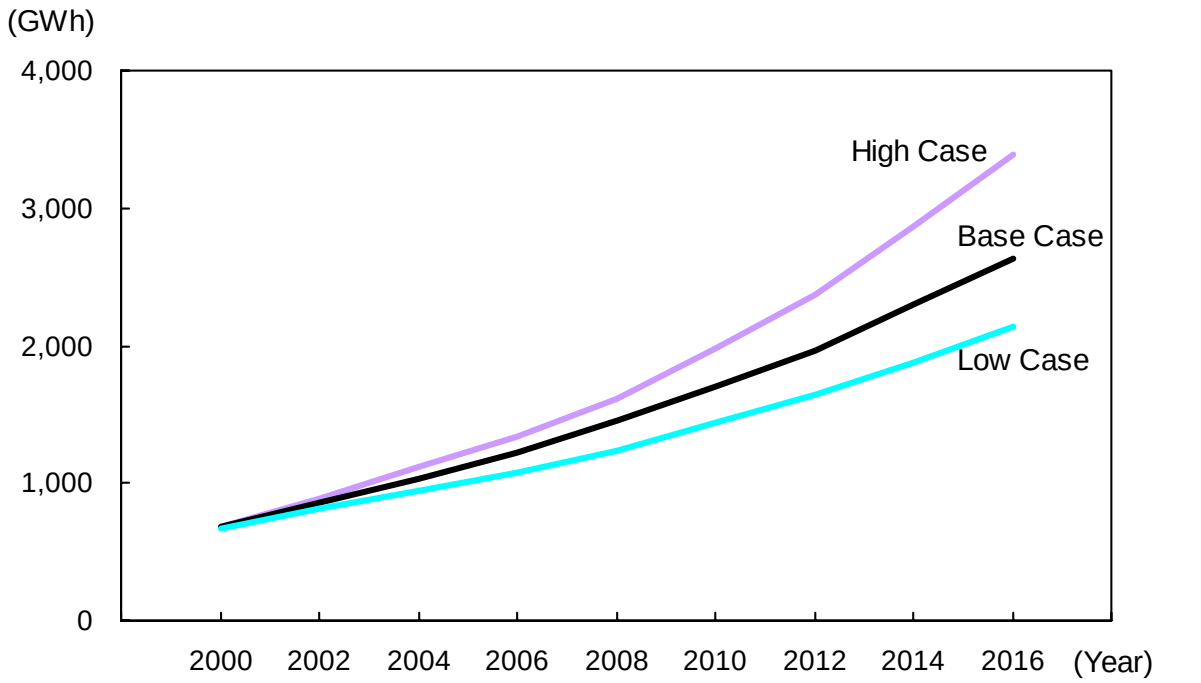
Year	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**
Banteay Meanchey	24.8	28.1	32.7	37.6	43.8	51.2	59.9	70.1	77.8
Battambang	28.8	36.0	43.5	50.6	59.6	69.8	81.5	95.1	102.0
Kampong Cham	34.0	39.3	44.8	50.3	58.1	65.3	73.1	82.9	92.9
Kampong Chhnang	6.1	7.3	8.3	9.5	11.0	12.6	14.4	16.4	18.2
Kampong Speu	9.4	11.0	12.7	14.3	16.8	19.6	23.4	29.6	38.8
Kampong Thom	9.1	11.1	13.3	15.1	17.5	20.3	23.5	27.0	30.9
Kampot	16.9	22.7	26.3	34.3	39.2	45.2	52.1	59.5	68.4
Kandal	21.0	27.5	34.0	41.1	49.6	60.0	69.9	82.1	95.6
Koh Kong	5.5	6.5	7.5	8.8	10.1	11.5	13.1	14.9	17.4
Kratie	11.2	14.3	17.6	20.7	24.3	28.4	33.1	38.4	44.6
Mondul Kiri	0.7	1.0	1.3	1.4	1.7	1.9	2.1	2.8	3.1
Phnom Penh	438	566	695	820	994	1168	1355	1584	1829
Preach Vihear	1.9	2.4	2.8	3.2	3.9	4.4	5.0	6.0	6.6
Prey Veng	12.4	14.5	16.3	18.2	20.8	23.7	26.7	30.0	33.5
Pursat	8.9	11.0	13.2	15.4	17.9	20.7	23.9	27.6	31.8
Ratanak Kiri	3.6	4.2	4.4	4.8	5.6	6.0	7.0	7.7	8.9
Siem Reap	15.2	18.2	21.1	23.9	27.5	31.4	36.2	41.4	47.3
Sihanoukville	11.9	14.0	16.2	18.3	20.8	23.7	27.0	30.8	35.4
Stung Treng	1.4	1.7	2.0	2.6	3.0	3.4	3.9	4.5	5.6
Svay Rieng	6.3	7.3	8.1	8.8	10.1	11.1	12.3	14.0	15.4
Takeo	10.4	12.3	14.2	16.2	18.4	21.6	24.6	27.4	31.6
TOTAL	**678**	**856**	**1036**	**1215**	**1454**	**1700**	**1968**	**2292**	**2634**

(Source : EDC)



(Source : IBRD Report)

Fig.2.1-5 Peak Demand Forecast until 2016 (by IBRD)



(Source : IBRD Report)

Fig.2.1-6 Power Generation Forecast until 2016 (by IBRD)

(3) Revision of the Previous Forecast

Power demand forecast in Cambodia is based on the IBRD Report. Comparison between IBRD demand forecast and the actual record is shown in Fig.2.1-7. The actual record is slightly lower than the IBRD forecast. Therefore, the demand forecast should be revised.

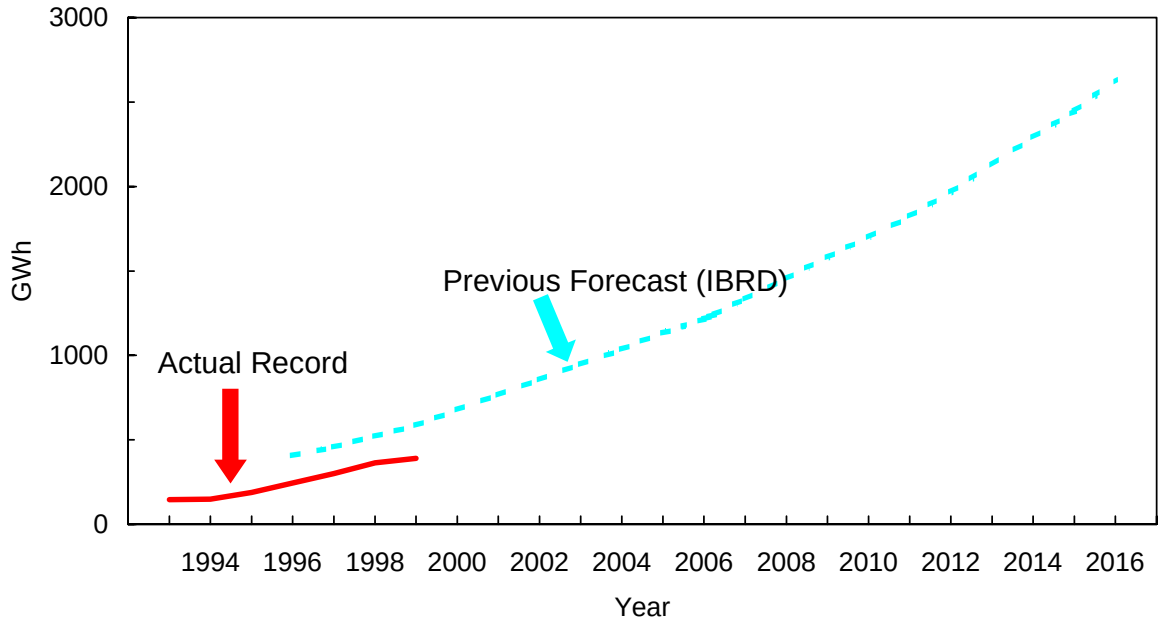
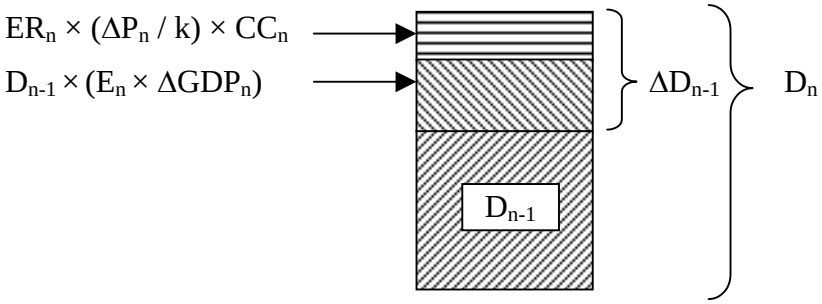


Fig.2.1-7 Comparison between IBRD Forecast and Actual Record

Power demand forecast was revised by means of macro method, according to the data obtained by the JICA Study Team, including the actual record in 2000. The following equations were used for the demand forecast of each sector.

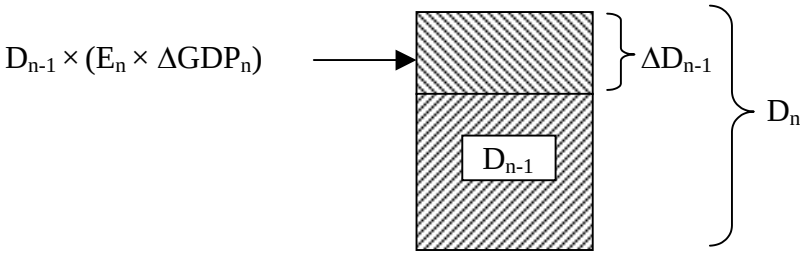
- Residential sector

$$\mathbf{D_n = D_{n-1} \times (1 + E_n \times \Delta GDP_n) + ER_n \times (\Delta P_n / k) \times CC_n}$$



- Industry, commercial and service sector

$$\mathbf{D_n = D_{n-1} \times (1 + E_n \times \Delta GDP_n)}$$



where, D : Demand
ΔP : Population Growth Rate
E : Elasticity (estimated from the past record)
ER : Electrification Ratio
CC : Demand per Residential Customer
ΔGDP : GDP Growth Rate by Sector
n, n-1 : Year
k : Population per Customer

The comparison of power demand forecasts made by IBRD and revised by the JICA Study Team are shown in Fig.2.1-8 and Fig.2.1-9. The revised forecasts are lower than the IBRD's forecasts.

The detailed data of total demand forecast is shown in Attachment 2.1.

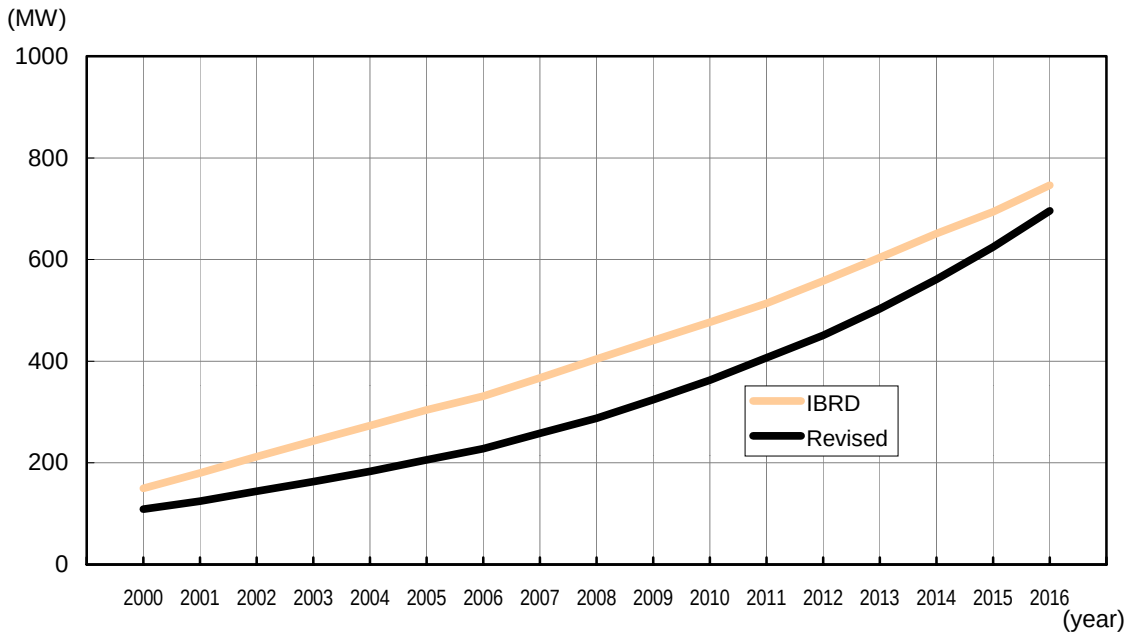


Fig.2.1-8 Comparison of Total Peak Demand Forecast

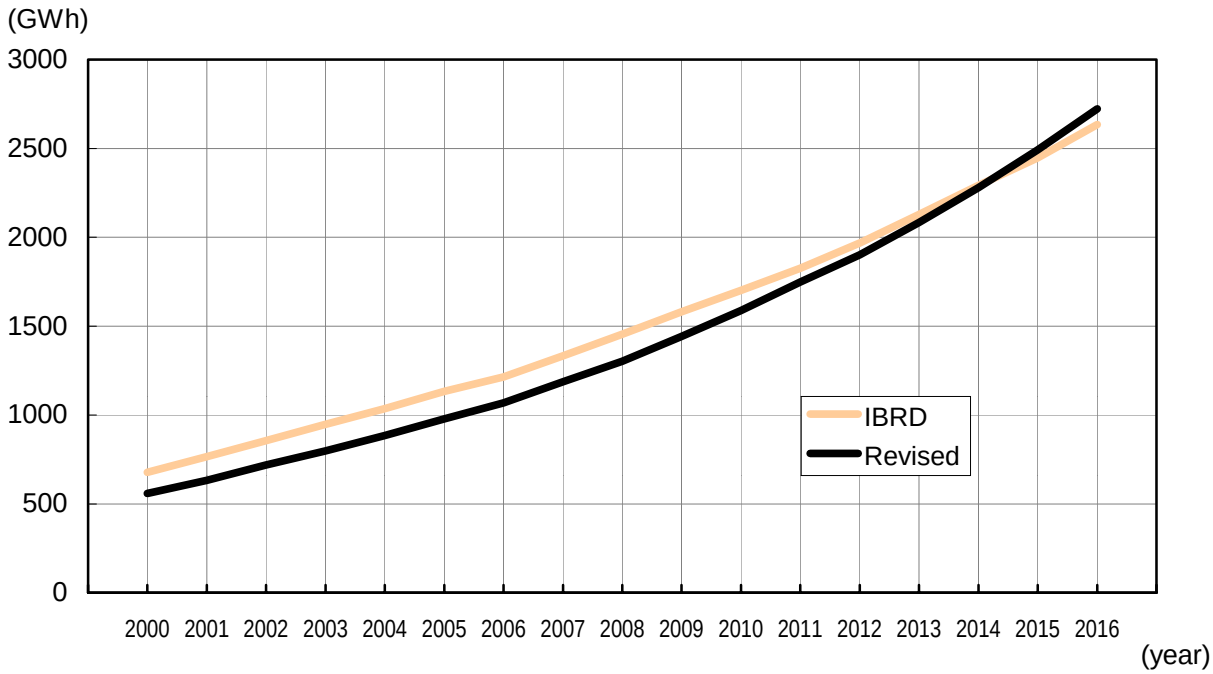


Fig.2.1-9 Comparison of Total Power Generation Forecast

Table 2.1-8 shows the electricity consumption per capita of each country in and around Southeast Asia. Fig.2.1-10 shows the relation between the electricity consumption per capita and GDP per capita of each country. According to the data, the present situation of Cambodia is similar to Myanmar and Nepal. In future, it is expected to be developed close to other Southeast Asia countries, such as Lao PDR and Vietnam.

Table 2.1-8 Electricity Consumption per Capita

Countries	Consumption kWh/cap.(1997)
Malaysia	2352
Thailand	1360
Philippines	432
Indonesia	329
Vietnam	203
Lao PDR	94
Bangladesh	76
Myanmar	57
Nepal	39
Cambodia	37 (in 2000) 86 (in 2010) 121 (in 2015)

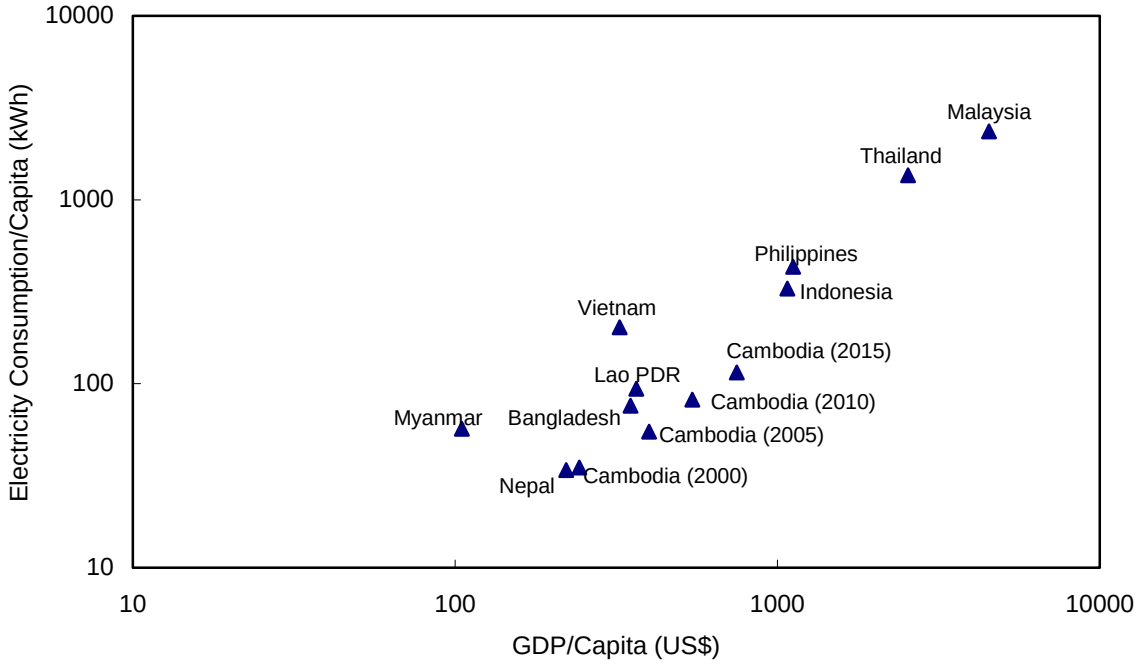


Fig.2.1-10 Relation between Electricity Consumption per Capita and GDP per Capita

(4) Effects by Economic Development Plan

At present, Cambodia Government has several economic development plans, such as, Industrial zone and free-export-processing zone in Sihanoukville, industrialization plan of areas along with National Road Rout 4 (Phnom Penh - Sihanoukville), free-export-processing zones at the border areas with Thailand, etc. However, every plan is only under preliminary planning stage and there is no specific plan. Only for the plan of industrial zone in Sihanoukville, it was reported that the developer obtained the area of 200 ha near Sokimex Oil Terminal for his plan. This plan, however, also does not show any information about "what kinds of industrial are introduced" and "how much electricity is consumed in this area".

At any rate, likely industries in Cambodia are light industries like a garment, and heavy or chemical industries, which consume much electricity, could not be expected in near future. Therefore, the effect by economic development plans to the power demand was not considered in the study.

(5) Demand Forecast taking account of Grid Connection

It is necessary to develop the demand forecast taking account of the connection of each area load to the main grid, for the study of power development program. Therefore, the load distribution is based on the IBRD Report.

In addition to Base Case (mentioned above), Low Case is also considered taking into account uncertainty of economic growth, which is based on a demand growth rate of 10% less than that of Base Case.

Forecasted peak demand and energy generation, taking account of the grid connection, are shown in Table 2.1-9 and Table 2.1-10, respectively.

Table 2.1-9 (1) Forecasted Peak Demand Taking Account of Grid Connection (MW)

- Base Case -

Year	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**
Banteay Meanchey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.6
Battambang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.8
Kampong Cham	0.0	0.0	0.0	0.0	0.0	15.6	18.7	22.4	26.9
Kampong Chhnang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2
Kampong Speu	0.0	2.0	2.5	3.2	4.2	5.5	7.2	10.0	14.6
Kampong Thom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kampot	0.0	0.0	6.8	9.6	11.6	14.4	20.1	24.5	30.3
Kandal	2.8	3.7	4.6	5.4	6.6	8.1	9.7	11.6	14.0
Koh Kong	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kratie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mondul Kiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phnom Penh	67	89	114	143	183	232	288	360	451
Preach Vihear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prey Veng	0.0	0.0	0.0	0.0	0.0	0.0	8.3	9.9	11.8
Pursat	0.0	0.0	0.0	0.0	0.0	0.0	6.5	7.9	9.8
Ratanak Kiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siem Reap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.8
Sihanoukville	0.0	0.0	0.0	3.8	4.5	5.6	6.7	8.2	10.3
Stung Treng	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Svay Rieng	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Takeo	0.0	0.0	2.8	3.4	4.1	5.1	6.1	7.2	8.7
TOTAL	**70**	**95**	**131**	**168**	**214**	**286**	**371**	**462**	**655**

Table 2.1-9 (2) Forecasted Peak Demand Taking Account of Grid Connection (MW)

- Low Case -

Year	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**
Banteay Meanchey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2
Battambang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.5
Kampong Cham	0.0	0.0	0.0	0.0	0.0	14.1	16.6	19.6	23.1
Kampong Chhnang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4
Kampong Speu	0.0	1.9	2.4	3.0	3.9	5.0	6.4	8.7	12.6
Kampong Thom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kampot	0.0	0.0	6.5	9.0	10.7	13.0	17.9	21.5	26.1
Kandal	2.8	3.7	4.4	5.1	6.1	7.3	8.6	10.2	12.0
Koh Kong	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kratie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mondul Kiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phnom Penh	67	87	109	134	168	210	256	315	388
Preach Vihear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prey Veng	0.0	0.0	0.0	0.0	0.0	0.0	7.4	8.7	10.2
Pursat	0.0	0.0	0.0	0.0	0.0	0.0	5.7	6.9	8.4
Ratanak Kiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siem Reap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5
Sihanoukville	0.0	0.0	0.0	3.6	4.1	5.0	6.0	7.2	8.8
Stung Treng	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Svay Rieng	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Takeo	0.0	0.0	2.7	3.2	3.8	4.6	5.4	6.3	7.5
TOTAL	**70**	**93**	**125**	**158**	**197**	**259**	**330**	**404**	**563**

Table 2.1-10 (1) Forecasted Energy Generation Taking Account of Grid Connection (GWh)

- Base Case -

Year	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**
Banteay Meanchey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.4
Battambang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.4
Kampong Cham	0.0	0.0	0.0	0.0	0.0	61.0	70.6	82.4	96.0
Kampong Chhnang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.8
Kampong Speu	0.0	9.2	10.8	12.6	15.1	18.3	22.6	29.4	40.1
Kampong Thom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kampot	0.0	0.0	22.5	30.2	35.1	42.2	50.3	59.2	70.7
Kandal	17.3	23.2	29.0	36.2	44.4	56.0	67.5	81.6	98.8
Koh Kong	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kratie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mondul Kiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phnom Penh	362	475	593	721	891	1091	1309	1575	1890
Preach Vihear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prey Veng	0.0	0.0	0.0	0.0	0.0	0.0	25.8	29.8	34.6
Pursat	0.0	0.0	0.0	0.0	0.0	0.0	23.2	27.4	32.9
Ratanak Kiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siem Reap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.9
Sihanoukville	0.0	0.0	0.0	16.1	18.6	22.1	26.1	30.6	36.6
Stung Treng	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Svay Rieng	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Takeo	0.0	0.0	12.1	14.3	16.5	20.2	23.9	27.3	32.7
TOTAL	**379**	**508**	**668**	**831**	**1021**	**1311**	**1619**	**1943**	**2586**

Table 2.1-10 (2) Forecasted Energy Generation Taking Account of Grid Connection (GWh)

- Low Case -

Year	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**
Banteay Meanchey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.1
Battambang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.6
Kampong Cham	0.0	0.0	0.0	0.0	0.0	55.2	62.8	72.1	82.5
Kampong Chhnang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2
Kampong Speu	0.0	9.0	10.4	11.8	13.9	16.6	20.1	25.7	34.5
Kampong Thom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kampot	0.0	0.0	21.5	28.4	32.4	38.2	44.8	51.7	60.8
Kandal	17.3	22.6	27.8	34.0	41.0	50.7	60.1	71.4	84.9
Koh Kong	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kratie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mondul Kiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phnom Penh	362	464	568	678	822	987	1164	1377	1625
Preach Vihear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prey Veng	0.0	0.0	0.0	0.0	0.0	0.0	23.9	26.1	29.8
Pursat	0.0	0.0	0.0	0.0	0.0	0.0	20.6	24.0	28.2
Ratanak Kiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siem Reap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.0
Sihanoukville	0.0	0.0	0.0	15.1	17.2	20.0	23.2	26.8	31.4
Stung Treng	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Svay Rieng	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Takeo	0.0	0.0	11.6	13.5	15.2	18.3	21.2	23.9	28.1
TOTAL	**379**	**496**	**639**	**781**	**941**	**1186**	**1440**	**1698**	**2223**

2.2. Optimum Power Development Program

2.2.1. Power Development Program

(1) Projects of Power Development

According to MIME/EDC, Cambodian Power Development Program as of the beginning of 2000 was as follows:

- 2001 : IPP2 Combined Cycle Power Project (60 MW)
- 2002 : Kirirom and Prek Thnot Hydropower Projects (29 MW)
- 2003 : Power import from Vietnam and Thailand
- 2003 - 5: Temporary power purchase from New IPP (15 MW until 2005)
- 2004 / 5: Sihanoukville Combined Cycle Power Project (90 MW × 2)
- 2008 : Kamchay Hydropower Project (47 - 127 MW)
- 2011 : Battambang Hydropower Project (60 MW)
- 2012 : Stung Atay Hydropower Project (110 MW)
- 2014 : New Combined Cycle Power Project (90 MW)
- 2016 : Russei Chrum Hydropower Project (125 MW)

The above development plan has been already modified as follows:

- The construction of IPP2 is suspended.
- Kirirom and Prek Thnot Hydropower (29 MW) is changed to;
  2003 : Kirirom Hydropower (12 MW)
- Operation time of Temporary IPP (15 MW) is changed to “from 2000 to 2003”.

(2) Sihanoukville Combined Cycle Power Project

In the above program, the Sihanoukville Project Stage 1 (90 MW) and Stage 2 (90 MW) are planned to be commissioned in 2004 and 2005, respectively. However, taking account of the practical construction schedule, the commissioning year of the Stage 1 is 2006 at the earliest. According to the annual report of the year 2000 made by EDC, Stage 1 of 90 MW is planned to be commissioned in 2007.

(3) Power Import

Power import from Vietnam is planned to be commissioned in 2003, however the transmission project by IBRD is already delayed (refer to Section 2.4), so it may possibly be in 2004. Available import power is designed to be limited to 80 MW until 2005 and 200 MW after 2005.

Power import from Thailand is also planned to be commissioned in 2003. However, progress of the negotiation is seems to be behind, compared with the import from Vietnam.

Concrete import power in real operation for each power trade has not been decided yet. Regarding power trade with Vietnam, the interconnection line will be connected to the Cambodian main grid. Therefore, the import power should be limited, taking account of impact on the Cambodian power system under emergency condition due to an accident in the Vietnam power system. In other words, system frequency decrease in Cambodia when the interconnection is suddenly disconnected, should meet the frequency deviation criteria. Otherwise, the power system may collapse.

Low frequency criteria of Cambodian power system is 47 Hz under fault condition. According to the frequency characteristics of the power system as shown in Fig.2.3-6 (described later), loss of generation power should be limited to 15% of total generation power in the Cambodian power system, not to cause frequency drop below 47 Hz. It means that power flow on the interconnection line, namely import power, should be limited to 15% of total generation power in the Cambodia power system. However, if this restriction is applied to the Cambodia power system in 2004, the import power should be limited to unrealistic small power (only 20 MW).

Frequency drop caused by loss of generation power can be mitigated by means of appropriate load shedding, so this means is realistic.

But, it is not agreeable to increase the import power from Vietnam immoderately, because the load shedding area should be increased in according to the import volume from Vietnam.

And, in this case, low frequency relay system should be installed.

2.2.2. Study on the Least Cost Power Development Program

(1) Data of Power Plants

Data of existing power plants and planned plants for the study on power development program are shown in Table 2.2-1 and Table 2.2-2. In these tables, standard data was substituted for unavailable data. IPP2 and Prek Thnot Project were excluded from the study because of uncertainty of the project status.

Table 2.2-1 Existing and Committed Major Plants

Plant Name	Capacity (MW)	SMD (days/yr)	FOR (%)	Plant Life (years)	Fixed O/M Cost ($/kW-yr)	Variable O/M Cost ($/MWh)	Fuel Type	Heat Rate (MMBTU/ MWh)	Fuel Cost ($/ MMBTU)	Installed Year
IPP1	35	28	6	20	21	3	HFO	9.0	3.99	1997
Temporary IPP	15	28	6	20	21	3	Diesel	9.0	6.02	2000-3
C2 (1)	18	28	6	20	21	3	HFO (3)	11.9	3.99	1999 (Rehabili.)
C3 (2)	14.2	28	6	20	21	3	Diesel	11.9	6.02	1996
C5	10	28	6	20	21	3	Diesel	11.9	6.02	1995
C6	18	28	6	20	21	3	HFO (3)	11.9	3.99	1996

SMD : Scheduled maintenance day (Source : EDC, Consultant's data-base)
FOR : Forced outage rate

Note : (1) Demolished in 2004, (2) Demolished in 2004 and 2006, (3) Sifted to HFO in 2000

Table 2.2-2 Planned Alternative Plant Specifications and Restrictions

Plant Name	Capacity (MW)	Annual Hydro Energy (GWh) per Unit	Total Installed Cost ($/kW)	SMD (days/ yr)	FOR (%)	Plant Life (years)	Fixed O/M Cost ($/kW -yr)	Variable O/M Cost ($/MWh)	Fuel Type	Heat Rate (MMBTU /MWh)	Fuel Cost ($/ MMBTU)	Maximum Units Allowed in Study	Maximum Units Allowed per year	First Year Available
Sihanoukville	90	-	870	49	8	20	20	2.5	natural gas	6.83	4.0	2	2	2006
Kirirom	12	53	2,027	6	1	40	10	0.25	hydro	-	-	1	1	2003
Kamchay	127	558	1,961	6	1	40	10	0.25	hydro	-	-	1	1	2008
Stung Atay	110	588	1,422	6	1	40	10	0.25	hydro	-	-	1	1	2011
St. Russei Chrum	125	668	2,197	6	1	40	10	0.25	hydro	-	-	1	1	2012
Battambang 1 & 2	60	307	1,900	6	1	40	10	0.25	hydro	-	-	1	1	2016

SMD : Scheduled maintenance day (Source : EDC, Consultant's data-base)
FOR : Forced outage rate

(2) Results of the Study

For the study, the following criteria were adopted.

- Reserve margin : 15% minimum
- Loss of load hours : 24 hours maximum

The results of the study on the least cost power development program is shown in Figs.2.2-1(1) and (2). According to the study result, the Sihanoukville Project (Stage 1 of 90 MW and Stage 2 of 90 MW) should be commissioned in 2006 and 2008 for Base Case, and 2006 and 2009 for Low Case, respectively. However, the commissioning time of 2006 for Stage 1 is not determined by a required generation capacity, but by the earliest possible completion time of Stage 1 (refer to Chapter 9). The Sihanoukville Project is required to be commissioned earlier than the follow-on import power from Vietnam, because this project has advantage over the import power from Vietnam.
Therefore, this Project should be carried out early.

While, a short construction interval of two years in Base Case would require further detailed study in consideration of a possible financial arrangement, issues raised by overlapped construction works, etc.

The detailed result included in Attachments 2.2 and 2.3.

- Remarks -

Feasibility studies of Kamchay hydropower projects have not yet been completed, therefore, the JICA Study Team could not obtain accurate data about hydropower projects by the time the Final Report was prepared. After completion of the feasibility studies of hydropower projects, power development plan shall be reviewed.

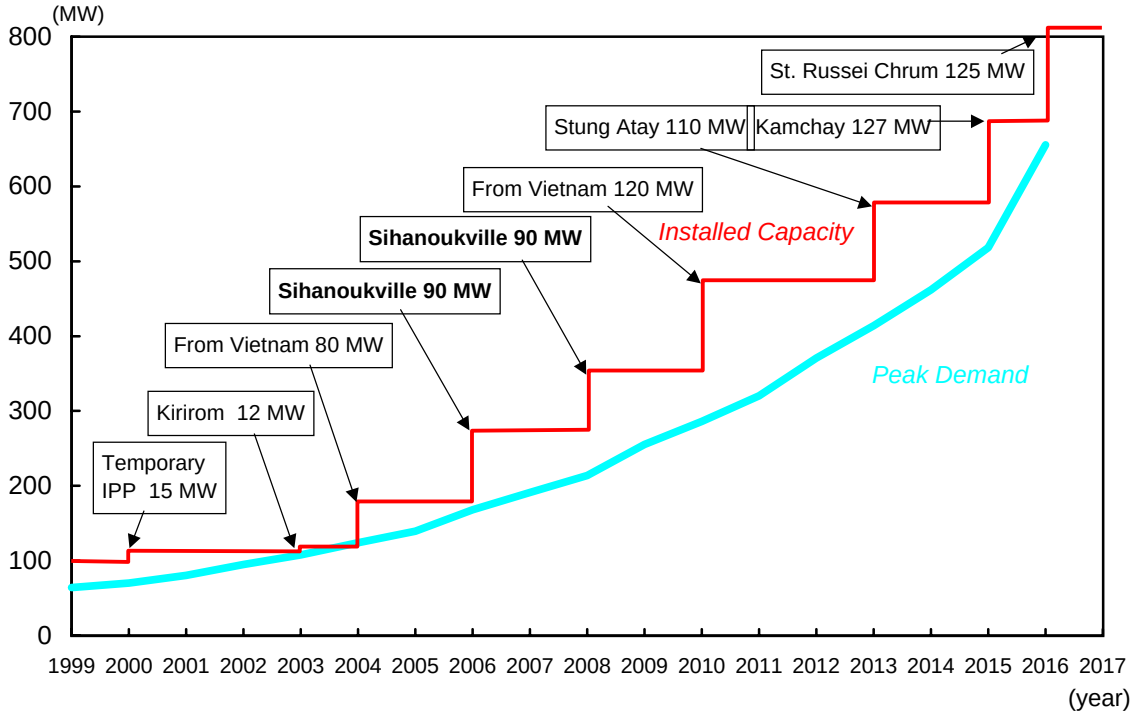


Fig.2.2-1 (1) Proposed Power Generation Expansion Plan (Base Case)

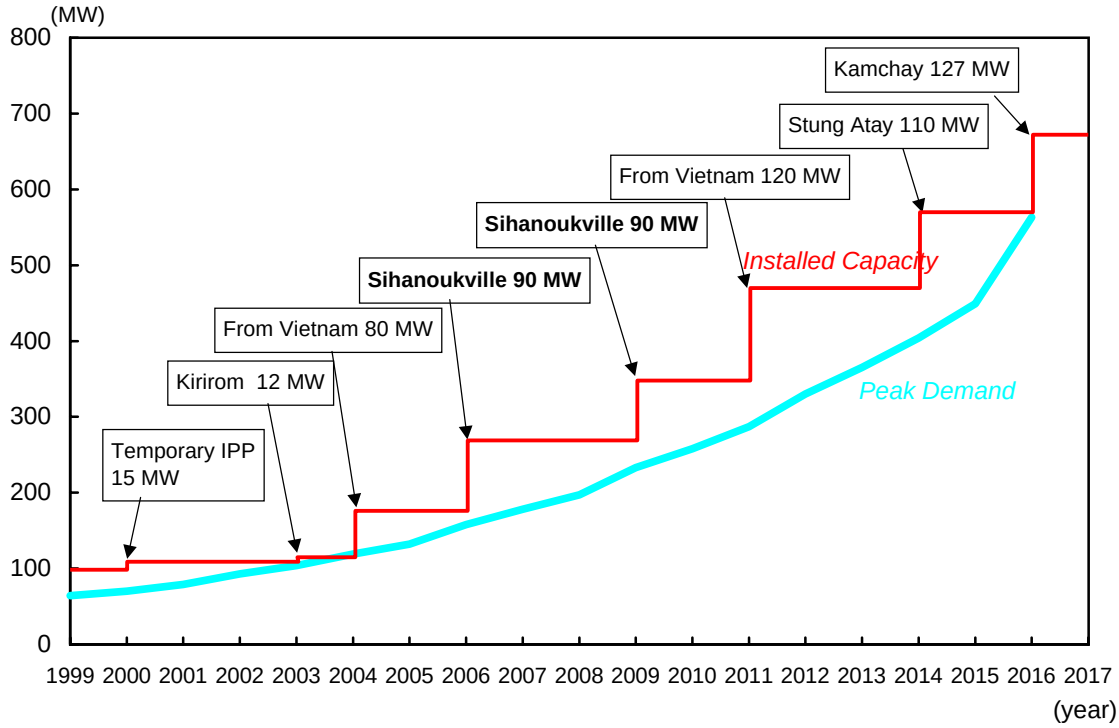


Fig.2.2-1 (2) Proposed Power Generation Expansion Plan (Low Case)

2.3. Power System Planning

Power transmission system in Cambodia is still undeveloped on the whole, excluding the 115 kV transmission system around Phnom Penh City. At present, almost all areas relies on the power supply by the scattered small power plants independently. To supply the stable power from newly constructed power plants to consumers effectively, it is indispensable to develop the power transmission system in Cambodia. EDC plans to construct 220 kV and 115 kV transmission system in Cambodia as shown in Fig.2.3-1.

According to the power system expansion plan of EDC, the double circuits, 220 kV transmission lines between Sihanoukville and the load center, Phnom Penh City will be constructed. The Sihanoukville Combined Cycle Power Plant will be connected to this transmission system. For justification of this transmission system, the system analysis such as load flow analysis, fault analysis, stability analysis, etc. were carried out, using the data shown in Table 2.3-2 and Table 2.3-3. The data include some standard data as substitutes for unavailable data.

For the analysis, the criteria will be applied as shown in Table 2.3-1

Table 2.3-1 Criteria of Cambodian Power System

Operation limit of equipment	Current flow of each equipment should not exceed each rated capacity
System stability	In case that 3-phase fault is occurred in power system, the system should recover the stable condition within around 10 seconds after fault clearing. The fault clearance times are estimated to be 0.1 seconds for 220 kV line and 0.14 seconds for 115 kV line.
System frequency	Not to exceed 50 ±0.5 Hz under normal condition, and 47 Hz to 52 Hz under fault condition.
Voltage deviation	Not to exceed ±5% under normal condition, and -10% to + 5% under fault condition.
Short circuit current level	Allowable interrupting circuit current of circuit breaker is set at 31.5 kA as design value.

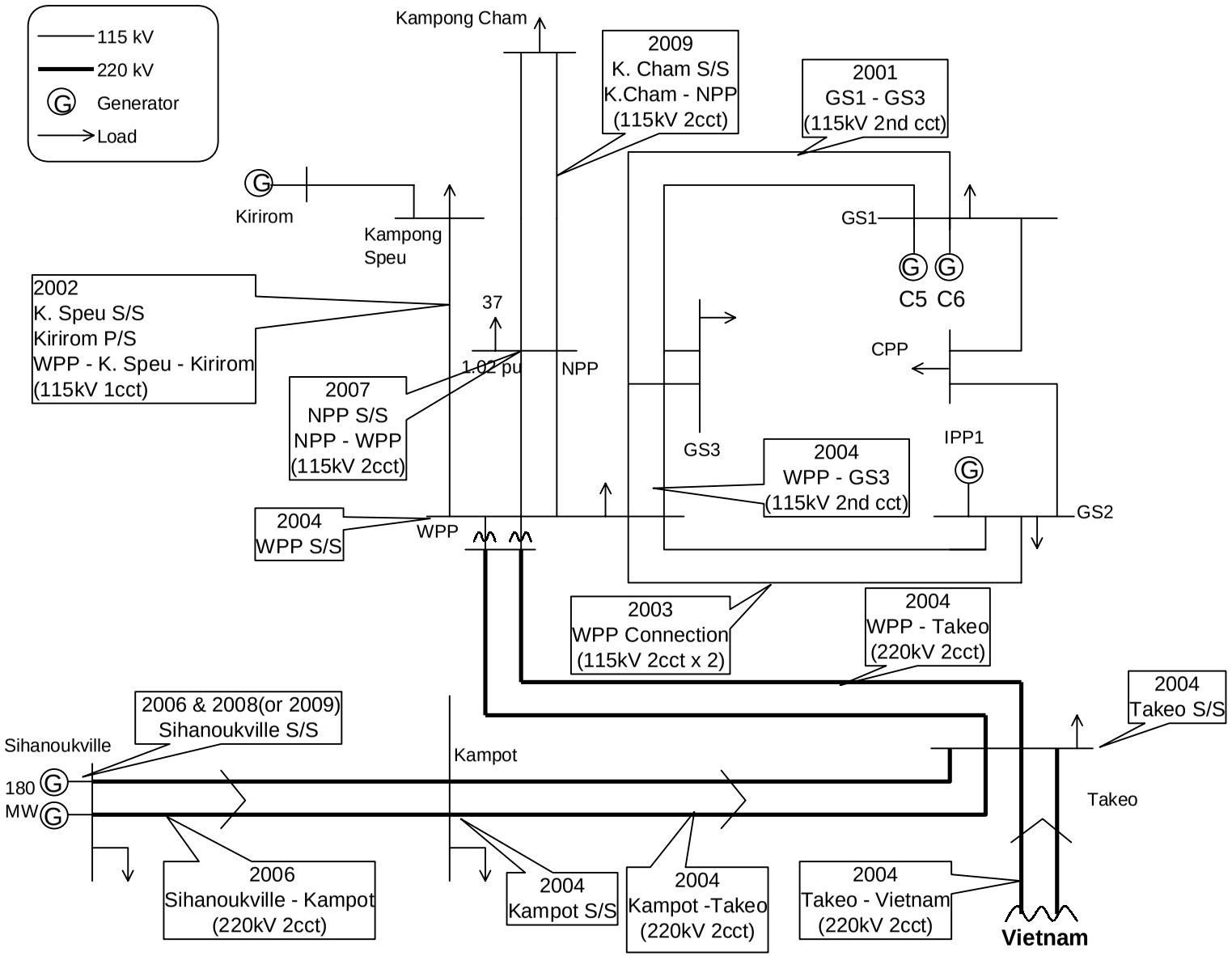


Fig.2.3-1 Transmissin Expansion Plan (until 2010)

Table 2.3-2 Main Characteristics of Generators and Step-Up Transformers

Station	Type	Cap (MW)	Reactance					
			Nominal Rating					
			(Own MVA base) Xd (%)	(Own MVA base) Xd' (%)	(Own MVA base) Xd" (%)	(Own MVA base) Xq (%)	H (Sec)	(100 MVA base)
C2	Diesel	18.0	245	37	21	106	6	60
C3	Diesel	14.2	245	37	21	106	6	76
C5	Diesel	10	245	37	21	106	6	108
C6	Diesel	18	245	37	21	106	6	60
IPP1	Diesel	35	245	37	21	106	6	31
Sihanoukville	C/C	90	240	36	22	106	6	6
Kirirom	Hydro	12	120	30	20	90	4	10

(Source : EDC, Consultant's data-base)

Table 2.3-3 Main Characteristics of Transmission Lines and Transformer

No.	Volt (kV)	Location			Length (km)	No.of Circuits	Conductor		Current Carrying Capacity (MVA/cct)	Impedance : Z = R + jX		%p.u. /cct (100 MVA base)
							Type	Size (mm^2)		%p.u. line total /cct (100 MVA base)		
1.	115	GS1 (Phonm Penh)	-	Branch	10	2	ACSR	2 × 240	226	0.576 + j	2.053	0.550
2.	115	WPP	-	Branch	14	2	ACSR	2 × 240	226	0.733 + j	2.874	0.770
3.	115	GS3 (Phonm Penh)	-	Branch	1	2	ACSR	2 × 240	226	0.052 + j	0.205	0.055
4.	115	WPP	-	GS2 (Phonm Penh)	16	2	ACSR	2 × 240	226	0.838 + j	3.285	0.880
5.	115	Kirirom	-	Kampong Speu	65	1	ACSR	1 × 400	143	4.089 + j	17.960	2.691
6.	115	Kampong Speu	-	WPP	55	1	ACSR	1 × 400	143	3.460 + j	15.197	2.277
7.	115/220	WPP (115kV)	-	WPP (220kV)	-	2 Bank	(Transformer)		200/bank	+ j	6.000	-
8.	220	WPP (220kV)	-	Takeo	70	2	ACSR	1 × 630	430	0.631 + j	5.110	12.348
9.	220	Takeo	-	Kampot	80	2	ACSR	1 × 630	430	0.722 + j	5.840	14.112
10.	220	Kampot	-	Sihanoukville	110	2	ACSR	1 × 630	430	0.992 + j	8.030	19.404
11.	220	(Vietnam)	-	Takeo	130	2	ACSR	1 × 300	251	2.462 + j	10.517	20.566
12.	115	NPP	-	Kampong Cham	100	2	ACSR	1 × 400	143	6.291 + j	27.630	4.140
13.	115	WPP	-	NPP	20	2	ACSR	1 × 400	143	1.258 + j	5.526	0.828
14.	115	GS1	-	CPP	15	1	ACSR	2 × 240	226	0.785 + j	3.080	0.825
15.	115	GS2	-	CPP	15	1	ACSR	2 × 240	226	0.785 + j	3.080	0.825

(Source : EDC, Consultant's data-base)

2.3.1. Load Flow Analysis

Load flow analysis was carried out for the power system in 2006 and 2010. The following criteria were taken into account to estimate the results of the load flow analysis.

1) Under Normal Condition
   Load flow of each equipment should be lower than 100% of the rated capacity. Fluctuation of each substation voltage should be kept within ±5%.

2) Under Fault (namely, "N-1") Condition (ex. outage of one line)
   Load flow of each equipment should be lower than 150% of the rated capacity. Fluctuation of each substation voltage should be kept from -10% to +5%.

The results of load flow analysis for the power system in 2006 and 2010 are shown in Fig.2.3-2, respectively. Each load flow meets the above criteria under normal and fault condition. However, voltage decrease at 115 kV substations become severe in 2010 under fault condition. Therefore, 40 MVA shunt capacitance is necessary to be installed at some substations.

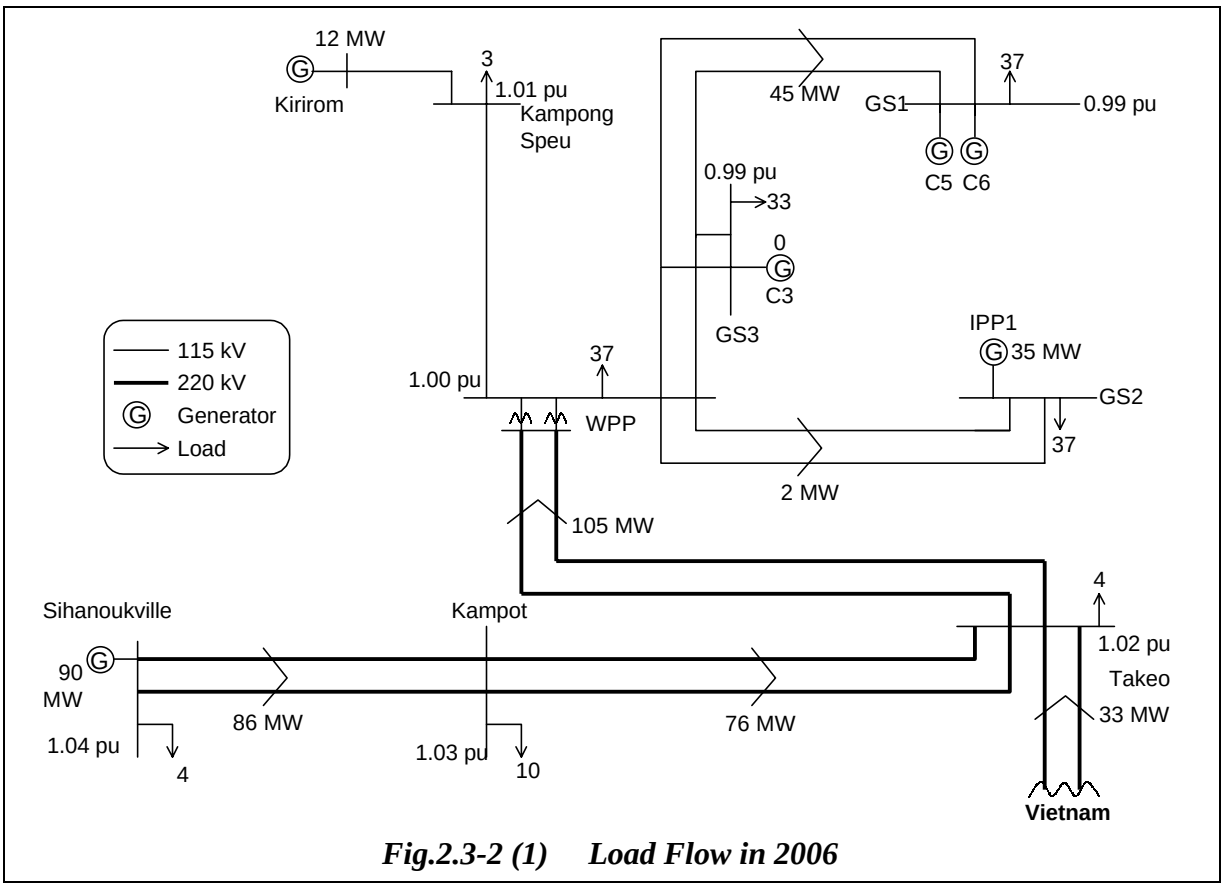


Fig.2.3-2 (1) Load Flow in 2006

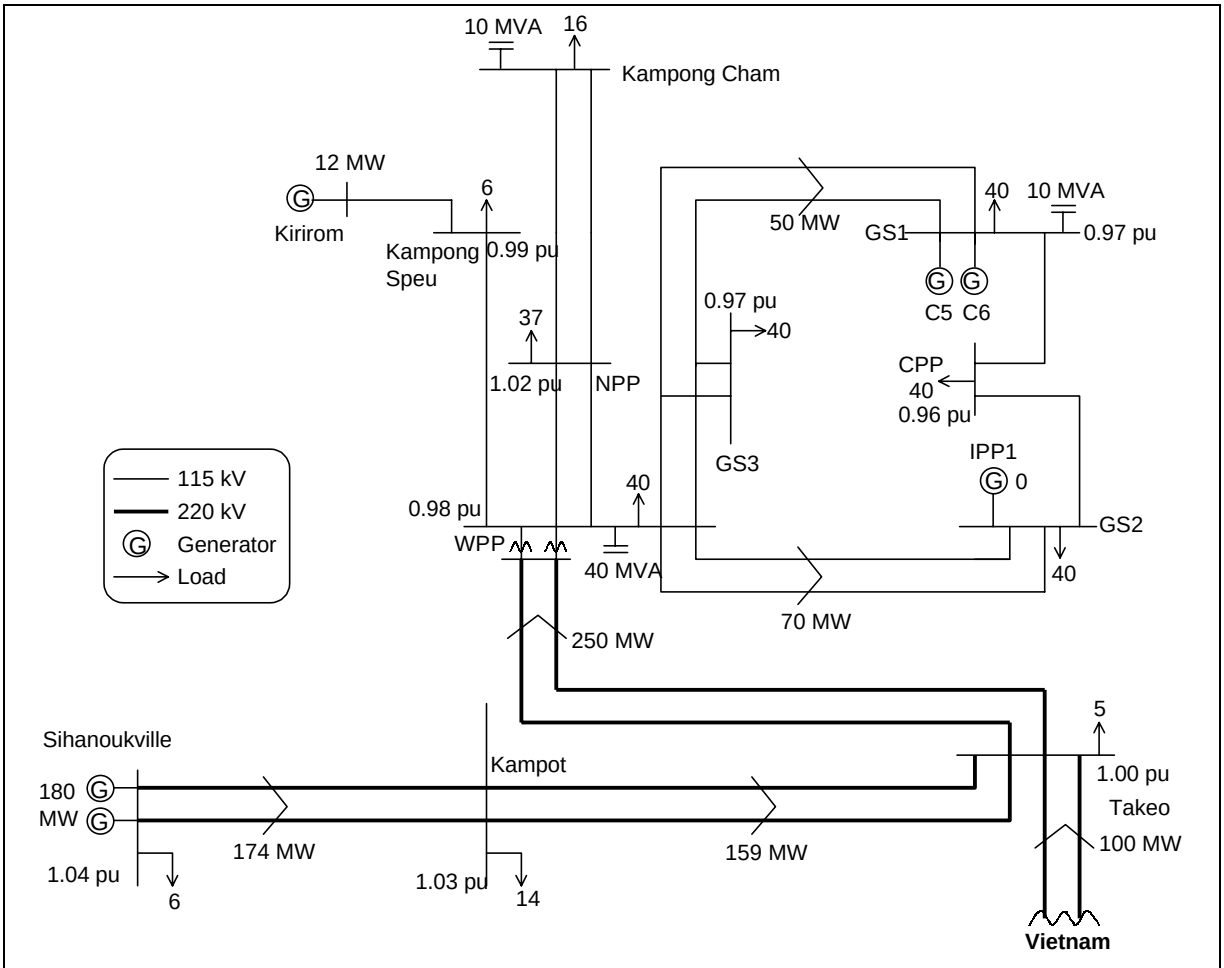


Fig.2.3-2 (2) Load Flow in 2010

2.3.2. Stability Analysis

Stability analysis for the power system in 2006 and 2010 was carried out. The following condition was assumed.

- 3 phase fault occurs near Sihanoukville Plant
- open the faulted circuit without reclosing

The results of stability analysis for the power system in 2006 and 2010 are shown in Fig.2.3-3 and Fig.2.3-4, respectively. As shown in these figures, each power swing converges within 10 seconds.

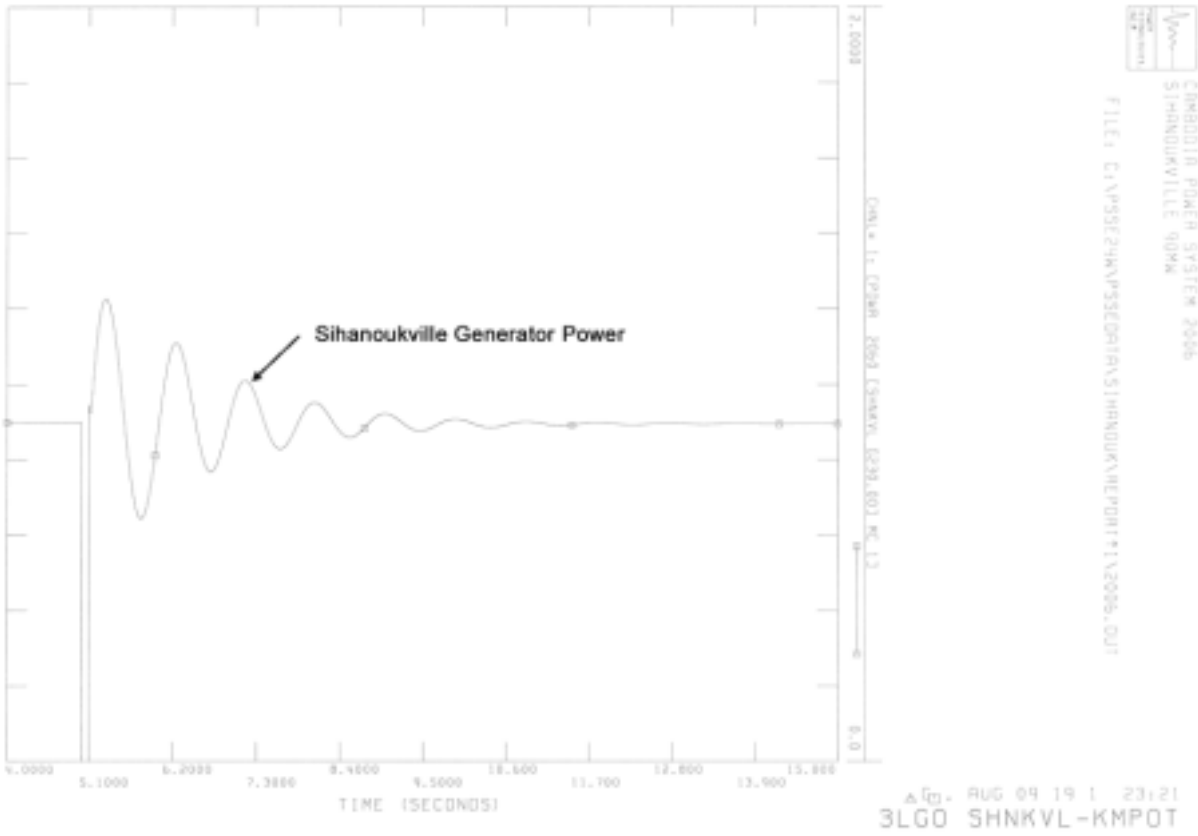


Fig.2.3-3 System Stability Analysis (in 2006)

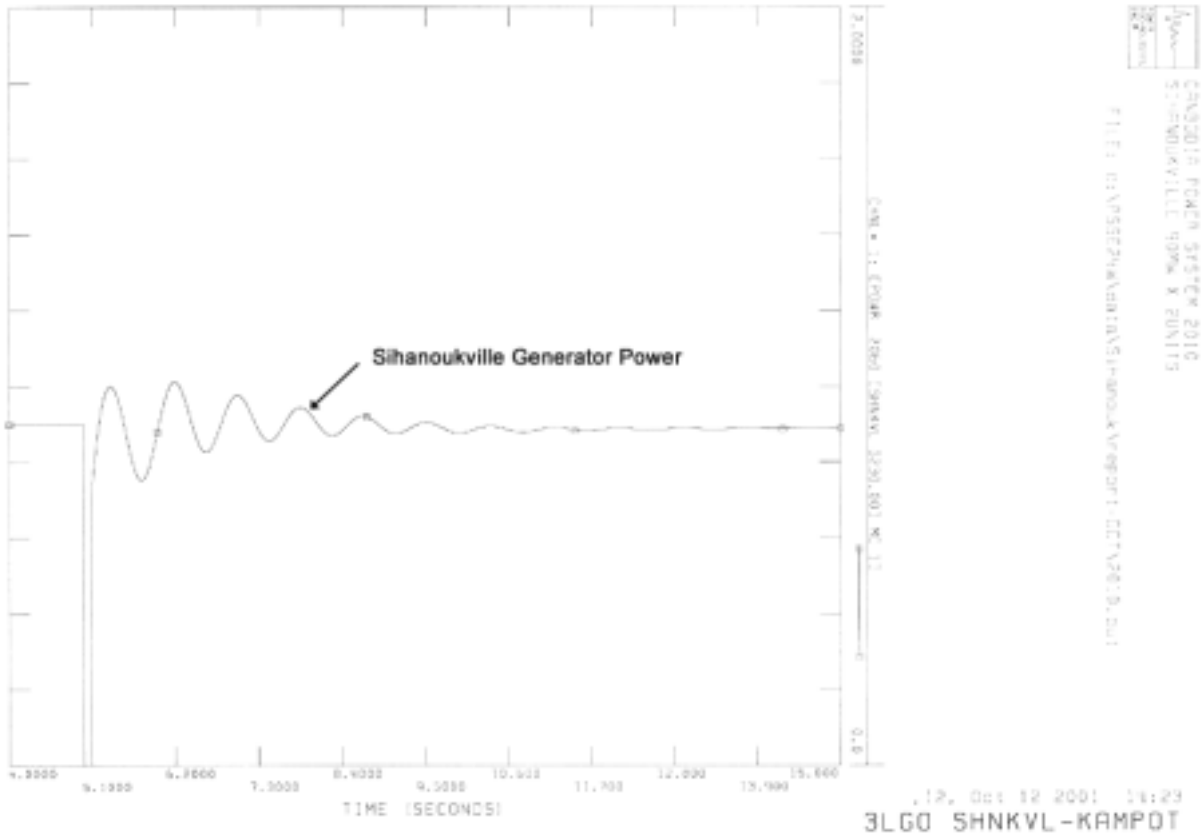


Fig.2.3-4 System Stability Analysis (in 2010)

2.3.3. Fault Analysis

The short circuit current at each station is shown in Fig.2.3-5. Each short circuit current is lower than the design level 31.5 kA.

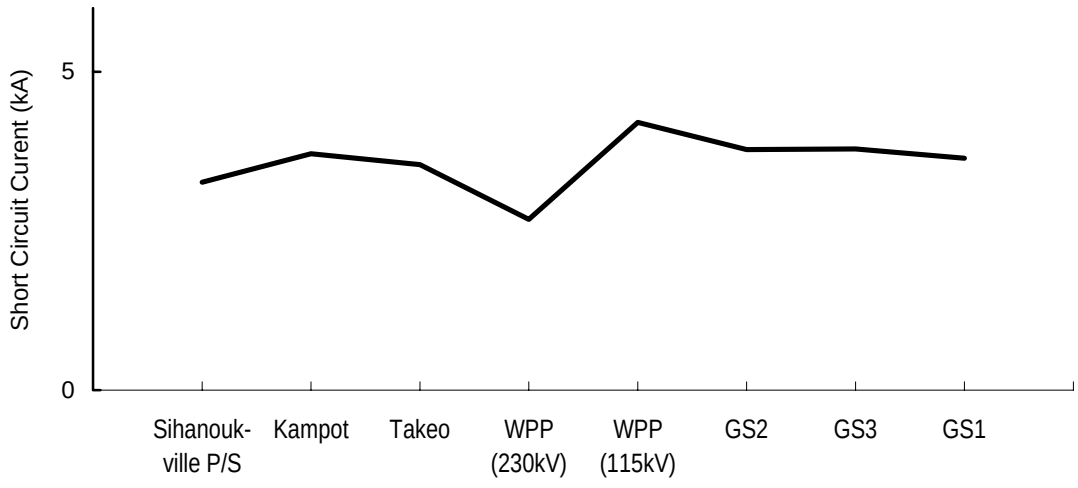


Fig.2.3-5 Short Circuit Current at Each Station in 2010

2.3.4. System Frequency Analysis

Power system frequency should be kept within the criteria, even if one generator unit is disconnected. In other words, generation unit capacity should be limited, taking account of frequency decrease due to the generation unit trip. Low frequency criteria for the Cambodian power system is 47 Hz under fault condition, as mentioned above.

Fig.2.3-6 shows the relation between loss power due to generator trip (% capacity of total generation power) and decrease of power system frequency. According to Fig.2.3-6, generation unit capacity should be limited to about 15% of total generation power.

The total generation power of the power system will be large, year by year. Fig.2.3-7 shows the yearly trend of frequency decrease due to generation unit trip. In case that the power plant is installed until 2006, the recommended unit capacity is smaller than 20 MW. However, a smaller unit capacity is not recommendable, in terms of plant efficiency.

Around 30 MW unit capacity is recommendable, on condition that the load shedding due to generation unit trip is acceptable to some extent (less than 10 MW).

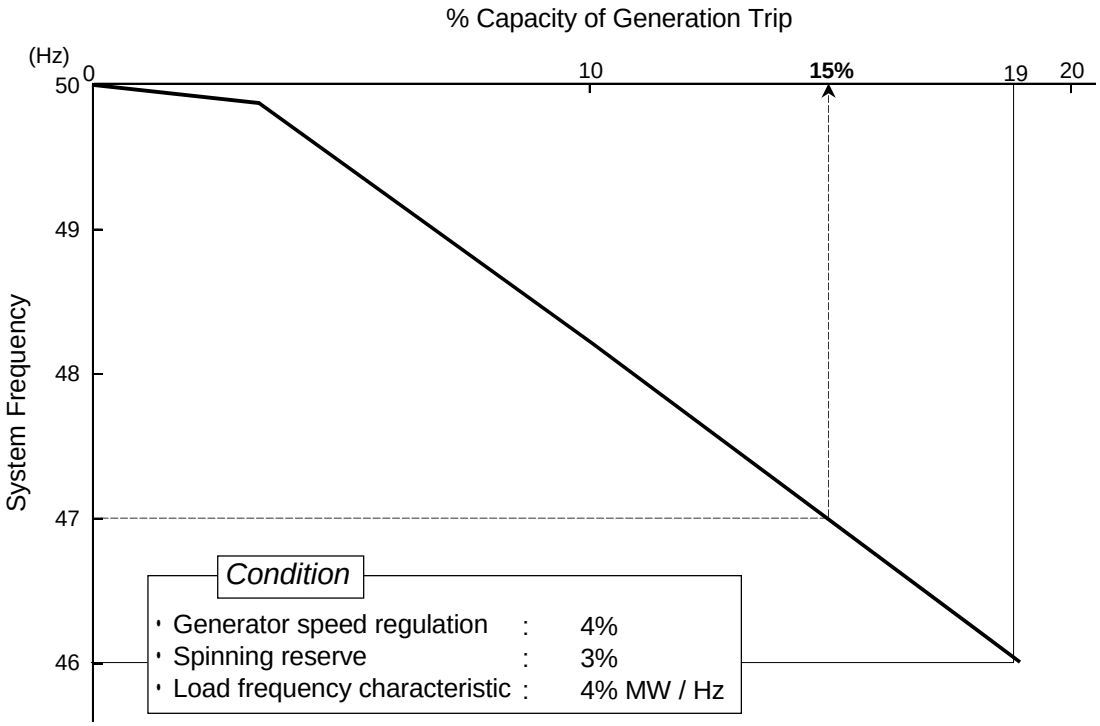


Fig.2.3-6 Frequency Characteristic of Cambodian Power System

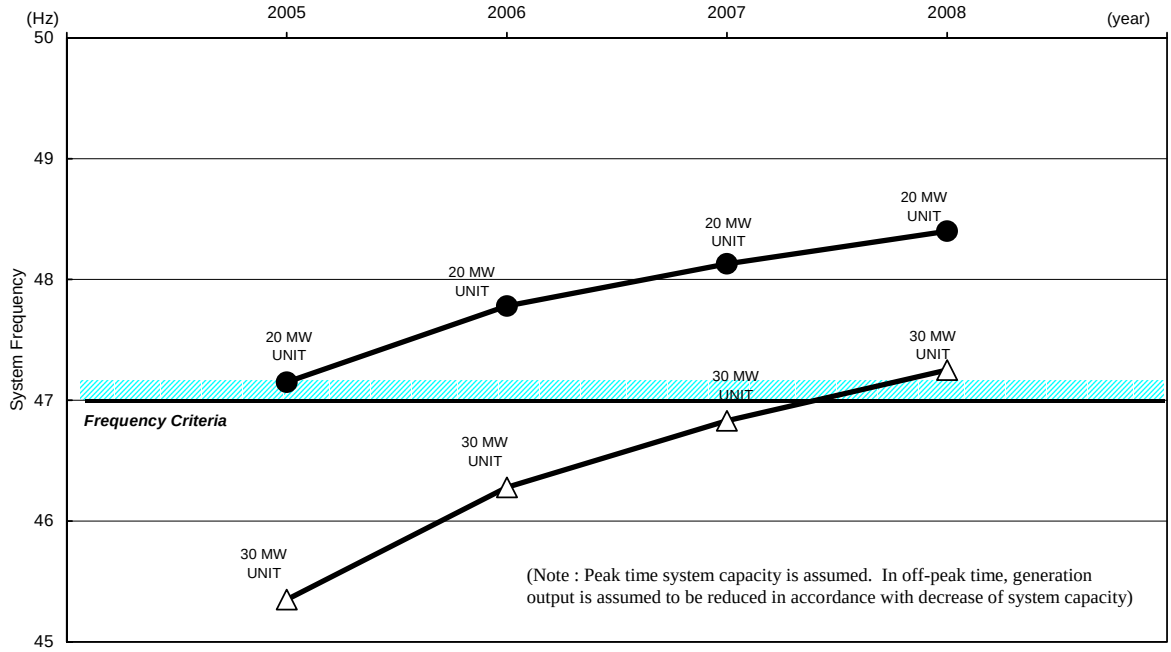


Fig.2.3-7 Frequency Drop after Generation Unit Trip

2.4. Information about Related Transmission/Substation Project

This Feasibility Study was commenced on the condition that the transmission line between Phnom Penh and Sihanoukville would be constructed by the World Bank's Project.

Then, the JICA Study Team has obtained the information about the related World Bank's project "Cambodia Rural Electrification and Transmission Project" (RE & T project) in Cambodia, and the other related plans.

The information obtained until November 2001 is shown below.

2.4.1. Information about RE & T Project

(1) Scope of the Project

The RE & T project consists of three main components; the rural electrification component, the transmission component and technical assistance for the power sector. The transmission component includes the following systems:

- 220 kV interconnection transmission line from Phnom Penh to Vietnam via intermediate Take substation, its total length is around 109 km.
- 220/110/22 kV substation at West Phnom Penh.
- Reinforcement of 115 kV grid in Phnom Penh area, connecting the West Phnom Penh S/S to the existing substations, GS1, GS2 and GS3.

The transmission line between Phnom Penh and Sihanoukville had been planned to be constructed until 2003. However, this plan was already cancelled and the transmission lines from Takeo to Kampot and from Kampot to Sihanoukville are not included in the present scope of work (Phase 1) of the project. And the plan of transmission line from Takeo to Sihanoukville is now ranked as one of the second stage development projects. Therefore, the implementation of the power plant of Sihanoukville will require additional feasibility study work, including environmental impact assessment, for the associated transmission line between

Takeo and Sihanoukville. In the Consultant's Report of the RE & T project, the power generation in Sihanoukville is recommended to be commenced in 2007 with initial capacity of 30 MW.

(2) Financing Plan

Total cost of the RE & T project is estimated around 89 Million US$, including contingencies and interest during construction. The expected financing sources are Japan Bank for International Cooperation (JBIC), International Development Association (IDA), Global Environmental Facility (GEF) and Cambodian Government. The transmission component is, of which cost is estimated around 44 Million US$, planned to be co-funded by JBIC and IDA, but agreement on co-finance between the World Bank and JBIC is not yet settled as mentioned below.

(3) Schedule of the Project Implementation

The project implementation had been scheduled as follows:

Pre-appraisal mission	February 2001 (already done)
Final Consultant's Reports	December 2000 - March 2001 (already done)
Project appraisal	April 2001
Board approval	July 2001

The construction of transmission line is envisaged to be completed within 2003.

However, the above project implementation schedule has already delayed due to unsettled co-finance agreement between the World Bank and JBIC. The World Bank had requested officially JBIC to arrange their finance to the project, but so far JBIC is holding their final decision with referring to the following technical issues which are involved in the present power distribution system in Phnom Penh. JBIC expressed to the World Bank that after these issues have been concluded they will reconsider the matter of co-finance.

- Frequent power failure
- Unstable voltage and frequency
- Lack of data and information necessary for analyzing the condition of system

Due to this circumstance, the time schedule of the transmission project is likely to be further delayed. The expected commissioning time has been already changed from 2003 to 2004 in the latest report of the project.

(4) Information about Vietnam's Plan

The above transmission line of RE & T Project is to be connected with the transmission line from Chau Doc Substation in Vietnam. Transmission line up to the border will be constructed by Cambodia, and that from the border to Chau Doc Substation will be done by Vietnam. The above Vietnam's transmission line will be extended to O Mon Power Station via Thot Not Substation.

According to the Vietnam's power development plan as of June 2001, the implementation schedule of the above transmission line and power station is planned as below:

O Mon oil-gas fired power station (600 MW)	2004 - 2005
O Mon - Thot Not T/L, 220 kV double circuits (28 km)	2004
Thot Not - Chau Doc - Tien Bien T/L, 220 kV double circuits (96 km)	2003
Thot Not Substation	2002 - 2003
Chau Doc Substation	2003 - 2004

Thot Not - Chau Doc - Tien Bien transmission line is planned to be constructed by the World Bank's project.

2.4.2. Transmission Line between Takeo and Sihanoukville

Regarding a transmission line from Takeo to Kampot, the location of Kampot is about mid-point between Takeo and Sihanoukville, MIME/ EDC is considering to construct a 220 kV-double circuit transmission line by the year 2004 under German aid. However, at present, there is no concrete plan to construct a transmission line between Kampot and Sihanoukville.

Fig.2.4-1 shows the route of transmission lines and locations of substations which are described above.

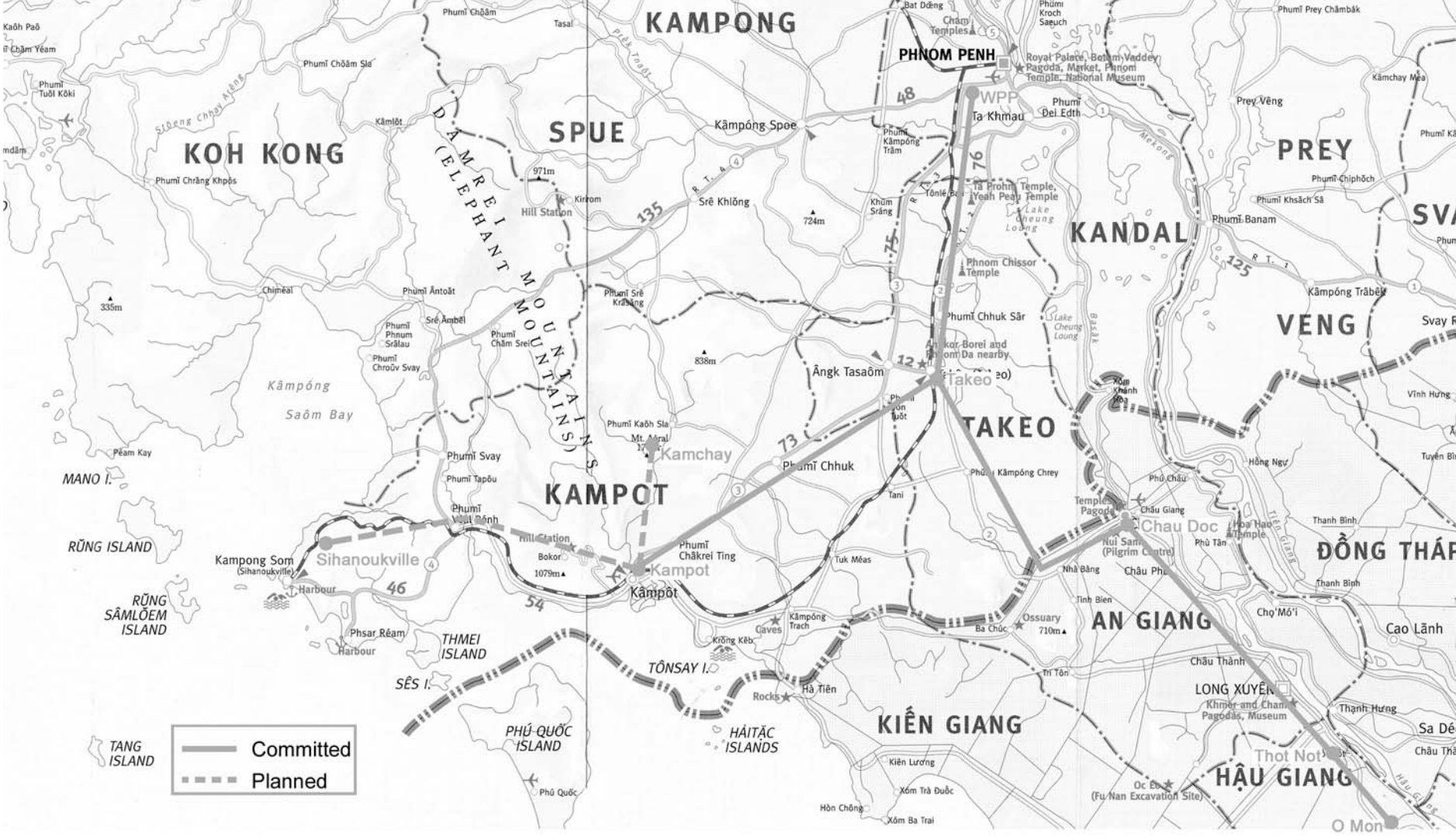


Fig.2.4-1 Plan of 220 kV Transmission Lines