Chapter 3 Problems Facing the Electric Power Sector, and Proposed Solutions

3.1 Verification of Electric Power Development Plan

3.1.1 Demand Forecasting

(1) Verification of Demand Forecasting Methods

The World Bank report adopted by Cambodia presents "hybrid" demand forecasts that combine macroeconomic methods (which explore the relationship between demand and GDP growth) with microeconomic methods (based on the aggregation of household-level demand data). Examination of demand forecasting in neighboring countries shows that, in Vietnam, an electric power system development master plan is employed alongside reports that are compiled every five years by EVN's Institute of Energy, and which use a combination of demand aggregation based on economic growth scenarios (i.e. microeconomic methods) and methods based on energy-GDP elasticity calculations (i.e. macroeconomic methods). In Thailand, demand forecasting is carried out separately for the household sector and the commercial sector, using econometric analysis and customer modeling; this method involves examination of the statistical relationship between historic fuel prices and changes in the level of economic activity (reliable, standardized time-series data is a prerequisite for this type of analysis). Demand forecasting in Laos is based on the population growth rate (as it affects energy consumption per household), the GDP growth rate, and development plan targeting the industrial sector (particularly mining). In light of the current situation in Cambodia, the demand forecasting methods employed in the World Bank report would appear to be suitable for the purpose.
Using a system provided by the World Bank, in 2010 Cambodia's MIME, EAC and EDC revised their demand forecasts to take into account actual performance over the period up until 2009. Given the high rate of growth in demand for electric power in Cambodia, there is a clear need for demand forecasts to be revised at frequent intervals, so as to facilitate the formulation of appropriate electric power development plans and the provision of a stable, reliable power supply.

(2) Verification of Existing Demand Forecasts, and Implementation of Realistic Demand Forecasting

If we examine the rate of increase in maximum system demand in the Phnom Penh system, as shown in Figure 2-28(p.2-57) (which presents a record of maximum system demand), it is apparent that, due to the impact of the global financial crisis, growth in demand for electric power became less pronounced during the 2008 - 2009 period. While the demand forecasts presented in Tables 2-33, 2-34 and 2-35(pp.2-76 to 78) reflect actual performance over the period up until 2009, comparison of maximum system demand in the Phnom Penh system in 2010 and 2011 with the different scenarios gives the results shown below.

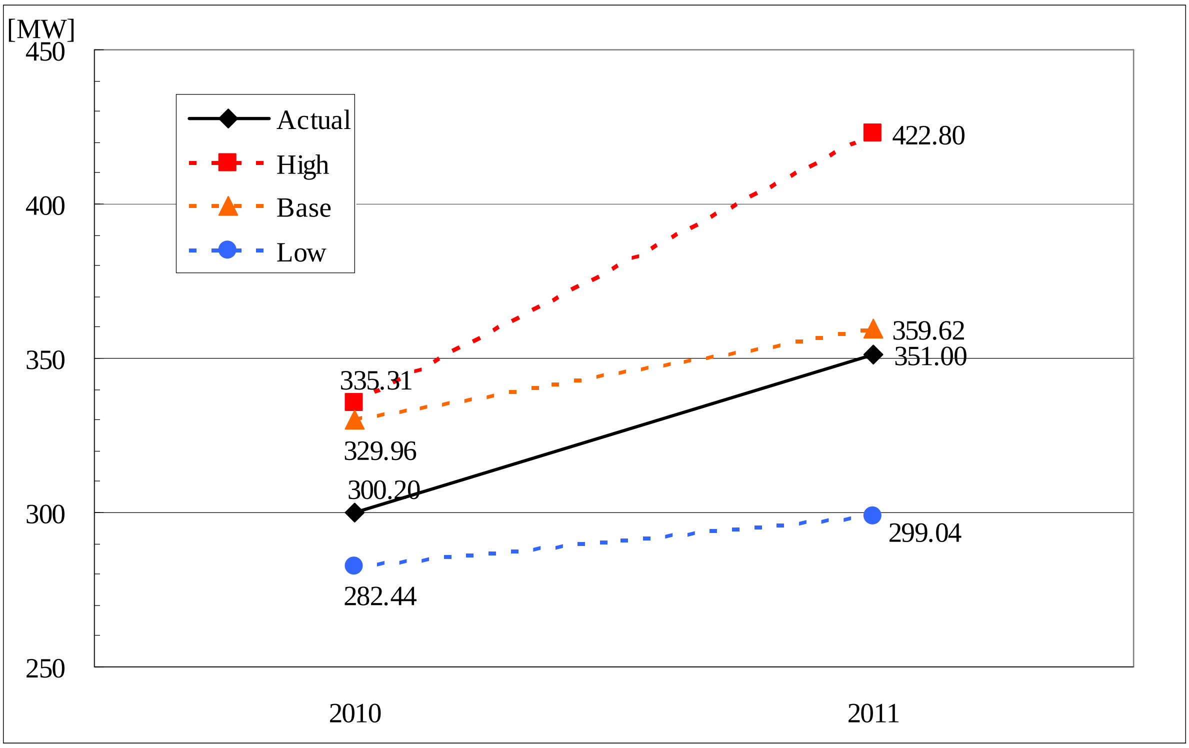


Figure 3-1 Comparison of Actual Demand in the Phnom Penh System with Forecasting Results

As shown in Figure 3-1, the slope of the actual demand line most closely resembles the "High Case" scenario. The main reason for this similarity is that the High Case assumed a high GDP growth rate of 6%, while Cambodia's growth rate in 2010 - 2011 did in fact exceed 6%. However, there is a disparity of approximately 70 MW between the demand forecast for 2011 under the High Case scenario and the actual level of demand in that year, so the High Case forecasts cannot be used without modification. Given that Cambodia is expected to maintain an average GDP growth rate in excess of 6% from 2012 onwards, it appears that the most suitable approach would be to implement demand forecasting based on actual demand in 2010 and the High Case demand growth rate scenario for 2011 onwards. The procedure adopted in this report when formulating the demand forecasts for the period from 2011 onwards was as shown below:

① The electrical energy output [including the output of Rural Electricity Enterprises (REEs)] and electrical energy import volume for every province in Cambodia was added together.

② The forecast electrical energy demand for 2010 under the High Case scenario was compared with the actual recorded demand total calculated in ① above, to give a ratio.

③ The ratio obtained in ② above was applied to the High Case peak demand forecast for 2010 to obtain a demand estimate for 2010.

④ The estimate obtained in ③ above was combined with the anticipated growth rates for each province over the 2011 - 2024 timeframe to calculate forecast maximum demand.

⑤ The actual recorded demand total for each province calculated in ① above and the grid connection rates used when calculating the High Case forecasts were used to obtain a figure for overall demand for each province in 2010.

⑥ The values obtained in ⑤ above and the High Case growth rates for each province were used to calculate overall demand for each province over the 2011 - 2024 timeframe.

⑦ Based on the most recent transmission line plan, the year in which each province will be connected to the national grid was forecast. Then, using the results obtained in ④ and ⑥, the peak demand and the amount of electrical energy generated were calculated for the national grid, reflecting the years in which each province will be connected to the grid.

The computation results for items ① to ③ above were as shown in Table 3-1.

Table 3-1 Estimated Peak Demand in Each Province of Cambodia in 2010

	Energy in 2010 (High case, GWh) A	Energy in 2010 (Record, GWh) B	Ratio C=B/A	Peak Demand in 2010 (High case, MW) D	Peak Demand Forecast in 2010 (High case, MW) C*D
Banteay Meanchey	71.08	82.19	1.16	15.31	17.70
Battambang	136.63	66.26	0.48	29.43	14.27
Kampong Cham	152.09	86.13	0.57	37.02	20.96
Kampong Chhnang	42.37	7.05	0.17	8.79	1.46
Kampong Speu	39.70	5.07	0.13	8.24	1.05
Kampong Thom	48.32	6.51	0.13	10.03	1.35
Kampot	241.57	30.78	0.13	68.94	8.79
Kandal	135.08	68.51	0.51	30.84	15.64
Kep	4.60	4.08	0.89	1.05	0.93
Koh Kong	80.68	22.32	0.28	17.38	4.81
Kratie	23.30	9.52	0.41	6.33	2.59
Mondul Kiri	5.36	2.59	0.48	1.75	0.84
Oddar Meanchey	6.16	14.23	2.31	2.01	4.64
Pailin	9.02	13.05	1.45	1.94	2.81
Phnom Penh	2,236.33	1,652.45	0.74	381.03	281.55
Preah Vihear	12.23	1.98	0.16	3.99	0.64
Prey Veng	91.78	12.85	0.14	34.92	4.89
Pursat	39.43	8.57	0.22	8.49	1.84
Ratanak Kiri	23.92	8.24	0.34	9.10	3.13
Siemreap	174.02	198.35	1.14	37.48	42.72
Sihanoukville	88.25	61.57	0.70	19.37	13.52
Stung Treng	30.22	5.82	0.19	8.21	1.58
Svay Rieng	40.76	79.01	1.94	9.31	18.04
Takeo	36.76	11.39	0.31	8.39	2.60

The growth rates used in ④ and ⑥ for the High Case growth rate in peak demand and amount of electrical energy generated over the period from 2011 to 2024 were as shown in Table 3-2 and Table 3-3.

Table 3-2 High Case Growth Rates for Peak Demand

No.	Provincial Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	Phnom Penh	25.00%	25.00%	23.00%	20.00%	16.00%	14.00%	12.00%	10.00%	9.80%	9.50%	9.10%	8.90%	8.90%	8.90%
2	Kandal	12.43%	12.27%	10.84%	11.33%	11.31%	12.11%	11.25%	11.22%	11.20%	11.20%	13.06%	13.05%	13.06%	13.07%
3	Kampong Speu	14.79%	14.37%	12.70%	13.67%	13.38%	16.28%	14.75%	14.51%	14.31%	14.15%	13.23%	13.20%	13.26%	13.34%
4	Takeo	14.31%	14.01%	12.46%	13.52%	13.33%	14.22%	13.01%	12.89%	12.80%	12.35%	14.14%	14.19%	14.25%	14.33%
5	Kampot	4.23%	4.32%	3.21%	4.19%	4.24%	4.85%	4.36%	4.38%	4.38%	4.38%	4.35%	4.30%	4.25%	4.19%
6	Kep	18.40%	17.37%	15.20%	15.83%	15.23%	16.04%	14.32%	13.95%	13.63%	13.35%	15.02%	14.80%	14.63%	12.03%
7	Sihanoukville	9.45%	9.23%	9.17%	8.99%	8.82%	9.57%	7.79%	6.07%	6.12%	6.18%	7.95%	6.28%	6.35%	8.03%
8	Kampong Cham	15.02%	12.74%	10.33%	10.58%	11.13%	12.47%	9.41%	8.74%	14.73%	9.63%	10.05%	10.25%	11.68%	11.38%
9	Banteay Meanchey	13.30%	13.07%	11.56%	12.64%	12.44%	13.20%	12.11%	13.82%	13.65%	12.73%	12.47%	12.47%	12.48%	12.49%
10	Battambang	13.37%	13.12%	7.76%	12.69%	12.50%	13.12%	11.36%	13.17%	13.09%	13.04%	13.00%	12.97%	12.95%	12.95%
11	Siemreap	11.08%	10.81%	9.92%	10.31%	10.08%	10.85%	9.68%	10.94%	10.05%	9.98%	9.93%	9.88%	9.84%	9.81%
12	Kampong Chhnang	14.39%	14.13%	12.62%	13.73%	13.57%	16.36%	15.16%	14.43%	13.97%	14.05%	14.13%	14.23%	14.34%	14.45%
13	Pursat	14.76%	14.55%	13.05%	14.17%	14.02%	16.79%	15.67%	15.52%	15.38%	14.62%	14.32%	14.38%	14.44%	14.52%
14	Koh Kong	13.05%	12.34%	8.06%	9.32%	9.34%	11.82%	11.22%	11.04%	10.88%	10.86%	10.84%	9.33%	9.29%	9.25%
15	Oddar Meanchey	16.63%	15.86%	13.88%	14.60%	14.08%	15.23%	13.23%	12.84%	12.47%	12.15%	11.88%	11.64%	11.44%	11.02%
16	Pailin	15.79%	15.49%	13.91%	14.99%	14.78%	15.47%	14.45%	16.20%	16.05%	15.91%	14.43%	13.71%	13.87%	14.04%
17	Prey Veng	8.58%	8.59%	10.41%	11.41%	11.18%	12.40%	10.79%	10.63%	10.50%	10.41%	10.36%	10.07%	10.10%	10.18%
18	Svay Rieng	13.71%	13.50%	11.65%	12.64%	12.58%	13.58%	12.47%	12.45%	12.44%	12.46%	14.38%	14.41%	14.47%	14.55%
19	Kratie	20.99%	18.27%	12.75%	11.40%	10.10%	10.91%	9.11%	8.86%	8.73%	8.53%	8.30%	8.23%	8.02%	8.52%
20	Stung Treng	16.61%	15.68%	12.73%	11.00%	10.57%	11.57%	9.89%	15.29%	10.84%	12.03%	13.21%	12.68%	12.78%	12.88%
21	Ratanak Kiri	9.36%	9.74%	9.62%	12.06%	12.24%	12.95%	12.38%	12.52%	12.64%	12.76%	12.89%	13.01%	13.13%	13.25%
22	Mondul Kiri	14.06%	13.78%	12.25%	13.34%	13.18%	13.94%	12.95%	12.86%	12.78%	12.73%	12.71%	11.63%	11.54%	11.74%
23	Kampong Thom	14.70%	14.31%	12.69%	13.71%	13.47%	16.21%	14.96%	14.80%	14.66%	14.56%	14.02%	13.56%	13.71%	13.87%
24	Preah Vihear	15.82%	15.24%	13.43%	14.30%	13.92%	14.89%	13.30%	13.04%	12.79%	12.58%	12.41%	12.27%	12.01%	10.35%

Table 3-3 High Case Growth Rates for Amount of Electrical Energy Generated

No.	Provincial Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	Phnom Penh	25.00%	25.00%	23.00%	20.00%	16.00%	14.00%	12.00%	10.00%	9.80%	9.50%	9.10%	8.90%	8.90%	8.90%
2	Kandal	14.68%	14.47%	12.97%	13.43%	13.37%	14.14%	13.23%	13.17%	13.12%	13.08%	13.06%	13.05%	13.06%	13.07%
3	Kampong Speu	16.88%	16.41%	14.68%	15.63%	15.30%	16.28%	14.75%	14.51%	14.31%	14.15%	13.23%	13.20%	13.26%	13.34%
4	Takeo	16.60%	16.25%	14.62%	15.66%	15.43%	16.29%	15.03%	14.87%	14.74%	14.25%	14.14%	14.19%	14.25%	14.33%
5	Kampot	6.84%	6.86%	5.67%	6.61%	6.61%	7.19%	6.62%	6.60%	6.55%	6.51%	6.43%	6.35%	6.26%	6.16%
6	Kep	20.77%	19.67%	17.42%	18.01%	17.37%	18.15%	16.36%	15.94%	15.59%	15.27%	15.02%	14.80%	14.63%	12.03%
7	Sihanoukville	11.56%	11.30%	11.19%	10.97%	10.76%	11.50%	9.65%	7.87%	7.89%	7.92%	7.95%	7.99%	8.04%	8.03%
8	Kampong Cham	18.93%	16.67%	13.37%	13.48%	13.07%	13.95%	10.89%	10.20%	16.27%	10.80%	10.98%	11.17%	11.37%	11.57%
9	Banteay Meanchey	15.44%	15.16%	13.59%	14.65%	14.42%	15.15%	14.01%	13.82%	13.65%	12.73%	12.47%	12.47%	12.48%	12.49%
10	Battambang	15.51%	15.22%	9.72%	14.70%	14.47%	15.07%	13.25%	13.17%	13.09%	13.04%	13.00%	12.97%	12.95%	12.95%
11	Siemreap	13.18%	12.86%	11.92%	12.28%	12.01%	12.76%	11.54%	10.94%	10.05%	9.98%	9.93%	9.88%	9.84%	9.81%
12	Kampong Chhnang	16.47%	16.17%	14.60%	15.69%	15.49%	16.36%	15.16%	14.43%	13.97%	14.05%	14.13%	14.23%	14.34%	14.45%
13	Pursat	16.93%	16.67%	15.11%	16.21%	16.02%	16.79%	15.67%	15.52%	15.38%	14.62%	14.32%	14.38%	14.44%	14.52%
14	Koh Kong	15.18%	14.42%	10.02%	11.28%	11.26%	11.82%	11.22%	11.04%	10.88%	10.86%	10.84%	9.33%	9.29%	9.25%
15	Oddar Meanchey	19.96%	19.07%	16.95%	17.62%	17.01%	18.11%	15.99%	15.52%	15.09%	14.70%	14.37%	14.07%	13.81%	13.33%
16	Pailin	17.98%	17.62%	15.98%	17.04%	16.79%	17.46%	16.39%	16.20%	16.05%	15.91%	14.43%	13.71%	13.87%	14.04%
17	Prey Veng	15.82%	15.37%	13.66%	14.60%	14.27%	15.44%	13.70%	13.46%	13.26%	13.10%	12.98%	12.63%	12.60%	12.63%
18	Svay Rieng	15.99%	15.72%	13.80%	14.76%	14.66%	15.64%	14.48%	14.42%	14.38%	14.36%	14.38%	14.41%	14.47%	14.55%
19	Kratie	23.87%	21.03%	15.31%	13.87%	12.49%	13.27%	11.38%	11.08%	10.90%	10.66%	10.38%	10.27%	10.02%	10.49%
20	Stung Treng	19.39%	18.37%	15.30%	13.47%	12.97%	13.94%	12.18%	17.65%	13.06%	13.13%	14.31%	13.76%	13.85%	13.95%
21	Ratanak Kiri	16.65%	16.59%	12.84%	15.26%	15.36%	16.00%	15.34%	15.40%	15.45%	15.52%	15.58%	15.64%	15.70%	15.77%
22	Mondul Kiri	17.32%	16.94%	15.29%	16.32%	16.08%	16.79%	15.71%	15.55%	15.40%	15.29%	15.21%	14.06%	13.92%	14.07%
23	Kampong Thom	16.78%	16.36%	14.67%	15.67%	15.39%	16.21%	14.96%	14.80%	14.66%	14.56%	14.02%	13.56%	13.71%	13.87%
24	Preah Vihear	19.13%	18.44%	16.50%	17.30%	16.84%	17.76%	16.07%	15.73%	15.41%	15.13%	14.91%	14.71%	14.39%	12.65%

The expansion of the national grid in each year is shown in Table 3-4. A yellow background indicates that the province in question will have been connected to the national grid as of December 31 of that year. A blue background indicates that the province in question will have been connected to the north-west grid as of the end of that year. A light green background indicates that the province in question will have been connected each other as of the end of that year. As planning has not yet been undertaken for the period from 2021 onwards, it as assumed, for convenience, that all provinces not connected to the national grid as of the end of 2020 will have been connected to the grid by 2021.

Table 3-4 The Expansion of the National Grid

N.	Provincial Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	Phnom Penh															
2	Kandal															
3	Kampong Speu															
4	Takeo															
5	Kampot															
6	Kep															
7	Sihanoukville															
8	Kampong Cham															
9	Banteay Meanchey															
10	Battambang															
11	Siemreap															
12	Kampong Chhnang															
13	Pursat															
14	Koh Kong															
15	Oddar Meanchey															
16	Pailin															
17	Prey Veng															
18	Svay Rieng															
19	Kratie															
20	Stung Treng															
21	Ratanak Kiri															
22	Mondul Kiri															
23	Kampong Thom															
24	Preah Vihear															

The demand forecasts for the period 2011 - 2024 reflecting the results of the calculations in items ① to ⑦ are shown in Table 3-5 and Table 3-6.

Table 3-5 Peak Demand Forecast Results

No.	Provincial Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	Phnom Penh	281.55	351.93	439.92	541.10	649.32	753.21	858.66	961.70	1,057.87	1,161.54	1,271.88	1,387.63	1,511.12	1,645.61	1,792.07
2	Kandal	15.64	17.59	19.74	21.89	24.37	27.12	30.40	33.82	37.62	41.83	46.51	52.59	59.46	67.22	76.01
3	Kampong Speu	1.05	1.21	1.38	1.56	1.77	2.01	2.33	2.68	3.06	3.50	4.00	4.53	5.12	5.80	6.58
4	Takeo	2.60	2.97	3.39	3.81	4.33	4.90	5.60	6.33	7.15	8.06	9.06	10.34	11.81	13.49	15.42
5	Kampot	8.79	9.16	9.55	9.86	10.27	10.71	11.23	11.72	12.23	12.77	13.32	13.90	14.50	15.12	15.75
6	Kep	0.93	1.10	1.29	1.49	1.73	1.99	2.31	2.64	3.01	3.41	3.87	4.45	5.11	5.86	6.56
7	Sihanoukville	13.52	14.79	16.16	17.64	19.23	20.92	22.93	24.71	26.21	27.82	29.54	31.88	33.89	36.04	38.93
8	Kampong Cham	20.96	24.11	27.19	29.99	33.17	36.86	41.46	45.36	49.32	56.58	62.03	68.26	75.26	84.05	93.62
9	Banteay Meanchey	17.70	20.06	22.68	25.30	28.50	32.04	36.27	40.67	46.29	52.61	59.30	66.70	75.01	84.37	94.91
10	Battambang	14.27	16.18	18.30	19.72	22.23	25.00	28.28	31.50	35.65	40.31	45.57	51.49	58.17	65.70	74.21
11	Siemreap	42.72	47.46	52.58	57.80	63.76	70.19	77.80	85.33	94.67	104.18	114.58	125.96	138.40	152.02	166.93
12	Kampong Chhnang	1.46	1.67	1.91	2.15	2.45	2.78	3.23	3.72	4.26	4.85	5.53	6.32	7.22	8.25	9.44
13	Pursat	1.84	2.12	2.43	2.74	3.13	3.57	4.17	4.82	5.57	6.43	7.37	8.42	9.63	11.02	12.62
14	Koh Kong	4.81	5.43	6.10	6.60	7.21	7.89	8.82	9.81	10.89	12.07	13.39	14.84	16.22	17.73	19.37
15	Oddar Meanchey	4.64	5.41	6.27	7.14	8.18	9.34	10.76	12.18	13.75	15.46	17.34	19.40	21.66	24.14	26.79
16	Pailin	2.81	3.25	3.76	4.28	4.92	5.65	6.52	7.47	8.67	10.07	11.67	13.35	15.18	17.29	19.72
17	Prey Veng	4.89	5.31	5.76	6.36	7.09	7.88	8.86	9.82	10.86	12.00	13.25	14.62	16.09	17.72	19.52
18	Svay Rieng	18.04	20.51	23.28	25.99	29.28	32.96	37.44	42.11	47.35	53.24	59.87	68.48	78.34	89.68	102.73
19	Kratie	2.59	3.13	3.70	4.17	4.65	5.12	5.68	6.20	6.74	7.33	7.96	8.62	9.33	10.08	10.93
20	Stung Treng	1.58	1.84	2.13	2.40	2.67	2.95	3.29	3.62	4.17	4.62	5.18	5.86	6.61	7.45	8.41
21	Ratanak Kiri	3.13	3.43	3.76	4.12	4.62	5.19	5.86	6.58	7.41	8.34	9.41	10.62	12.00	13.58	15.38
22	Mondul Kiri	0.84	0.96	1.09	1.23	1.39	1.58	1.80	2.03	2.29	2.58	2.91	3.28	3.66	4.09	4.57
23	Kampong Thom	1.35	1.55	1.77	2.00	2.27	2.58	2.99	3.44	3.95	4.53	5.19	5.92	6.72	7.64	8.70
24	Preah Vihear	0.64	0.75	0.86	0.98	1.11	1.27	1.46	1.65	1.87	2.11	2.37	2.67	2.99	3.35	3.70
Main Grid		**300.84**	**373.70**	**600.36**	**735.05**	**871.55**	**999.37**	**1,133.64**	**1,271.38**	**1,459.42**	**1,613.96**	**1,773.42**	**2,000.12**	**2,193.51**	**2,407.30**	**2,642.88**
Whole country		**468.37**	**561.93**	**675.02**	**800.33**	**937.64**	**1,073.69**	**1,218.14**	**1,359.88**	**1,500.84**	**1,656.25**	**1,821.10**	**2,000.12**	**2,193.51**	**2,407.30**	**2,642.88**

Table 3-6 Electrical Energy Generation Forecast Results

No.	Provincial Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	Phnom Penh	1,921.45	2,401.81	3,002.26	3,692.79	4,431.35	5,140.36	5,860.01	6,563.21	7,219.53	7,927.05	8,680.1	9,470.0	10,312.8	11,230.7	12,230.2
2	Kandal	114.18	130.95	149.90	169.35	192.10	217.77	248.57	281.46	318.54	360.33	407.47	460.69	520.83	588.84	665.83
3	Kampong Speu	8.45	9.87	11.49	13.18	15.24	17.57	20.43	23.44	26.84	30.68	35.02	39.66	44.89	50.84	57.62
4	Takeo	18.99	22.14	25.74	29.50	34.12	39.39	45.80	52.69	60.52	69.44	79.34	90.56	103.41	118.15	135.09
5	Kampot	51.31	54.81	58.58	61.90	65.99	70.35	75.41	80.40	85.71	91.32	97.27	103.53	110.10	116.99	124.20
6	Kep	6.79	8.20	9.82	11.53	13.60	15.96	18.86	21.95	25.45	29.41	33.91	39.00	44.77	51.32	57.49
7	Sihanoukville	102.61	114.47	127.40	141.66	157.20	174.11	194.13	212.86	229.61	247.73	267.35	288.62	311.69	336.73	363.77
8	Kampong Cham	143.56	170.73	199.18	225.81	256.26	289.75	330.18	366.13	403.48	469.12	519.80	576.87	641.30	714.19	796.83
9	Banteay Meanchey	136.98	158.14	182.11	206.86	237.16	271.35	312.46	356.23	405.48	460.84	519.51	584.27	657.11	739.09	831.43
10	Battambang	110.43	127.56	146.97	161.26	184.97	211.73	243.64	275.92	312.26	353.15	399.18	451.05	509.55	575.56	650.11
11	Siemreap	330.59	374.14	422.25	472.58	530.62	594.34	670.18	747.53	829.33	912.64	1,003.73	1,103.38	1,212.40	1,331.71	1,462.30
12	Kampong Chhnang	11.74	13.68	15.89	18.21	21.06	24.33	28.31	32.60	37.30	42.51	48.49	55.34	63.22	72.28	82.72
13	Pursat	14.28	16.69	19.47	22.42	26.05	30.22	35.30	40.83	47.16	54.42	62.37	71.30	81.56	93.34	106.89
14	Koh Kong	37.20	42.85	49.02	53.94	60.02	66.78	74.67	83.04	92.21	102.25	113.35	125.64	137.36	150.12	164.01
15	Oddar Meanchey	23.72	28.45	33.88	39.62	46.60	54.53	64.41	74.71	86.30	99.32	113.92	130.28	148.61	169.14	191.68
16	Pailin	21.74	25.65	30.17	34.99	40.96	47.83	56.19	65.39	75.99	88.19	102.22	116.98	133.02	151.47	172.74
17	Prey Veng	21.41	24.80	28.61	32.52	37.27	42.58	49.16	55.89	63.42	71.83	81.24	91.79	103.38	116.41	131.11
18	Svay Rieng	131.68	152.73	176.75	201.14	230.83	264.68	306.08	350.41	400.94	458.59	524.45	599.85	686.30	785.61	899.87
19	Kratie	15.87	19.65	23.78	27.43	31.23	35.13	39.79	44.32	49.23	54.60	60.42	66.69	73.54	80.91	89.40
20	Stung Treng	9.69	11.57	13.70	15.80	17.92	20.25	23.07	25.88	30.45	34.43	38.95	44.52	50.65	57.67	65.71
21	Ratanak Kiri	13.73	16.01	18.67	21.07	24.28	28.01	32.49	37.48	43.25	49.94	57.68	66.67	77.10	89.21	103.27
22	Mondul Kiri	4.31	5.06	5.91	6.82	7.93	9.21	10.75	12.44	14.37	16.59	19.13	22.03	25.13	28.63	32.66
23	Kampong Thom	10.85	12.67	14.74	16.90	19.55	22.56	26.22	30.14	34.60	39.68	45.45	51.83	58.85	66.92	76.20
24	Preah Vihear	3.29	3.92	4.64	5.41	6.35	7.42	8.73	10.14	11.73	13.54	15.59	17.91	20.55	23.50	26.48
Participation to the Main Grid(Rural)		60.0%	61.0%	62.0%	63.0%	64.0%	65.0%	66.0%	67.0%	68.0%	69.0%	70.0%	71.0%	72.0%	73.0%	74.0%
Participation to the Main Grid(Urban)		86.0%	87.0%	88.0%	89.0%	90.0%	91.0%	92.0%	93.0%	94.0%	95.0%	96.0%	97.0%	98.0%	99.0%	100.0%
Main Grid Total		2,063.07	2,564.77	4,243.66	5,227.03	6,214.86	7,152.62	8,146.14	9,162.95	10,588.52	11,757.71	12,961.75	14,668.48	16,128.16	17,739.31	19,517.64
Main Grid Connected		**1,737.42**	**2,188.98**	**3,411.66**	**4,253.16**	**5,129.66**	**5,985.70**	**6,900.05**	**7,845.61**	**9,077.27**	**10,173.85**	**11,330.06**	**13,160.93**	**14,499.87**	**15,981.98**	**17,622.91**
Whole country		3,264.86	3,946.57	4,770.95	5,682.67	6,688.66	7,696.22	8,774.84	9,845.11	10,903.73	12,077.59	13,325.95	14,668.48	16,128.16	17,739.31	19,517.64

Comparisons of the national grid peak demand forecasting results with the results for the Base Case, High Case and Low Case scenarios are shown in Table 3-7 and Figure 3-2. It can be seen that the peak demand forecasting results are somewhat higher than the Base Case results.

Table 3-7 Comparison of National Grid Peak Demand Forecasting Results

Peak in Main Grid (MW)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
High case	507	724	898	1,114	1,299	1,496	1,801	2,022	2,242	2,478
Base case	351	495	587	710	814	925	1,093	1,217	1,332	1,452
Low case	237	327	365	426	466	514	588	651	703	758
Forecase Result	374	600	735	872	999	1,134	1,271	1,459	1,614	1,773

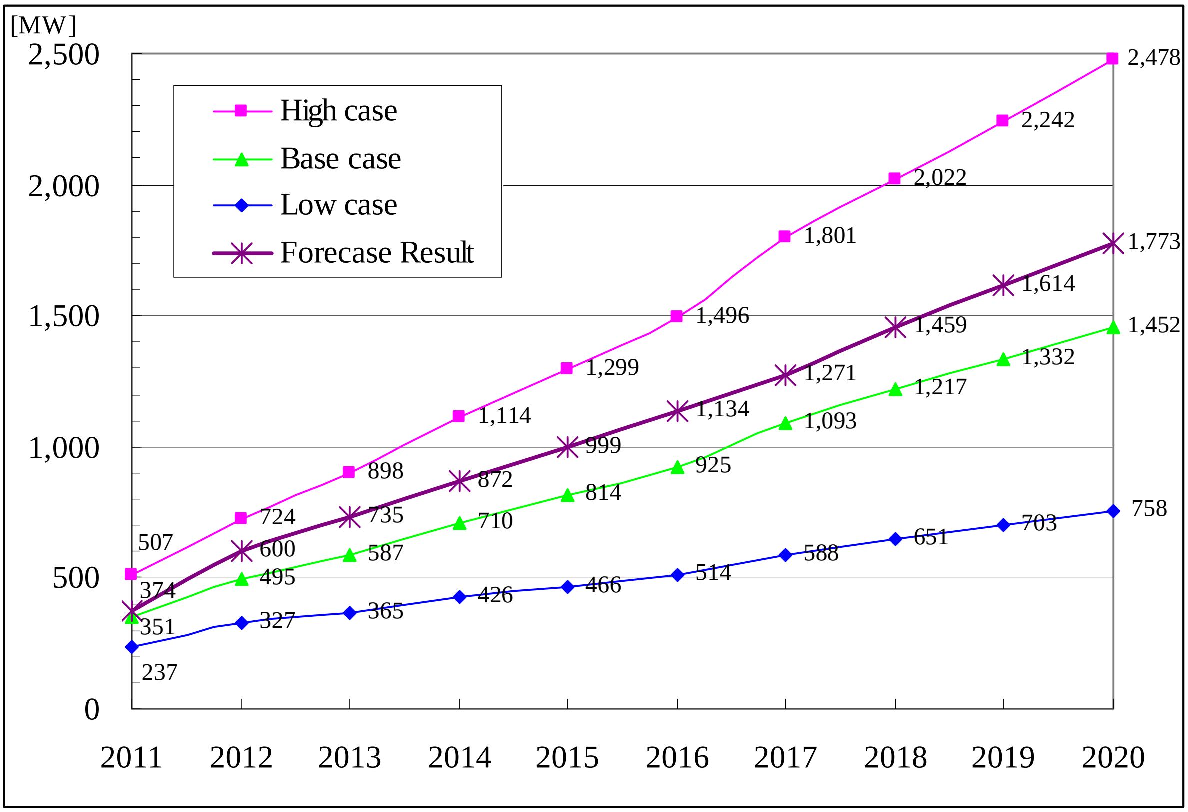


Figure 3-2 Comparison of National Grid Peak Demand Forecasting Results

Comparisons of the electrical energy generation forecasting results with the results for the Base Case, High Case and Low Case scenarios are shown in Table 3-8 and Figure 3-3. Regardless of the month in which a particular province is connected to the national grid, it is assumed that all of the power used in that province is supplied from the national grid in the year in which a province is first connected to the grid. It can be seen that the energy generation forecasting results are somewhat higher than the Base Case results.

Table 3-8 Comparison of National Grid Electrical Energy Generation Forecasting Results

Energy in Main Grid (GWh)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
High case	2,802	4,001	4,962	6,154	7,173	8,266	9,947	11,172	12,387	13,689
Base case	1,940	2,735	3,244	3,919	4,499	5,112	6,038	6,724	7,357	8,019
Low case	1,309	1,806	2,016	2,355	2,577	2,840	3,250	3,594	3,885	4,188
Forecase Result	2,189	3,412	4,253	5,130	5,986	6,900	7,846	9,077	10,174	11,330

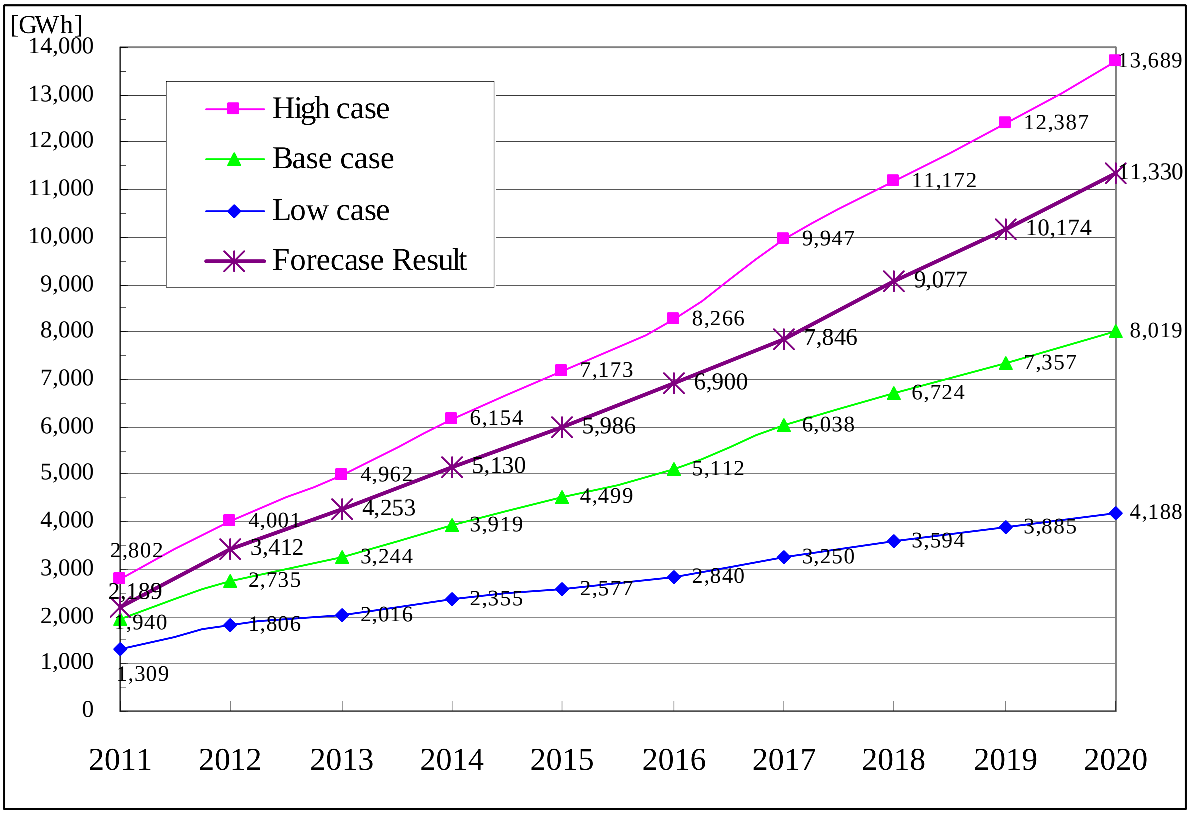


Figure 3-3 Comparison of National Grid Electrical Energy Generation Forecasting Results

(3) The Phnom Penh System

The Phnom Penh system peak demand forecast results needed for Phnom Penh area transmission and distribution equipment plan are as shown in Table 3-9. The demand forecasts obtained in the present study and actual data for the period up until 2011 are shown in Figure 3-4. The demand forecast result in 2011 is nearly the same as the record. Therefore it is reasonable to think that the demand forecast is appropriate.

Table 3-9 Peak Demand Historical Data and Forecast Results for the Phnom Penh System

[MW]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
High case	381.0	476.3	595.4	732.3	878.7	1019.3	1162.1	1301.5	1431.6	1572.0	1721.3	1877.9	2045.1	2227.1	2425.3
Base case	385.4	417.4	452.0	483.8	523.7	566.8	615.9	665.8	719.6	777.5	839.8	907.0	971.6	1040.6	1114.5
Low case	331.6	349.2	367.7	382.7	402.9	424.0	448.4	471.6	495.9	521.3	548.0	575.9	602.1	629.4	657.9
Record	300.2	351.0													
Forecast Result	281.5	351.9	439.9	541.1	649.3	753.2	858.7	961.7	1057.9	1161.5	1271.9	1387.6	1511.1	1645.6	1792.1

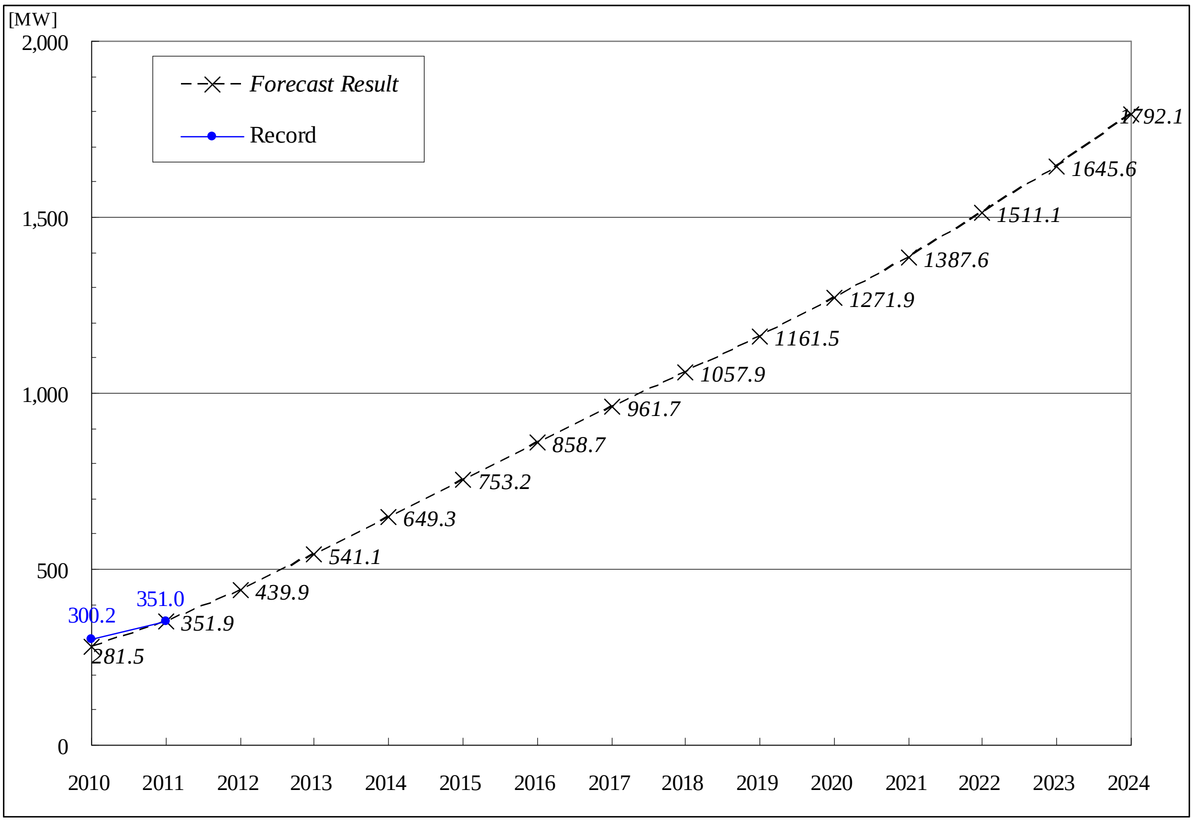


Figure 3-4 Peak Demand Historical Data and Forecast Results for the Phnom Penh System

3.1.2 Electric Power Development Plan

(1) Supply Capability Forecasts

The climate of Cambodia is tropical monsoon except for a part of mountainous region, and there are two seasons in a year: rainy season (May to October) and dry season (November to April). Accordingly, supply capacities of storage type hydropower stations vary greatly between rainy and dry seasons and capacities of water reservoirs at stations and specifications of generators also vary. Therefore, supply capacities of existing hydropower stations as well as those of hydropower stations under construction and at the planning stage were estimated based on the following conditions.
Since most of the existing hydropower stations do not have detailed operation plans, supply capacities of newly-build hydropower stations have been estimated based on the following conditions using the latest operation plans for Kirirom I (in operation) and Kamchay hydropower stations (to be in full operation in the near future):

- ① Rainy and dry seasons should be calculated separately
- ② During rainy season, electricity may be needed at the maximum output for 24 hours
- ③ Supply capacity during dry season should be calculated as follows:
    1) That of Kirirom III hydropower should be calculated according to the operation plan of the nearby Kirirom I hydropower
    2) Other hydropower stations under construction: Calculate based on the analysis of the operation pattern of Kamchay hydropower and the effective reservoir capacity for each dam
    3) Hydropower stations at the planning stage: Calculate the output during dry season vs. rainy season/maximum output ratio for the stations mentioned in 2) above. Multiply the reported maximum output by the ratio to obtain the hypothetical supply capacity.

The output pattern for each hydropower station during dry and rainy seasons calculated with the conditions above are shown in Table 3-10~Table 3-14.
For thermal power stations, the maximum output is usually considered the supply capacity throughout the year.

Table 3-10 Kirirom I

Kirirom I (unit:MW)

From ' - to	Dry Season	Rainy Season
0-1	-	**11.0**
1-2	-	**11.0**
2-3	-	**11.0**
3-4	-	**11.0**
4-5	-	**11.0**
5-6	-	**11.0**
6-7	-	**11.0**
7-8	-	**11.0**
8-9	-	**11.0**
9-10	**6.0**	**11.0**
10-11	**6.0**	**11.0**
11-12	**6.0**	**11.0**
12-13	**6.0**	**11.0**
13-14	**6.0**	**11.0**
14-15	**6.0**	**11.0**
15-16	-	**11.0**
16-17	-	**11.0**
17-18	-	**11.0**
18-19	-	**11.0**
19-20	-	**11.0**
20-21	-	**11.0**
21-22	-	**11.0**
22-23	-	**11.0**
23-24	-	**11.0**

Source: Kirirom I Generation Schedule for Year 2011 by EDC

Table 3-11 Kirirom III

Kirirom III (unit:MW)

From ' - to	Dry Season	Rainy Season
0-1	-	**16.5**
1-2	-	**16.5**
2-3	-	**16.5**
3-4	-	**16.5**
4-5	-	**16.5**
5-6	-	**16.5**
6-7	-	**16.5**
7-8	-	**16.5**
8-9	-	**16.5**
9-10	**9.0**	**16.5**
10-11	**9.0**	**16.5**
11-12	**9.0**	**16.5**
12-13	**9.0**	**16.5**
13-14	**9.0**	**16.5**
14-15	**9.0**	**16.5**
15-16	-	**16.5**
16-17	-	**16.5**
17-18	-	**16.5**
18-19	-	**16.5**
19-20	-	**16.5**
20-21	-	**16.5**
21-22	-	**16.5**
22-23	-	**16.5**
23-24	-	**16.5**

Table 3-12 Stung Atay

Stung Atay (unit:MW)

From	Dry Season			Rainy Season		
' - to	1st	2nd	Total	1st	2nd	Total
0-1	-	-	**0.0**	20.0	100.0	**120.0**
1-2	-	-	**0.0**	20.0	100.0	**120.0**
2-3	-	-	**0.0**	20.0	100.0	**120.0**
3-4	-	-	**0.0**	20.0	100.0	**120.0**
4-5	-	21.0	**21.0**	20.0	100.0	**120.0**
5-6	-	21.0	**21.0**	20.0	100.0	**120.0**
6-7	-	21.0	**21.0**	20.0	100.0	**120.0**
7-8	-	21.0	**21.0**	20.0	100.0	**120.0**
8-9	-	21.0	**21.0**	20.0	100.0	**120.0**
9-10	5.2	21.0	**26.2**	20.0	100.0	**120.0**
10-11	5.2	21.0	**26.2**	20.0	100.0	**120.0**
11-12	5.2	21.0	**26.2**	20.0	100.0	**120.0**
12-13	5.2	21.0	**26.2**	20.0	100.0	**120.0**
13-14	5.2	21.0	**26.2**	20.0	100.0	**120.0**
14-15	5.2	21.0	**26.2**	20.0	100.0	**120.0**
15-16	5.2	21.0	**26.2**	20.0	100.0	**120.0**
16-17	5.2	21.0	**26.2**	20.0	100.0	**120.0**
17-18	5.2	21.0	**26.2**	20.0	100.0	**120.0**
18-19	5.2	21.0	**26.2**	20.0	100.0	**120.0**
19-20	-	21.0	**21.0**	20.0	100.0	**120.0**
20-21	-	21.0	**21.0**	20.0	100.0	**120.0**
21-22	-	21.0	**21.0**	20.0	100.0	**120.0**
22-23	-	21.0	**21.0**	20.0	100.0	**120.0**
23-24	-	21.0	**21.0**	20.0	100.0	**120.0**

Table 3-13 Stung Tatay

Stung Tatay (unit:MW)

From	Dry Season		Rainy Season	
' - to	Main	Total	Main	Total
0-1	-	**0.0**	246.0	**246.0**
1-2	-	**0.0**	246.0	**246.0**
2-3	-	**0.0**	246.0	**246.0**
3-4	-	**0.0**	246.0	**246.0**
4-5	-	**0.0**	246.0	**246.0**
5-6	-	**0.0**	246.0	**246.0**
6-7	-	**0.0**	246.0	**246.0**
7-8	-	**0.0**	246.0	**246.0**
8-9	-	**0.0**	246.0	**246.0**
9-10	55.3	**55.3**	246.0	**246.0**
10-11	55.3	**55.3**	246.0	**246.0**
11-12	55.3	**55.3**	246.0	**246.0**
12-13	55.3	**55.3**	246.0	**246.0**
13-14	55.3	**55.3**	246.0	**246.0**
14-15	55.3	**55.3**	246.0	**246.0**
15-16	55.3	**55.3**	246.0	**246.0**
16-17	55.3	**55.3**	246.0	**246.0**
17-18	55.3	**55.3**	246.0	**246.0**
18-19	55.3	**55.3**	246.0	**246.0**
19-20	-	**0.0**	246.0	**246.0**
20-21	-	**0.0**	246.0	**246.0**
21-22	-	**0.0**	246.0	**246.0**
22-23	-	**0.0**	246.0	**246.0**
23-24	-	**0.0**	246.0	**246.0**

Table 3-14 Stung Lower Russey Churum

Stung Lower Russey Churum (unit:MW)

From	Dry Season			Rainy Season		
' - to	1st	2nd	Total	1st	2nd	Total
0-1	-	-	**0.0**	174.0	164.0	**338.0**
1-2	-	-	**0.0**	174.0	164.0	**338.0**
2-3	-	-	**0.0**	174.0	164.0	**338.0**
3-4	-	-	**0.0**	174.0	164.0	**338.0**
4-5	-	-	**0.0**	174.0	164.0	**338.0**
5-6	-	-	**0.0**	174.0	164.0	**338.0**
6-7	-	-	**0.0**	174.0	164.0	**338.0**
7-8	-	-	**0.0**	174.0	164.0	**338.0**
8-9	-	-	**0.0**	174.0	164.0	**338.0**
9-10	48.2	39.4	**87.6**	174.0	164.0	**338.0**
10-11	48.2	39.4	**87.6**	174.0	164.0	**338.0**
11-12	48.2	39.4	**87.6**	174.0	164.0	**338.0**
12-13	48.2	39.4	**87.6**	174.0	164.0	**338.0**
13-14	48.2	39.4	**87.6**	174.0	164.0	**338.0**
14-15	48.2	39.4	**87.6**	174.0	164.0	**338.0**
15-16	48.2	39.4	**87.6**	174.0	164.0	**338.0**
16-17	48.2	39.4	**87.6**	174.0	164.0	**338.0**
17-18	48.2	39.4	**87.6**	174.0	164.0	**338.0**
18-19	48.2	39.4	**87.6**	174.0	164.0	**338.0**
19-20	-	-	**0.0**	174.0	164.0	**338.0**
20-21	-	-	**0.0**	174.0	164.0	**338.0**
21-22	-	-	**0.0**	174.0	164.0	**338.0**
22-23	-	-	**0.0**	174.0	164.0	**338.0**
23-24	-	-	**0.0**	174.0	164.0	**338.0**

(2) Changes in Demand Forecasts and Supply Capability

Table 3-15 and Figure 3-5 show the supply capability and forecast demand for the rainy season and dry season of each year, reflecting the supply capability approach adopted in the previous section. Figure 3-6 presents an extract of the data covering the period 2012 – 2015 of Figure 3-5. It should be noted that supply capability includes the power sources listed in Table 2-39 (p. 2-82) that are still at the planning stage.

Table 3-15 Demand and Supply Capacities in rainy and dry season

Unit:MW	2012	2013	2014	2015	2016	2017	2018	2019	2020
Demand	600	735	872	999	1,134	1,271	1,459	1,614	1,773
Supply capacity in rainy season	514	514	1,286	1,409	2,245	2,833	5,023	7,623	7,623
Supply capacity in dry season	352	432	731	827	1,150	1,395	2,317	3,104	3,104

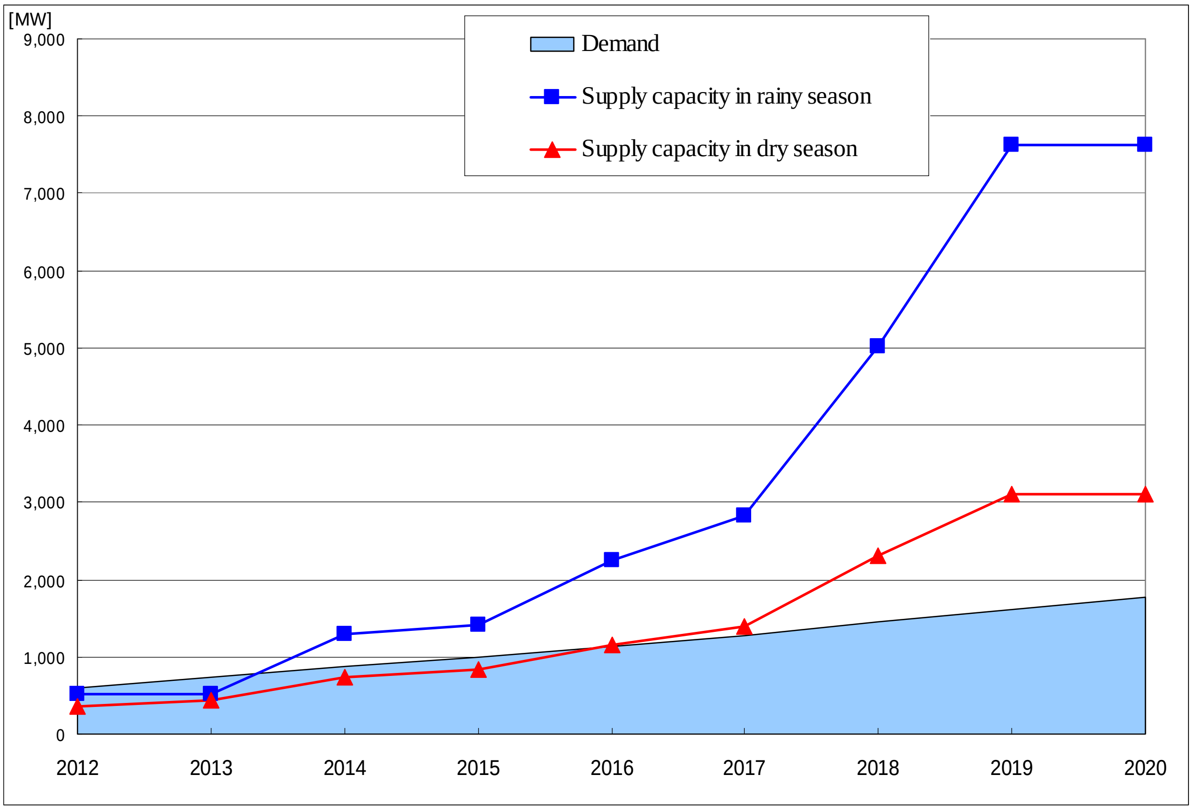


Figure 3-5 Comparison of Supply Capability and Demand in the Dry Season and Rainy Season

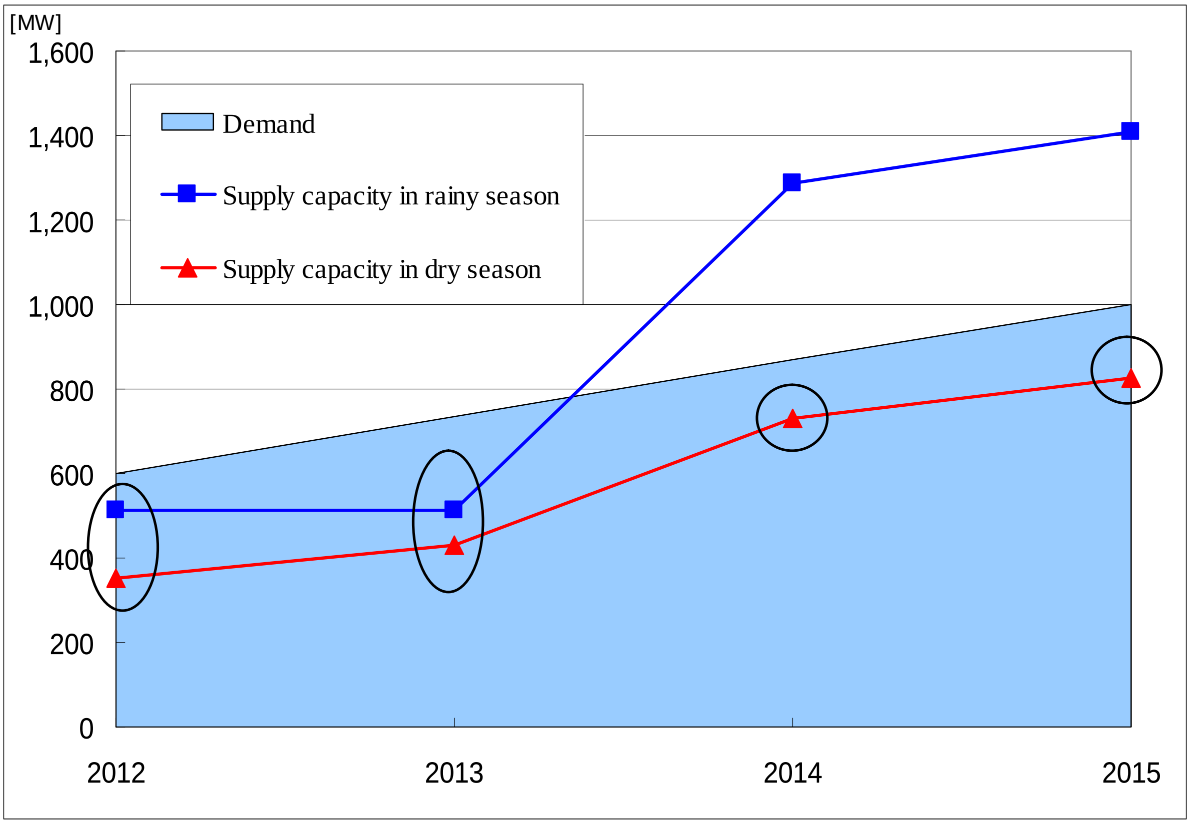


Figure 3-6 Comparison of Supply Capability and Demand in the Dry Season and Rainy Season (2012-2015)

It can be seen from the above that the supply capability is likely to be inadequate during both the rainy season and the dry season in the 2012 - 2013 timeframe, and at peak times in the dry season in 2014 - 2015.

(3) Power Generation Development Plan Review

In Cambodia, it is necessary to make a long-term power generation development plan. Now, because it has not been made, the amount of future power generation will much larger than demand in 2020. Namely, as a result of attracting many large hydropower IPPs in order to secure the amount of power generation to meet demand, not in rainy season but in dry season, there is plenty amount of power generation. But there is no plan to export electric power in order to dissolve its inefficiency. To make a long-term power generation development plan to solve this problem, it is needed to research and analyze 1) a high accuracy long-term demand forecasting, 2) year operation plan of each power plant and 3) detail study about each power plant's PPA and analysis of electricity purchase price in the future.

Next, considering the near future, it is readily apparent that the first priority for Cambodia is to develop power generation sources that are adequate to meet demand for electric power. According to current power generation plan, if power stations with which power purchase agreements (PPAs) have not yet been signed are included, and assuming that new stations begin operation on schedule, then by 2018 Cambodia should have a power generation system in place capable of providing a stable supply of electric power throughout the year, even if one of the generators with the highest output suffers a breakdown. However, this scenario is based on several assumptions: that the development of new power stations by independent power producers (IPPs) will proceed according to schedule; that IPPs (with guidance from EDC) will be able to ensure a stable supply of power in the dry season through efficient management of hydroelectric power station reservoirs; that IPP power stations will be able to maintain breakdown-free operation in line with electric power development plan by carrying out effective maintenance management; and that there is sufficient rainfall. Given the high level of uncertainty relating to these factors, it is difficult to avoid the conclusion that, from the point of view of maintaining a stable supply of electric power, relying too heavily on IPP hydroelectric power plants (the output of which is likely to be unstable) may cause problems. What Cambodia needs is power stations that can provide a stable supply to meet base load needs even in the dry season.

Ensuring a stable supply of electric power in the dry season will require power stations except hydropower such as energy derived from fossil fuel. Assuming that getting new power stations operational quickly is a key priority, thermal power stations would appear to be the best option. Given that off-peak demand – which is an important consideration for power stations that will be meeting Cambodia's base-load energy needs – is still relatively low, in order to achieve economies of scale when building a large-scale thermal power plant, Cambodia might want to consider undertaking the development of such a plant as a joint project with neighboring Thailand or Vietnam, or negotiating an electricity sale contract with one of its neighbors with respect to part of the new plant's output. When developing a new power plant of this type, it would be advisable to formulate a plan that involves the establishment of a special purpose company (SPC) whose shareholders include both a private-sector firm and EDC (Generation Department of EDC) or another Cambodian agency, to facilitate the transfer of know-how relating to power station design, maintenance, operation, etc. However it is necessary to evaluate economic efficiency compared to power importing from neighboring countries and energy security when Cambodia constructs the large-scale power plant to export the electricity to neighboring countries.

At the same time, from the point of view of energy security, there is a serious problem due to more than 60% import for electricity. To solve the problem and development cost, since Cambodia (like Japan) is a country with limited natural resources, it is important for Cambodia to undertake further development of hydroelectric power, which is the cheapest form of electricity generation that Cambodia can develop. By way of reference, Thailand caps the shares of total installed capacity that can be provided from neighboring countries at the following percentages:

- Total imports from 1 country 13%
- Total imports from 2 countries 25%
- Total imports from 3 countries 33%

- Total imports from 4 countries 38%

(4) Review of Marginal Supply Capability in Cambodia

The reserve rate in Cambodia and neighboring countries is shown in Table 3-16 below. Generation capacity and maximum power in Cambodia are used the number of Table 2-28(p.2-69) and Table 2-24(p.2-56), respectively. The reserve rate in Cambodia is 15.8% and it is lower then that of neighboring countries and to see this number, it seems that there is no problem. But, in fact, that scheduled outages are conducted in Phnom Penh System and that the volume of power import by 230kV transmission line from Vietnam is 120MW and it is approximately 1/4 of generation capacity, reserve rate should be more than 30% now.

Table 3-16 Comparison of marginal supply capability rates

	Indonesia (2009)	Malaysia (2009)	Philippine (2010)	Thailand (2009)	Vietnam (2010)	Cambodia (2010)
Generation Capacity (a) [MW]	30,360	23,957	16,360	30,607	21,297	486
Maximum Power (b) [MW]	23,440	15,960	10,375	23,064	16,048	409
Reserve Rate (c) [%]	22.8	33.4	36.6	24.6	24.6	15.8

By way of reference, electric power companies in Japan formulate and implement electricity supply plans that enable them to maintain marginal supply capability rates in the region of 8 - 10%. However, the figure of 8 - 10% is based on simulations that take into account quantitative analysis of the frequency of unscheduled outages, droughts, and fluctuations in demand, as well as the potential for electric power companies to assist one another through interconnection when demand is high relative to supply; this figure is not necessarily applicable to Cambodia. Nevertheless, in order to ensure a stable supply of electric power, there is definitely a need for Cambodia to formulate indicators relating to marginal supply capability that take into account the quantitative risk associated with both supply and demand. It should be noted that, in the case of Thailand, because Thailand relies on domestic gas-fired thermal power plants for more than half of its reserve capacity, the marginal supply capability in Thailand has been set at over 20% of overall installed capacity, to allow for shortages of supply caused by problems with gas pipelines in western Thailand.
While at present an inadequate supply capability means that Cambodia is forced to implement rolling power outages on a regular basis, in the future, given the importance of maintaining a stable supply of electric power, it is vital that Cambodia possess a reasonable amount of reserve power.

(5) Demand and Supply Planning in Neighboring Countries

A survey was undertaken of demand and supply planning in Thailand and Vietnam, both neighboring countries which will be of great importance to Cambodia in the joint development of large-scale electricity generating facilities in the future. Both countries are planning to import the energy from Cambodia, but there is no determined project. Therefore, there is a possibility of new power development project to export the energy in Cambodia.

a. Thailand
According to the “Summary of Thailand Power Development Plan 2010 – 2030 (PDP)”, which was compiled by the System Planning Division, Electricity Generating Authority of Thailand (EGAT), and approved by the Thai Cabinet in March 2010, demand and supply planning for the period up until 2030 will be as shown in Table 3-17 below.

Table 3-17 Demand and Supply Planning in Thailand

	Peak Demand [MW]	Domestic [MW]	Import from Lao PDR [MW]	Import from Myanmar [MW]	Import from Neighbouring Countries [MW]	Contract Capacity [MW]	Import Ratio [%]	Minimum Reserve Margin [%]
2009	22,045	28,872	340	0	0	29,212	1.2	27.6
2010	23,249	30,089	1,260	0	0	31,349	4.0	28.1
2011	24,568	31,135	1,857	0	0	32,992	5.6	27.1
2012	25,913	32,095	2,077	0	0	34,172	6.1	23.7
2013	27,188	34,926	2,077	0	0	37,003	5.6	25.4
2014	28,341	37,643	2,077	0	0	39,720	5.2	23.4
2015	29,463	36,931	3,059	0	0	39,990	7.6	26.0
2016	30,754	37,500	3,550	369	0	41,419	9.5	27.2
2017	32,225	38,015	3,990	369	0	42,374	10.3	23.2
2018	33,688	37,810	3,990	369	450	42,619	11.3	17.3
2019	34,988	38,880	3,990	369	1,050	44,289	12.2	15.0
2020	36,336	38,833	3,990	369	1,650	44,842	13.4	15.6
2021	37,856	41,009	3,990	369	2,250	47,618	13.9	15.4
2022	39,308	41,773	3,990	369	2,850	48,982	14.7	16.0
2023	40,781	43,640	3,776	369	3,450	51,235	14.8	16.7
2024	42,236	44,328	3,776	369	4,050	52,523	15.6	16.5
2025	43,962	43,987	3,776	369	4,650	52,782	16.7	16.3
2026	45,621	47,561	3,776	369	5,250	56,956	16.5	15.9
2027	47,344	46,835	3,776	369	5,850	56,830	17.6	15.4
2028	49,039	50,740	3,776	369	6,450	61,335	17.3	16.3
2029	50,959	52,629	3,776	369	7,050	63,824	17.5	16.3
2030	52,890	53,878	3,650	369	7,650	65,547	17.8	15.0

As can be seen from Figure 3-7, which shows only Thailand's electric power imports from neighboring countries, with regard to that part of the imports from neighboring countries with respect to which it is not yet clear which countries this part will be supplied from, this part will amount to 450MW in 2018, and is then expected to rise by 600MW per annum each year starting from 2019. According to Thailand's PDP, it is anticipated that Thailand will be importing electric power from Laos, Myanmar, China and Cambodia. The PDP notes that, while minutes of understandings (MoU) have already been signed between the Thai government and the governments of Laos, Myanmar and China, as yet no such Minutes of Understanding (MoU) has been signed between Thailand and Cambodia, but that a number of proposals have been made by private-sector companies, such as the proposal for a coal-fired power plant (1,800MW × 2 phases) at Koh Kong in Cambodia.

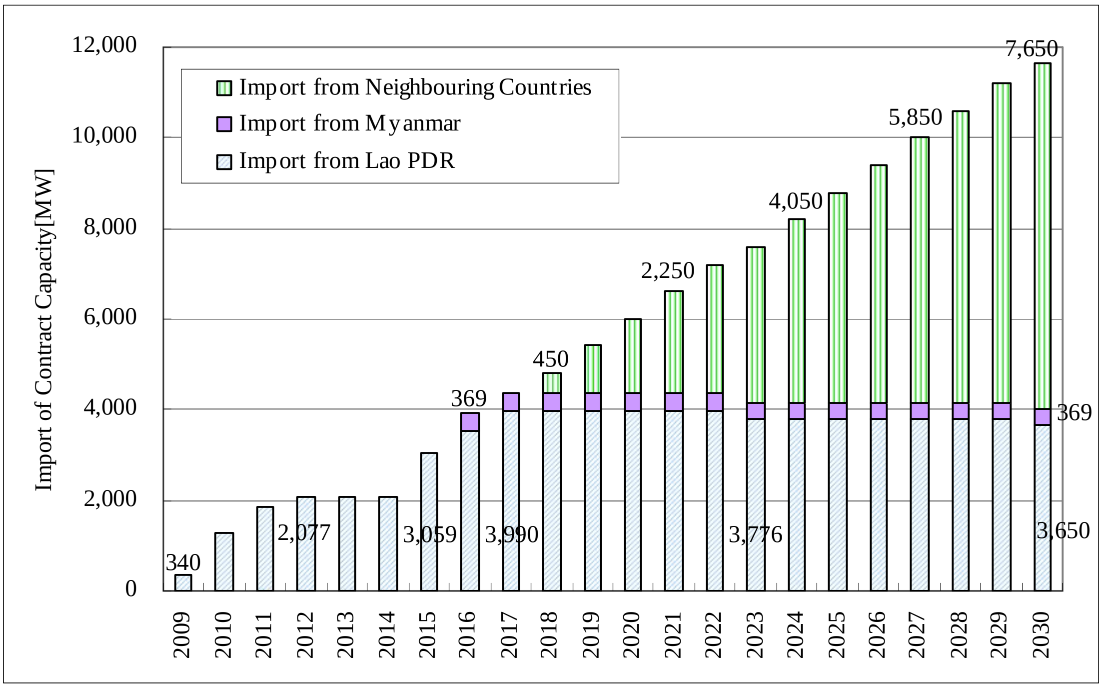


Figure 3-7 Thailand's Projected Electric Power Imports

b. Vietnam

According to the "National Master Plan for Power Development for the 2011 – 2020 Period with the Vision to 2030 (Power Master Plan VII)", which was compiled by Vietnam's Institute of Energy (IE) and approved by the Vietnamese government in July 2011, the structure of Vietnam's power sources in 2020 and 2030 will be shown in Figure 3-8 and Figure 3-9, respectively. Vietnam will be importing 2,200MW of electric power in 2020 and 7,000MW in 2030; it is anticipated that most of these imports will be from Laos, China and Cambodia, all of which have significant hydroelectric energy development potential.

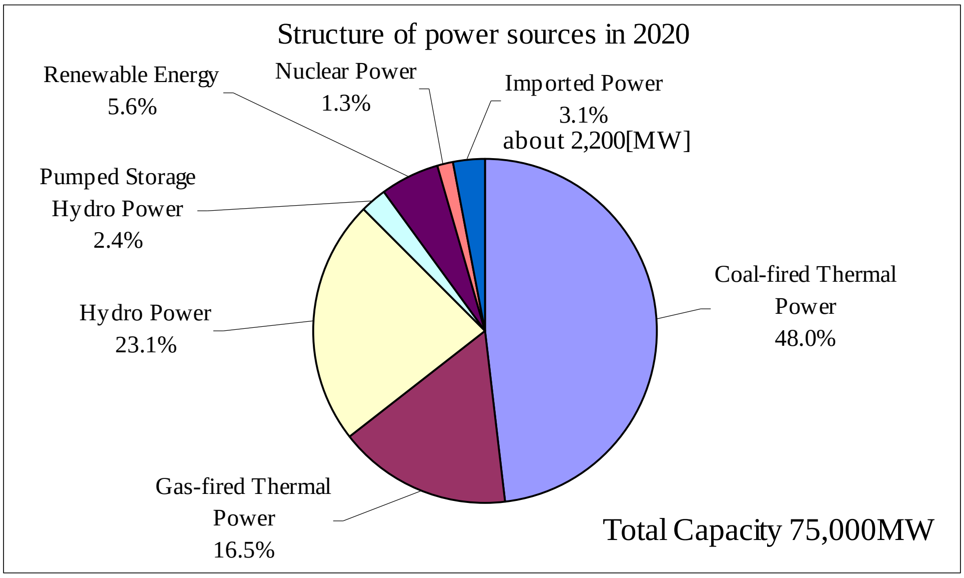


Figure 3-8 The Structure of Vietnam's Power Sources (2020)

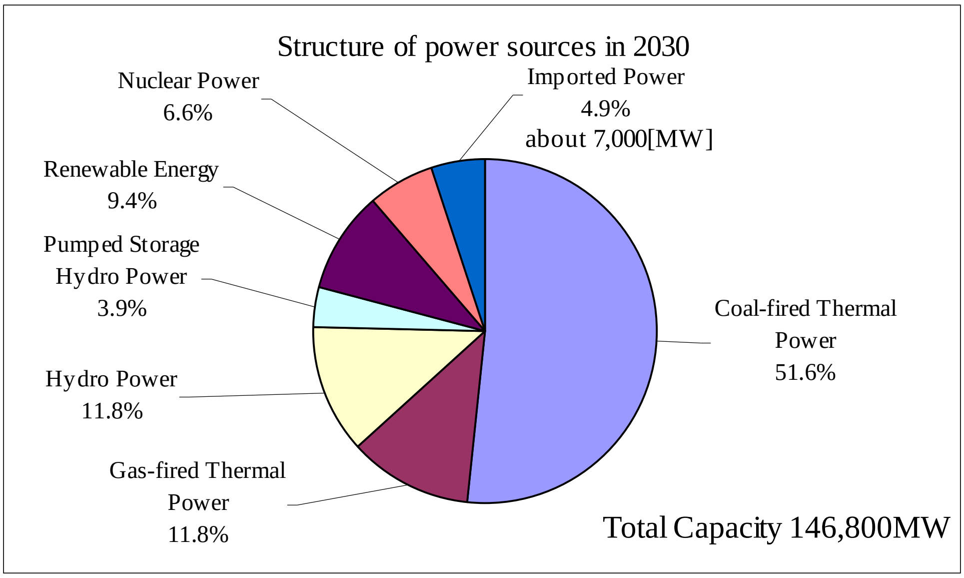


Figure 3-9 The Structure of Vietnam's Power Sources (2030)

3.1.3 Development plans for transmission lines

Given that the purpose of the transmission network is to bring electric power from where it is generated to where it is needed, transmission system development needs to cover the following areas:

- Linking power plants with existing transmission lines to carry electric power to the grid
- Importing and exporting electric power through interconnection with other countries' systems
- Extending the national grid to be able to provide a cheap, stable supply of electric power for rural areas

Regarding the first of these aspects – transmitting electric power from the power station to the grid – while the Stung Atay, Stung Tatay and Lower Stung Russei Churum power plants (which have a combined generating capacity of around 700 MW) will have begun operation by 2013, these plants will all be connected to the O'soam substation. Currently, the supply of electric power to Phnom Penh (serving the most important part of the country) relies heavily on a single transmission line running from O'soam to North Phnom Penh via Pursat. While there are plans to make this transmission line a two-circuit line, given the high generating capacity of the hydroelectric power plants in question, if a lightning strike etc. were to put both circuits out of action, it would be very difficult to maintain a stable supply of electric power. If the North Phnom Penh - Chhay Areng - O'soam transmission line can begin operation by 2018, then there will be two separate transmission routes from the O'soam substation to Phnom Penh, making for an enhanced level of reliability. Given the great importance of the transmission lines linking the O'soam substation to Phnom Penh, ideally the new transmission line route should be completed as early as possible after 2013, rather than leaving it until 2018.

As regards the exportation and importation of electric power to and from other countries, the 115kV transmission line belonging to CPTL that extends from the northwestern border to Battambang creates the potential for importing electric power from Thailand. With the 230kV West Phnom Penh - Kampong Chhnang - Pursat - Battambang transmission line scheduled to begin operation in 2012, it should in theory be possible to link up the Thai and Phnom Penh systems. However, CPTL's existing 115kV substation at Battambang and the new 230kV Battambang substation are not linked by a 115kV transmission line, so at present the Thai and Phnom Penh systems are not connected to one another. As the 115kV line could be extended to the new 230kV Battambang substation, ideally the two substations should be connected by a 115kV transmission line as soon as possible; it should be noted that the two substations are only about 1 km apart. Even so, a 115kV connection does not give significant potential for power pooling. Ideally, a 230kV line should be used for the importation and exportation of electric power between Thailand and Cambodia. In light of the above, and from the point of view not only of ensuring the importation and exportation of electric power but also of bringing about an enhancement of system stability, it is to be hoped that the following can be achieved:

- Using system interconnection to boost system capacity so that, when faced with fluctuations in demand, power source fallout, etc., the fluctuation in frequency can be minimized, and the ability to recover from the problem rapidly can be enhanced.
- When one country (or power company) is experiencing a shortage of supply, or has a surplus of supply, interconnection can be utilized to implement power pooling, on a supporting or collaborative basis.

The EPP - Neak Loeung - Svay Rieng 115kV transmission line is scheduled for completion in 2018, and the Kampong Cham - Kampong Thom - Siem Reap 230kV transmission line is due to begin operation in 2019. In light of the surplus power that could be generated during the rainy season, completion of these transmission lines ahead of schedule would facilitate the efficient utilization of supply capability.

3.2 Transmission and Distribution Facilities in the Phnom Penh Urban Area

3.2.1 Review of the Existing Phnom Penh System

At present, the transformer capacity of the Phnom Penh system is inadequate. It is anticipated that the installation of new 115kV/22kV transformer equipment at the SS (Switching Station) substation and the SPP (South Phnom Penh) substation (which are currently under construction), along with the installation of additional transformers to boost capacity at the existing GS1, GS2 and GS3 substations, will have been completed by the dry season of 2013. The planned increase in transformer capacity is shown in Table 3-18; demand forecasts and the transformer capacity based on these forecasts, along with the required transformer capacity as calculated based on power station output with the 22kV system, are shown in Table 3-19. It should be noted that, for these purposes, transformer capacity includes both 115/22kV and 115/22/15kV transformer capacity. Required transformer capacity is calculated by deducting the output of the C5 and Colben power stations connected to each grid substation from the forecast demand, and then adding a margin of 20% to allow for load pooling when faults occur.

Table 3-18 EDC's Transformer Capacity Increase Plan

	GS	GS1		GS2			GS3			GS4				SS	SPP	
2011	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	-	115/22	115/22	-	230/115	230/115	115/22	115/22	-	-	-
	Capacity [MVA]	50	50	50	50	-	50	50	-	200	200	50	50	-	-	-
	Capacity [MW]	47.5	47.5	47.5	47.5	-	47.5	47.5	-	190.0	190.0	47.5	47.5	-	-	-
2012	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	-	115/22	115/22	-	230/115	230/115	115/22	115/22	-	-	-
	Capacity [MVA]	50	50	50	50	-	50	50	-	200	200	50	50	-	-	-
	Capacity [MW]	47.5	47.5	47.5	47.5	-	47.5	47.5	-	190.0	190.0	47.5	47.5	-	-	-
2013	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	115/22/15	115/22	115/22	115/22	230/115	230/115	115/22	115/22	115/22	115/22	115/22
	Capacity [MVA]	75	75	50	50	50	50	50	50	200	200	50	50	50	50	50
	Capacity [MW]	71.3	71.3	47.5	47.5	47.5	47.5	47.5	47.5	190.0	190.0	47.5	47.5	47.5	47.5	47.5

Note: A yellow background denotes new or increased capacity.

Table 3-19 Forecast Demand and Transformer Capacity

PF=0.95, Unit: MW	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Phnom Penh Demand (A)	352	440	541	649	753	859	962	1,058	1,162	1,272
22kV Power Plants (B)	66	93	93	93	58	48	48	38	38	38
Necessary Transformer Capacity(A-B)	**343**	**416**	**538**	**668**	**834**	**973**	**1,096**	**1,224**	**1,348**	**1,481**
Existing Transformer Capacity	380	380	665	665	665	665	665	665	665	665

As can be seen from the above, the Phnom Penh system is affected by the following problems:

Table 3-20 Problems Affecting the Phnom Penh System

Problem	Causes
① Due to inadequate transformer capacity, even if the supply capability of the 115kV system is adequate, rolling power outages are still needed for the 22kV system.	Transformer capacity is insufficient to cope with demand.
② An outage on a single transmission line can cause a power outage affecting half of the Phnom Penh urban area.	Mainly because of problems with the protective relays on the transmission line, the Phnom Penh system does not constitute a loop.
③ The breakdown of a single transformer can prevent the supply of	The load that had been supplied by a transformer which breaks down cannot be supplied using another,

power from being maintained.	non-faulty transformer. The shortage of interconnection switches to permit switchover to another distribution line restricts the extent to which remote control can be implemented. As distribution switchover is performed manually, it takes time to carry out switchover when a breakdown has occurred.

① Due to inadequate transformer capacity, even if the supply capability of the 115kV system is adequate, rolling power outages are still needed for the 22kV system:
As shown in Table 3-19, as of 2012 existing transformer capacity was below the required transformer capacity. While this problem will be temporarily overcome in 2013, when one considers that demand is forecast to rise by around 100 MW a year in the near future, there is clearly a need for ongoing measures to strengthen Cambodia's transformer and distribution facilities through the systematic establishment of new substations, etc.

② An outage on a single transmission line can cause a power outage affecting half of the Phnom Penh urban area:
As can be seen from Figure 2-35(p.2-61), in the event of a fault on the transmission line linking GS4 to KEP, which also supplies power to GS2 and GS3, even in the best-case scenario the supply of power from the GS2 and GS3 substations would be halted. Methods of solving this problem would include making all of the transmission lines that link the grid substations together into two-circuit lines, or turning them into a loop. The transmission lines as they exist at present could be made into a loop by the insertion of the circuit breakers marked with an X on Figure 2-35(p.2-61). However, as it is currently difficult to get the transmission line protective relays to provide proper protection, turning the transmission lines into a loop might end up causing large-scale outages. This is why EDC has yet to implement loop-based power supply. There are two main problems affecting the transmission line protective relays:

- Suitable transmission line protective relays have not been installed.
- Despite the need to be able to exchange data between the transmission line protective relays installed between the grid substations, the necessary high-reliability communications network has not been put in place.

③ The breakdown of a single transformer can prevent the supply of power from being maintained:
In the transformer breakdown that occurred at GS1 in 2011, the outage relating to the load that would normally have been supplied by the transformer in question continued for an extended period. In order to restore the power supply when a single transformer unit has broken down at a substation, there are two methods that can be employed:

1) Where the substation where the breakdown occurs contains another transformer that is still working properly, the supply of electric power can be restored using the functioning transformer.
2) Where the power supply cannot be restored using method 1) above, the distribution network can be switched over so that power is being supplied from another substation.

The following strategies could thus be adopted:

a) Increase transformer capacity so that it exceeds demand (i.e. installing transformer equipment with spare capacity).
b) Increase distribution line capacity so that it exceeds the load (i.e. installing distribution equipment with spare capacity).
c) Adopt switches and distribution automation systems that facilitate remote control of feeder connection, so that, when a fault occurs, the power supply can be restored quickly by flipping the switch so that power is supplied to the area affected by the outage from another substation.

However, the current situation is that, as not all transformers and distribution lines have spare capacity, when a single transformer breaks down, there are places where the power supply cannot be restored immediately.
In order to be able to use the distribution network to supply power from another grid substation

in a situation of this kind, the size of the load that will be supplied through the other feeder needs to be calculated in advance to facilitate the switchover. A distribution automation system possesses this type of functionality, permitting automated switchover so that power can be restored rapidly to areas that have suffered outages.

3.2.2 Review of the Phnom Penh Underground Transmission Line Feasibility Study

In the feasibility study of New Underground Cable in Phnom Penh that was implemented by JBIC in 2008, it is planned to supply stable power to Phnom Penh, which is the center for economic activities, through installing loop transmission lines. Figure 3-10 shows an outline of the plans.

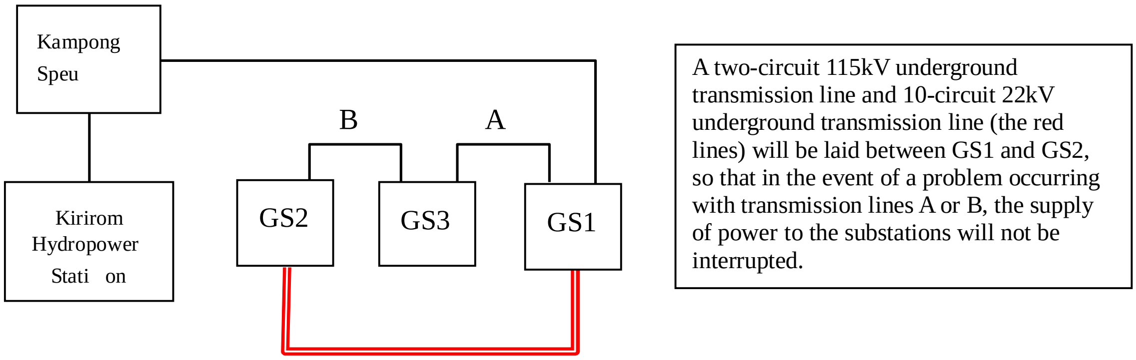


Figure 3-10 JBIC Feasibility Study Outline

However, following installation of new GS4 and transmission lines, the composition is currently as indicated in Figure 2-35(p.2-61) and it is physically possible to loop transmission lines. Reasons for not being able to make the loop have already been stated, however, in order to realize this, it will be necessary to maintain the transmission line protective relay system.

3.2.3 Direction of Phnom Penh System Expansion

Areas of Phnom Penh where development is advancing or is planned include the area near French embassy, Chroy Changvar district and Diamond Island. In addition, it is necessary to construct new substations near the center of Phnom Penh in order to respond to increased demand, and EDC headquarters and the Olympic Stadium are candidate sites for this.
The transformer facilities plan based on the above is shown in Table 3-21. Taking into account the relative difficulty of crossing the river, it was felt that the substation supplying electric power to Diamond Island should be located in Hun Sen Park on the western side of the river.
The required transformer capacity shown in Table 3-19 includes a 20% safety margin. This is partly to ensure that the grid substation transformers have sufficient spare capacity in the event of a breakdown, but also to try to ensure that transformer capacity will still be adequate 4 - 5 years in the future.
With regard to the actual construction of the facilities, demand forecasts and transformer equipment requirements forecasts will need to be compiled for each individual grid substation based on electrical power demand forecasts and distribution network improvement plan, and review will need to be undertaken to determine when new substations and new transformers will be needed. While the question of transmission line upgrade is not addressed, there is a strong possibility that exiting transmission lines may need to be improved to cope with the new transformer facilities being established to meet increased demand. As there is the potential for a number of possible variations, depending on what system configuration is adopted, there is a need for a detailed survey to serve as the basis for transmission facilities enhancement plan.

Table 3-21 Projection of Transformation Facilities at Each GS in the Phnom Penh System (2011 shows Actual Figures)

		GS1		GS2			GS3			GS4				SS
2011	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	-	115/22	115/22	-	230/115	230/115	115/22	115/22	-
	Capacity [MVA]	50	50	50	50	-	50	50	-	200	200	50	50	-
2012	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	-	115/22	115/22	-	230/115	230/115	115/22	115/22	-
	Capacity [MVA]	50	50	50	50	-	50	50	-	200	200	50	50	-
2013	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	115/22/15	115/22	115/22	115/22	230/115	230/115	115/22	115/22	115/22
	Capacity [MVA]	75	75	50	50	50	50	50	50	200	200	50	50	50
2014	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	115/22/15	115/22	115/22	115/22	230/115	230/115	115/22	115/22	115/22
	Capacity [MVA]	75	75	50	50	50	50	50	50	200	200	50	50	50
2015	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	115/22/15	115/22	115/22	115/22	230/115	230/115	115/22	115/22	115/22
	Capacity [MVA]	75	75	50	50	50	50	50	50	200	200	50	50	50
2016	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	115/22/15	115/22	115/22	115/22	230/115	230/115	115/22	115/22	115/22
	Capacity [MVA]	75	75	50	50	50	50	50	50	200	200	50	50	50
2017	Voltage [kV]	115/22	115/22/15	115/22	115/22/15	115/22/15	115/22	115/22	115/22	230/115	230/115	115/22	115/22	115/22
	Capacity [MVA]	75	75	50	50	50	50	50	50	200	200	50	50	50

		SPP			French Embassy		Hun Sen Park		Olympic Stadium		Chroy Changvar		EDC H.Q.		Kampong Speu
2011	Voltage [kV]	-	-	-	-	-	-	-	-	-	-	-	-	-	115/22
	Capacity [MVA]	-	-	-	-	-	-	-	-	-	-	-	-	-	6.3
2012	Voltage [kV]	-	-	-	-	-	-	-	-	-	-	-	-	-	115/22
	Capacity [MVA]	-	-	-	-	-	-	-	-	-	-	-	-	-	6.3
2013	Voltage [kV]	230/115	115/22	-	-	-	-	-	-	-	-	-	-	-	115/22
	Capacity [MVA]	200	50	-	-	-	-	-	-	-	-	-	-	-	6.3
2014	Voltage [kV]	230/115	115/22	-	115/22	115/22	-	-	-	-	-	-	-	-	115/22
	Capacity [MVA]	200	50	-	50	50	-	-	-	-	-	-	-	-	6.3
2015	Voltage [kV]	230/115	115/22	-	115/22	115/22	115/22	115/22	115/22	115/22	-	-	-	-	115/22
	Capacity [MVA]	200	50	-	50	50	50	50	50	50	-	-	-	-	6.3
2016	Voltage [kV]	230/115	115/22	-	115/22	115/22	115/22	115/22	115/22	115/22	115/22	115/22	-	-	115/22
	Capacity [MVA]	200	50	-	50	50	50	50	50	50	50	50	-	-	6.3
2017	Voltage [kV]	230/115	115/22	115/22	115/22	115/22	115/22	115/22	115/22	115/22	115/22	115/22	115/22	115/22	115/22
	Capacity [MVA]	200	50	50	50	50	50	50	50	50	50	50	50	50	6.3

Note: A yellow background denotes new or increased capacity.

The strengthening plans are shown in Figure 3-11 and Figure 3-12.

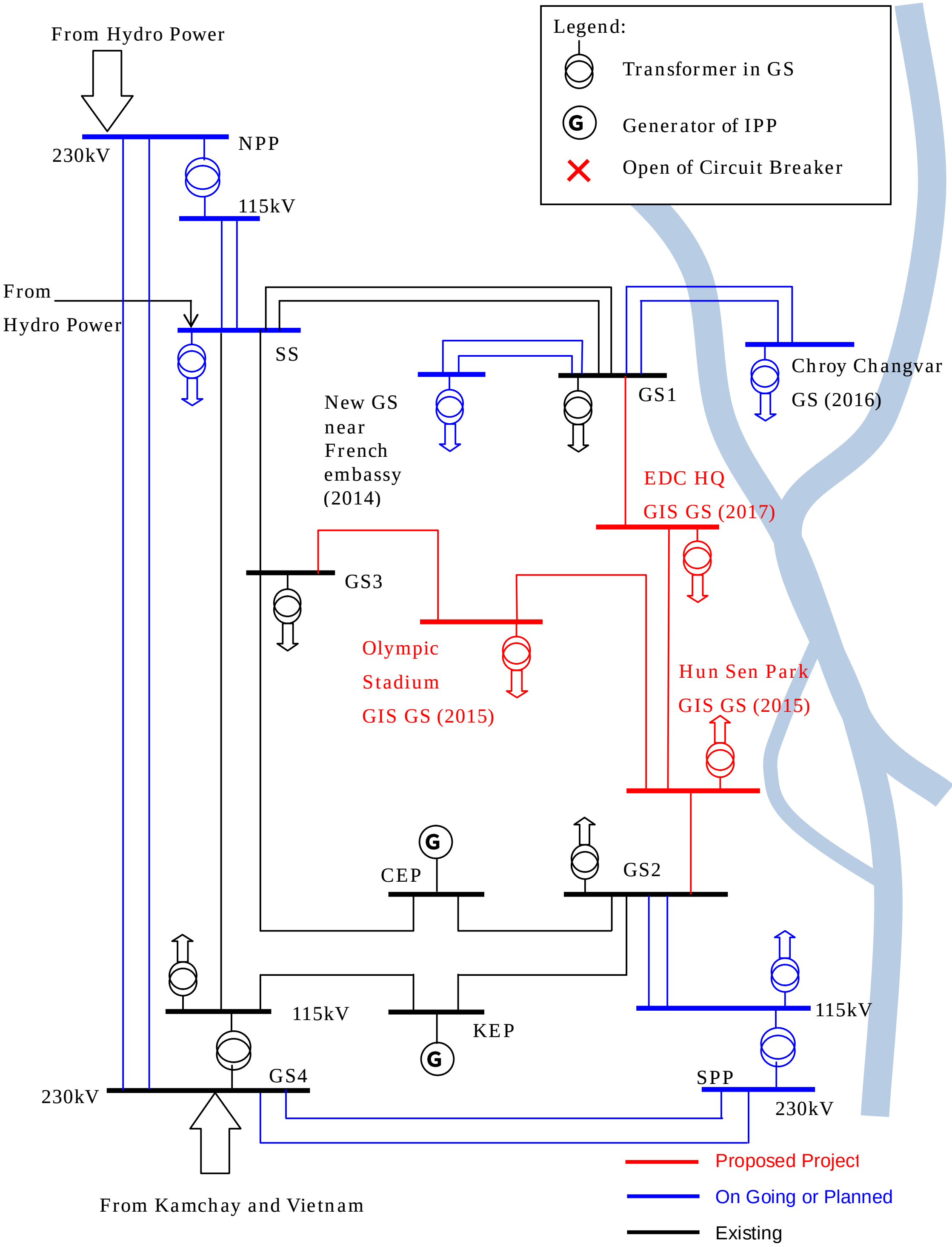


Figure 3-11 Phnom Penh System Transmission Lines and Transformers Strengthening Plan

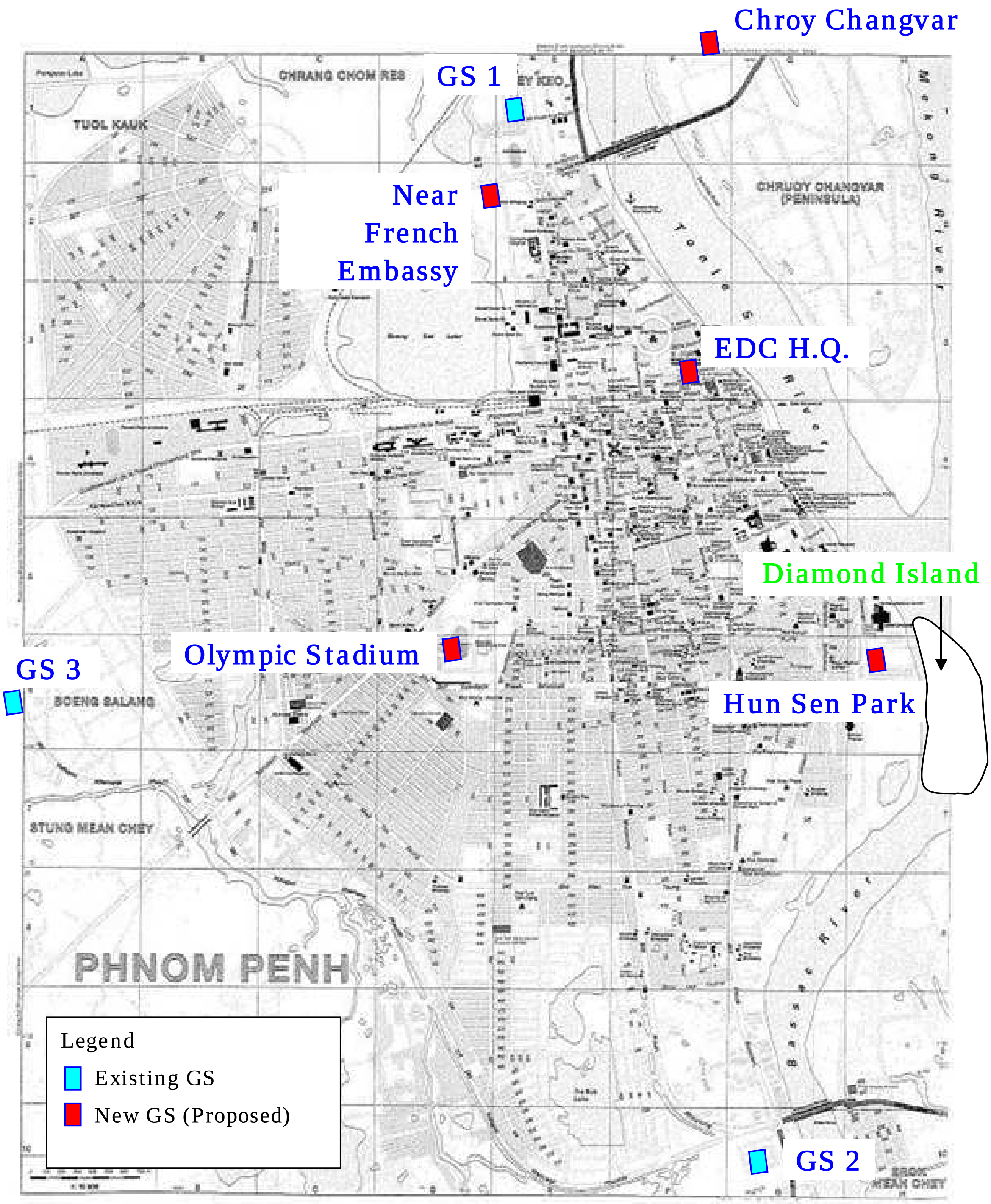


Figure 3-12 Map of Substation Locations in Phnom Penh

3.2.4 Plans for Expanding Transmission and Distribution Facilities in the Phnom Penh Urban Area

On the basis of the discussion presented above, the following proposal can be made for the improvement of the Phnom Penh urban area transmission and distribution network.

Table 3-22 Phnom Penh Transmission and Distribution Network Construction Plan

Item	Objective	Outline
① Establishment of new grid substations	To meet increasing demand within Phnom Penh city	New gas-insulated substation (GIS) indoor transformer facilities: 1) Hun Sen Park 2) Olympic Stadium 3) EDC H.Q. Each facility would house two 115kV/22kV 50MVA transformer units.
② Establishment of 115kV underground transmission line		Installation of a 115kV underground transmission line to link the existing substations with the new substations.
③ Improvement of the 115kV relay system	To enhance the stability of electric power supply within the Phnom Penh urban area.	Installation of PCM current differential relays. Improvement of the communications network.
④ Adoption of a Distribution Automation System (DAS)	To reduce the time needed to recover from faults, and to reduce loss through load equalization between feeders.	Installation of a Distribution Automation System (DAS) in the EDC headquarters building (including upgrade of the communications equipment). Improvement of the interconnection switches, etc.
⑤ Adoption of a System Stabilizing Controller (SSC)	To minimize the scope of power outages through electric power system stabilization.	Installation of a System Stabilizing Controller (SSC).

① Establishment of new grid substations:

Once the additional transformers have been installed in the GS2 and GS3 substations, there will be no space for the installation of further transformers in GS1, GS2 or GS3. While it might be possible to increase the capacity of existing transformers, in the event of a breakdown there could be problems switching the load supplied from such a transformer to another transformer, so ideally the use of very-large-capacity transformers should be avoided. There is also an issue regarding lack of space for the extension of 22kV distribution lines. For these reasons, we propose that new substations should be established.

According to EDC, the priority order for the establishment of new substations would as shown in Table 3-23.

Table 3-23 Candidate Sites for New Grid Substations in Phnom Penh

Priority Order	Location
1	New GS near French embassy
2	Hun Sen Park
3	Olympic Stadium
4	Chroy Changvar district
5	EDC headquarters building

Of the proposed sites listed in the table, Numbers 1 and 4 are located in areas where large-scale development is underway, so the timetable for the establishment of new substations at these locations would be heavily influenced by the construction schedule for the development work. The candidate sites for the establishment of new grid substations using ODA would thus be Numbers 2, 3 and 5, in that order.

While the new grid substations would in theory be designed as indoor facilities with gas-insulated switch (GIS) equipment, provided that a sufficiently large site could be found, the use of air-insulated indoor transformers would help to reduce costs.

As the EDC headquarters building is located on land belonging to EDC, and Hun Sen Park and the Olympic Stadium are both state-owned, acquiring the land needed for new transformer establishment should not present any particular problems. In the case of the area near French embassy and Chroy Changvar district candidate sites, the problem of land acquisition could be solved by requiring the developers to set aside land for use in substation construction.

② Establishment of 115kV underground transmission line:

New transmission line facilities would be needed in order to supply power to the new substations referred to in ① above. As all of the new substations would be located within Phnom Penh’s city center, the construction of overhead transmission lines would present difficulties. Underground transmission lines would thus need to be used; the ideal routes for the construction of such lines are, as shown in Figure 3-11:

- From GS1 to the EDC headquarters building
- From GS2 to Hun Sen Park
- From GS3 to the Olympic Stadium

The construction of underground transmission lines linking the EDC headquarters building, Hun Sen Park and the Olympic Stadium would also have the effect of linking up the transmission system, making for highly-reliable transformers able to continue supplying power even in the event of a fault on one transmission line.

Regarding the construction method, the shield tunneling method is recommended in order to minimize adverse impact of residents and avoid heavy traffic considering the construction in the central of Phnom Penh. Japanese companies have high technical capabilities about the shield tunneling method at soft foundation.

③ Improvement of the 115kV relay system:

As noted above, in order to turn the Phnom Penh system into a loop, current differential relays can be installed so as to be able to rapidly isolate sections where faults have occurred. As these relays require the constant transmission of information relating to current values, etc., between the grid substations linked by the transmission lines, a highly-reliable communications network is vital.

④ Upgrade of the distribution facilities:

Besides upgrading the substation facilities, the distribution facilities also need to be strengthened, so that load sharing can be used to eliminate overloading of transformers and distribution lines. In order to be able to switch over the distribution line in the event of a fault to supply power to unaffected sections, it must be possible to set the maximum permitted distribution line load capacity quickly, so as to divide up the load on the faulty distribution line among other distribution lines. For this reason, it is necessary that the distribution facilities should have a reasonable amount of spare capacity.

By adopting distribution line interconnection switches that support remote control, along with a Distribution Automation System (DAS), when a fault occurs, the switches can be used to rapidly redirect the supply of power from another substation to the section affected by the outage. In order to be able to use the distribution network to supply power from another grid substation in a situation of this kind, the size of the load that will be supplied through the other feeder needs to be calculated in advance to facilitate the switchover. A DAS possesses this type of functionality, permitting automated switchover so that power can be restored rapidly to areas that have suffered outages.

In addition, the use of a DAS permits analysis of current distribution in the distribution lines, facilitating the optimal utilization of distribution facilities (i.e. with minimum loss).
Regarding the DAS, Japanese companies have high technical capabilities.

⑤ Adoption of a System Stabilizing Controller (SSC)
Regarding the question of system stability with respect to international system interconnection, the current situation is that there is a serious risk of faults, etc. on the interconnector line from Vietnam that could lead to the interruption of the supply of power, causing the frequency to fall and possibly leading to a large-scale outage affecting the entire Phnom Penh area. Although actual implementation would require system simulations that take into account the dynamic characteristics of the generators, as well as detailed examination of costs, etc., possible solutions to the problem would include load shedding using frequency relays, or load shedding using a system stabilizing controller (SSC). With an SSC, system information is accessed in advance, so that appropriate load shedding levels can be set; then, when an anticipated problem (such as a fault on the interconnector with Vietnam) occurs, load shedding can be implemented immediately, thereby making it possible to prevent a pronounced drop in frequency. As the calculations require online data – such as trend values and system recognition data – from each power station, a highly-reliable communications network is a vital prerequisite.

3.2.5 Benefit by Expanding Transmission and Distribution Facilities in the Phnom Penh Urban Area

After implementing supporting plans described in 3.2.4, the benefits are below;
(1) Scheduled blackout can be evaded in Phnom Penh system and continuous power supply can be possible:
To make new grid substations, scheduled blackout due to lack of the capacity of transformers pointed out in table 3-20① can be evaded. The results of the questionnaire for Japanese companies described in 2.17(p.2-139), show complaint about non-planed blackout, facilities damage by sudden blackout, and problem not to be able to continue production, so benefits for companies is clear by dissolve scheduled blackout.
(2) To reduce power failure which is occurred when one of transmission lines in Phnom Penh system is fault is possible:
After maintain 115kV relay system in Phnom Penh system and transmission lines can be looped, electric power can be kept to supply when one transmission line will be failure. By the questionnaire of Japanese companies, some companies apprehensive about facilities damage by sudden power failure and power failure due to thunderbolt in rain season. To dissolve power failure by the failure of one transmission line, these concerns will be extremely low, so there is a bit benefit for companies.
(3) Recovery time from power failure by the distribution line's fault, etc., in Phnom Penh becomes short:
By introducing DAS and interconnection switches which can be operated remotely, in the case of the recovery from a distribution line failure where EDC staffs recover the failure by operating on-the-spot interconnection switches, it becomes possible to recover automatically and the power failure time becomes shorter greatly. From the questionnaire of Japanese companies, the power failure time which they can tolerate is maximally 12 minutes. Although the present condition that EDC staffs recover the failure by operating on-the-spot interconnection switches is obviously impossible to recover in 12 minutes, there are some cases to recover within 12 minutes using DAS. It can be possible to short the time of operation stop of factories due to power failure.
(4) To reduce the risk of black out of whole Phnom Penh system:
In table 2-85(p.2-135), the record of black out of whole Phnom Penh system was once (30 minutes) in 2010. The bigger the power system is, the longer the recovery time from black out is. To introducing SSC, when the international transmission line from Vietnam and a large hydropower plant is stopped, SSC can prevent black out of whole Phnom Penh system and can restrict power failure partly. This means that the quality of power becomes improve greatly

because the recovery time from the partial power failure is much shorter than that from black out. Namely, to introducing SSC is advantage to companies in Phnom Penh.
(5) Power supply area become larger:
Now, to supply power to Phnom Penh city is from not only GS1, 2, and 3 but also GS4 which is far from Phnom Penh city. If substations will be made in Phnom Penh city, GS4 does not supply power to Phnom Penh city so GS4 can increase power supply to the surround of GS4, for example Phnom Penh Special Economic Zone(PPSEZ) where there are many Japanese companies.

3.2.6 Proposed Timetable for Expanding Transmission and Distribution Facilities in the Phnom Penh Urban Area

The proposed timetable for expanding transmission and distribution facilities in the Phnom Penh urban area outlined in section 3.2.4 above, and for the related manpower cultivation activities, is shown in Figure 3-13.

Objective	Items	Content	2012	2013	2014	2015	2016	2017	Notes
To cope with increasing demand in Phnom Penh	Establishment of new transformer substations: ① Olympic Stadium ② Hun Sen Park ③ EDC H.Q.	Detailed demand forecasts							
		Deciding on machinery specifications			①②		③		
		Deciding on work methods to be used							
		New transformer substation construction							
		Testing							
		(Capability development) Maintenance and management of indoor substations							
	Establishment of new transmission facilities: ① GS3 - Olympic Stadium ② GS2 – Hun Sen Park ③ Olympic Stadium – Hun Sen Park ④ GS1 – EDC H.Q. ⑤ EDC HQ – Hun Sen Park	Deciding on transmission line routes							
		Deciding on transmission line types			①②③		④⑤		
		Deciding on work methods to be used							
		Transmission line construction							
		Testing							
		(Capability development) Maintenance and management of underground transmission lines							
	Enhancement of existing transmission lines	Transmission line power flow calculations							
		Deciding on transmission line type							
		Deciding on work methods to be used							
		Transmission line construction							To be implemented when the transmission lines require upgrade.
		Testing							
To enhance the stability of the power supply in Phnom Penh	Improvement of the 115kV relay system to facilitate creation of a 115kV system loop	Detailed design of relay system							
		Detailed design of communications network							
		Communications network construction							
		115kV relay system construction							
		Testing							
		(Capability development) Maintenance and management of DAS system and related communications equipment							
To strengthen the electric power distribution system: - Optimal utilization of distribution facilities - Rapid restoration of power when faults occur	DAS adoption Improvement of the interconnection switches, etc.	Detailed design of DAS							
		Detailed design of communications network							
		Construction of building to house DAS							
		Communications network construction							
		Interconnection switch construction, etc. (main unit and child stations)							
		Testing							
		(Capability development) Maintenance and management of DAS system and related communications equipment							
Using electric power system stabilization to minimize the scope of outages	SSC adoption	Detailed design of SSC							
		Detailed design of communications network							
		Communications network construction							
		SSC installation work							
		Testing							
		(Capability development) Maintenance and management of SSC and communications equipment							

Figure 3-13 Proposed Timetable for Expanding Transmission and Distribution Facilities in the Phnom Penh Urban Area

3.2.7 The Cambodian Participants' Views

Recognizing that the Phnom Penh system (which includes the capital city, Phnom Penh) is the most important electric power system in Cambodia, and that there is a need to upgrade facilities and improve the reliability of the electric power supply so as to be able to provide a stable, reliable supply of electric power in the future, EDC hopes to achieve the construction of highly-reliable underground transmission lines and indoor transformer substations.

MIME's Energy Development Department takes the view that most of the increase in demand for electric power in the Phnom Penh system derives from development in Phnom Penh's suburbs, with demand in the city center growing only relatively slowly; the Energy Development Department therefore questions the need to establish new transformer substation facilities in the city center.

However, EDC system information says that GS1, GS2 and GS3 which are supplying power to the center of Phnom Penh are nearly overloaded by the demand increase and the demand around GS3 is supplied by the long distribution line from GS4 which is located in the suburb. Therefore there is a substantial need to construct new GS in the central of Phnom Penh.

3.3 Human Resources Development

3.3.1 Load Dispatching and System Operation

As the EDC's National Control Center (NCC), which will be responsible for transmission and transformation system operation and for the issuing of load dispatching instructions, is scheduled to begin operation soon, the formulation of operating rules and the training of operatives have become pressing issues. To ensure that system operation is carried out in an appropriate manner, the acquisition of basic knowledge relating to relays, power flow calculations, voltage, stability and other aspects of electric power systems is vital. EDC is thus in urgent need of a high level of technical support. The main problems affecting the NCC can be summarized as follows:

- Rules for load dispatching operations have not been put in place
- Operatives' capabilities are inadequate; they lack the knowledge and experience that system operators need to possess
- The skills needed to operate the SCADA system effectively are lacking
- There is a shortage of communications engineers
- Relay and system analysis know-how is lacking

In addition, while the Transmission Department's Relay Protection Office has been given responsibility for relay setting, owing to a shortage of qualified human resources, the Relay Protection Office will (as is the case with the NCC) need technical support, in this case for relay setting and the related technical calculations.

Based on the above, it would appear that human resources development support with respect to load dispatching and system operation should take the following form:

- Purpose:
  To formulate rules for load dispatching and implement NCC operative training, so as to ensure the smooth running of the NCC once it begins operation; by achieving safe, precise operation, this will help to enhance the overall reliability of the electric power supply.
- Counterparties:
  The National Control Center (NCC) and Relay Protection Office of EDC's Transmission Department.
- Outputs:
  - Reducing the incidence of accidents and ensuring the stable supply of electric power by enhancing the load dispatching skills and capabilities of operatives.
  - Using efficient operational instructions to permit the supply electric power in an economical manner.
  - Clarifying the division of responsibility (in terms of a clear division of responsibility between operations and works) through rule formulation, thereby reducing the incidence of outages and accidents caused by mistaken operation and human error.
  - Enhancing the skills and capabilities of relay and communications technicians so that they are capable of maintaining and managing equipment by themselves.
- Activities:
  - Formulating rules relating to load dispatching operations (switch operation, generator operating instructions, etc.).
  - Providing skills training for operatives.
  - Implementing SCADA-related training.
  - Implementing communications-related training.
  - Implementing training relating to relay setting and system analysis.
  - Implementing on-the-job training relating to load dispatching.

Note: Relay setting and system analysis training will be provided for both the NCC and the Relay Protection Office; other training will be provided for the NCC only.

It should be noted in section 2.1.4(1)a.(p.2-7) that, while it was originally anticipated that the NCC would be run with 5 operatives per shift, because the scale of the monitoring and control systems has been reduced, it is now felt that the available number of staff should be adequate. For reference, a Japanese power company is able to operate its central dispatching center with 4 personnel per shift, with 3 operatives controlling around 20 to 60 substations each.

3.3.2 Maintenance and Management of Transmission and Transformation Facilities

As noted in section 2.1.4 (1) b.(p.2-8), EDC is responsible for the maintenance and management of the major part of the national grid. There are a number of new transmission and transformation facilities that, once they begin operation, will be EDC's responsibility. For example, the Kampot-Sihanouk Ville transmission line (with a length of 82 km) and the O'Soam Grid Substation are scheduled to begin operation by the end of 2013; once they are up and running, responsibility for operation and management will immediately be transferred to EDC, making for a significant increase in the scale of the facilities for which EDC is required to provide maintenance and management. EDC is itself well aware of this challenge, and of the need to build up stocks of the materials required for maintenance, and of having personnel available with the necessary maintenance and repair know-how. The cultivation of transmission facilities maintenance and management human resources is thus an urgent task for EDC.

In addition to human resources development, the formulation of rules relating to maintenance and management is also extremely important. While patrol inspection of transmission and transformation facilities is currently being carried out once or twice a month, the rules governing patrol inspection have yet to be drawn up. The compilation of rules relating to periodical patrol inspection is a vital task, since having these rules in place can facilitate the early discovery of problems and the prevention of accidents, thereby reducing the incidence of outages. Full-scale inspection of transmission and transformation facilities has not yet been carried out, and the relevant rules have not been drawn up. Since the putting in place of these rules can help to keep equipment in proper working order, facilitate systematic repair of equipment, and prevent accidents from occurring, thereby reducing the frequency of outages and damage to equipment, it would seem highly advisable that rules relating to regular inspection be formulated in the future. Besides the rules governing regular inspection, the drawing up of rules relating to operational safety and machinery operation is also extremely important.

It is also vitally important that all personnel familiarize themselves with and understand the rules once they have been formulated. While the already completed Safety Work Procedures for Transmission Line Work and the GREPTS and SREPTS are fully understood by team leaders, it does not appear that all personnel are fully familiar with these rules. Ensuring that all members of staff are conversant with the rules is important not only in terms of enhancing personnel's technical capabilities; it is also a vital prerequisite for proper equipment maintenance. It would seem highly advisable to put in place a framework that will ensure that all members of staff fully understand these rules.

As the equipment used in live-line work includes tools used to check for current and other equipment which comes into direct contact with the live part of the line, it is important that high potential testing be carried out on a regular basis. To ensure that the equipment is available when needed for facilities inspection, etc., an inspection cycle should be established for live-line work equipment, and the necessary testing equipment should be made available. It is also important that, as the number of sites and the number of personnel that need to be managed increases, there is a corresponding increase in the available stock of devices and tools of the types needed for maintenance work.

Based on the above, it would appear that human resources development support with respect to transmission and transformation facilities maintenance and management should take the following form:

- Purpose:
  To ensure that members of staff are fully familiar with the rules relating to transmission and transformation facilities maintenance and inspection and machinery operation, thereby facilitating the stable, reliable supply of power with as few accidents as possible.
- Counterparties:
  The Transmission Department's Transmission Unit
- Outputs:
  - Formulating rules relating to operational safety, thereby ensuring that human lives are protected when work is being performed.
  - Formulating rules relating to machinery operation, thereby reducing the incidence of outages

and damage to equipment caused by mistaken operation, etc.
- Formulating rules relating to patrol inspection, thereby facilitating early discovery of abnormalities and prevention of accidents, thus reducing the incidence of outages.
- Formulating rules relating to full-scale inspection, thereby facilitating the maintenance of equipment functionality, the implementation of systematic repair work, and the prevention of accidents, thus reducing the incidence of outages and damage to facilities.
- Using the formulation of rules to clarify responsibilities (including the division of labor between operations and works), thereby reducing the incidence of outages and accidents caused by mistaken operation or human error.

- Activities:
  - Formulating rules relating to operational safety.
  - Formulating rules relating to machinery operation.
  - Formulating rules relating to patrol inspection.
  - Formulating rules relating to full-scale inspection.
  - Putting in place internal systems designed to prevent accidents from occurring.
  - Putting in place the materials and equipment needed to meet safety needs.
  - Providing on-the-job training relating to machinery operation, patrol inspection and full-scale inspection.

3.3.3 EDC Training Center

While the training programs for transmission and transformation technicians provided at the EDC Training Center (which is responsible for providing transmission and transformation related training within EDC) make use of CBHV teaching materials and seek to be as comprehensive as possible, there are still deficiencies in the training, and further improvement is needed.
Based on the above, it would appear that human resources development support for the EDC Training Center should take the following form:

- Purpose:
  To put in place transmission and transformation related training facilities and training programs, so that the EDC Training Center can continue to enhance the skills and capabilities of EDC personnel on an ongoing basis.
- Counterparties:
  The EDC Training Center
- Outputs:
  - Enhancing the skills and capabilities of EDC personnel through the provision of training programs for the Transmission Department at the EDC Training Center, thereby eliminating the causes of accidents before they can occur, reducing the amount of time needed to remedy problems when they do occur, and reducing the incidence and length of outages.
- Activities:
  - Training trainers of transmission and transformer.
  - Putting in place training programs for transmission and transformation technicians.
  - Putting training facilities in place.
  - Implementing training for transmission and transformation technicians.

3.3.4 Hydroelectric Power Engineers

In Cambodia, where the electricity supply is not enough, electricity from hydropower should be taken full advantage. Referring to the PPAs of hydropower plant and the interview with IPPs and EDC, outage period plan and operation procedures etc. shall be accepted by EDC in advance. For example, regarding the yearly operation plan (2012) of Kirirom I hydropower plant, IPP changed it in accordance with the EDC's requirement. In light of Cambodia's electric power source development planning for the future, it can be anticipated that MIME, EAC and EDC will need hydroelectric civil engineers for hydroelectric power station planning, maintenance and operation, and for technical coordination with IPPs, etc. The number of hydro civil engineers currently available to each agency is as shown in Table

3-24 below; when compared with the number of engineers that Japanese experience suggests would be necessary, it is clear that there is a severe shortage in this area.

Table 3-24 Preferable Numbers of Hydro Civil Engineers for Hydropower Development and O&M

Entity / Class	Major	Nos. in Energy Sector in Cambodia as of 2011		Remarks*
		Present*	Preferable (min.)	
Political Organization		---	---	MIME
Director		1	1	
Manager	Civil or Hydro-mechanical	0	1	
Staff	Civil	0	2	3 for building (present)
Staff	Hydro-mechanical	0	1	
Regulating Organization		---	---	EAC
Director		1	1	
Manager	Civil or Hydro-mechanical	0	1	
Staff	Civil	0	1	
Staff	Hydro-mechanical	2	1	
Electric Utility Company				EDC
Headquarters		---	---	
Director	Civil or Hydro-mechanical	0	1	
Manager	Civil or Hydro-mechanical	0	1	
Staff	Civil	0	1-2	(Civil at present) 6*in Corporate Planning Dept. (for plan and design of SS, T/L etc. and assist Distribution Dept. and Generation Dept if necessary) 3 in Administration Dept. (for building) 1 in Distribution Dept. * all for other than hydro purpose
Staff	Hydro-mechanical	0	1	
Site Office (O&M)		---	---	per office having HPP
Manager	Civil or Hydro-mechanical	0	1	
Staff	Civil or Hydro-mechanical	0	1-2	

* Source: Interview with MIME, EAC and EDC

Based on the above, it is apparent that the development of hydroelectric power in Cambodia in the future will be affected by the following issues:

① Even after IPP power stations begin operation, the Cambodian authorities will not be in a position to implement effective inspection of IPP facilities.

② Even after IPP power stations begin operation, the Cambodian authorities will not be in a position to implement effective control over IPPs.

③ When electric power generating facilities are transferred from an IPP to EDC at the end of the BOT period, EDC will be unable to maintain and operate the facilities effectively.

The individual problems are examined in more detail below:

① Even after IPP power stations begin operation, the Cambodian authorities will not be in a position to implement effective inspection of IPP facilities:
SREPTS relating to hydroelectric power were compiled in 2009 (with support from JICA), and came into effect in 2010. In addition, the Guideline and Manual for Hydropower Development for Rural Electrification was issued by JICA in 2011. According to SREPTS, prior to the commencement of operation, inspection of hydropower plants will be conducted by MIME and EDC; once a power plant has become operational, inspection will be performed once every three years by EAC and EDC. The objective of the inspection on hydropower plants is to realize the safe and secure provision of electricity. In the inspection, it is checked if design and construction are conducted along the technical regulations are confirmed, or if function of generation are kept by maintenance. For appropriate inspection, skilled engineers who are good hydropower knowledge about not only planning, design, construction and O&M but also

inspection contents and backgrounds necessary. Regarding the knowhow on the inspection, important points will be understood deeply through the but also focused and efficient experience as well as checking along the sentences themselves. In Cambodia, inspection on the maintenance of hydropower is going to be conducted continuously in the near future. Support of training in the most initial stage in the series of it in Cambodia seems to be very effective for the establishment of sustainable and constructive inspection system.

With hydroelectric power plants built by Chinese-affiliated private-sector companies using the BOT model due to begin operation soon, EAC – which will have primary responsibility for power plant inspection – recognizes that EAC is facing with the following problems:

a) EAC lacks the human resources needed to fulfill its inspection obligations.
b) EAC has no experience whatsoever in implementing inspection of large-scale hydroelectric power plant facilities and machinery.
c) Given that there are currently very few non-diesel electricity generating facilities in Cambodia (although plans for the construction of 6 hydroelectric power stations and 3 thermal power stations have been approved), even it were possible to strengthen the relevant inspection capabilities, it would be difficult to maintain these inspection capabilities over the long term during the maintenance and operation stage.
d) The earliest inspection that EAC will need to carry out is that of the Kamchay hydroelectric power plant, which is scheduled for 2015; this gives EAC only a very short period of time in which to build up the necessary capabilities.

Faced with the problems outlined above, there is a strong need within the Cambodian electric power sector for OJT relating to the performance of inspection in line with SREPTS and the Guidelines and Manual on Hydroelectric Power Development for Rural Electrification.

② Even after IPP power stations begin operation, the Cambodian authorities will not be in a position to implement effective control over IPPs:

EDC has extensive experience in the development and operation of diesel-fired power stations. When a fault occurs in the facilities or machinery of a diesel-fired power station, EDC is able to determine the cause of the problem and carry out repairs. EDC is thus also capable of gauging how long outages will continue, and how much they will cost.

However, EDC has hardly any experience in the development and operation of hydroelectric power stations (EDC currently has only three micro hydroelectric power stations that were originally developed by foreign organizations). EDC is thus severely restricted in terms of the availability of locations for training relating to checks, inspections and repair, and to the reviewing of environmental impact strategies formulated with regard to the impact of dams on downstream areas, etc.

With regard to the annual power supply plans for the Kiriom I and O'Chum II hydroelectric power stations, EDC is in the process of acquiring the capability to implement review based on actual operation results and demand projections. However, in practice, appropriate improvement strategies can only be formulated when review is based on a thorough understanding of the original power generating schedule.

A further point is that, in the case of the O'Chum II hydroelectric power station, a problem is apprehensive about leakage from the earth dam upstream of the station. So far, no examination has been made of the quantity of water leaking out from the dam, or of the path followed by this water. In other words, hydroelectric power station dam risk management is not being implemented properly. As ongoing dam monitoring and surveys by EDC are a precondition for effective risk management, this work needs to be implemented as early as possible. The enhancement of the capabilities of EDC's engineers needed to make this possible has thus become an even more pressing issue.

③ When electric power generating facilities are transferred from an IPP to EDC at the end of the BOT period, EDC will be unable to maintain and operate the facilities effectively:

Given that the BOT period is 30 years, there is little that needs to be done now in relation to maintenance and management following the transfer of facilities at the end of the BOT period. Furthermore, provided that measures are taken to address problems ① and ②, and provided that the Cambodian authorities continue to undertake human resources development activities, it can be anticipated that this problem will disappear.

Based on the above, it would appear that human resources development support for the EDC Training Center should take the following form:

- Purpose:
  To enhance the management capabilities of MIME and EAC with respect to IPP hydropower stations, and to enhance EDC's ability to plan, design, management and maintain hydroelectric power stations.
- Counterparties:
  MIME, EAC and EDC personnel involved with electricity generation technology, and the EDC Training Center.
- Outputs:
  - Enabling EDC to implement hydropower station planning, construction, maintenance, and operation (including repair) on its own.
  - Enabling EDC to undertaken appropriate inspections of hydropower stations.
  - Establishing and implementing a training curriculum for hydroelectric power station engineers.
- Activities:
  - Implementing training with respect to hydropower station planning, design, maintenance and operation (including repair).
    (Please note that it may be considered more appropriate for training relating to hydroelectric power stations to be conducted as part of the separate O'Chum re-development project.)
  - Implementing training with respect to environmental assessment for power station development projects, and for environmental concerns relating to power stations that are already in operation.
  - Using OJT and classroom training to transfer skills, know-how and environmental knowledge relating to hydropower generation.
  - Considering detailed methods for hydropower station inspection, and compiling hydropower station inspection checklists.
  - Making use of hydropower station inspection that employs the hydropower station inspection checklists as a form of on-the-job training.
  - Compiling a training curriculum that makes effective use of the Guidelines and Manual on Hydroelectric Power Development for Rural Electrification.
  - Implementing "Training of Trainers" (TOT).

It should be noted that the Cambodian authorities' requirements with regard to coal-fired power station technology are the same as those applying to hydroelectric power stations.

3.4 Micro Hydropower and Rural Electrification

3.4.1 Rural Electrification using Renewal Energy (micro hydropower)

(1) Outline of the Study

In this section, data on the villages and NGD extension plan etc., which are related to Micro-Hydropower projects providing electricity to Mini-Grids for rural electrification in Northeast area (Ratana Kiri Province and Mondul Kiri Province), are upgraded. And, the most prospected projects are selected. Work flow are shown in Figure 3-14. The Study here targets northeastern area of Cambodia (Ratana Kiri Province and Mondul Kiri Province).

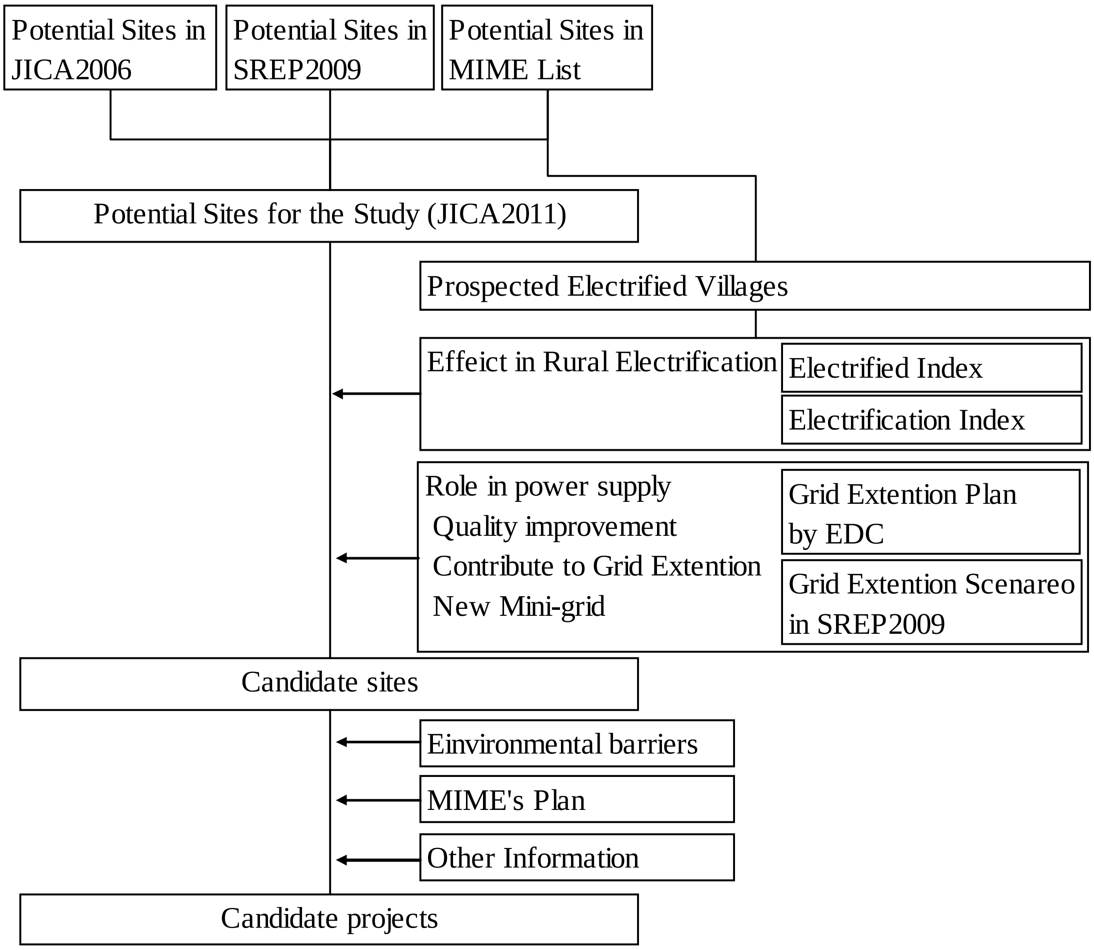


Figure 3-14 Workflow of the Study

(2) Hydropower development scale of the target sites

Table 3-25 shows classifications of hydropower plants in Cambodia. In this examination, as was also the case in MP2006, micro hydropower plants with maximum output of 10kW or more have been targeted.

Table 3-25 Classification of Hydropower Plants in Cambodia

Type of HPP	Installed Capacity (kW)
Small: - Micro	Up to 500
- Mini	501 – 5,000
- Small	5,001 – 10,000
Medium	10,001 – 50,000
Large	More than 50,000

Source: MIME: p.5, Hydropower, 2003

(3) Examination of rural electrification of northeastern areas based on micro hydropower

a. Potential sites for rural electrification (micro hydropower)

Micro hydropower sites for rural electrification were investigated in the “Pre-Investment Study of Community Scale Hydro Projects, Cambodia” (NZ Ministry of Foreign Affaires & Trade, by Meritec, 2003) and the “Development of Pipelines of Small Hydropower Projects in Cambodia” (funded by WB, 2002), and sites were also consolidated in the Master Plan Study on Rural Electrification using Renewable Energies (MP2006). After this, the Sustainable Rural Electrification Plans for Cambodia (funded by French Ministry of Economy, Industry and Labour, Direction Générale du Trésor, FASEP Facility – Fonds d’Aide et de Soutien au Secteur Privé, by IED Innovation Energie Développement, 2011) (SREP2011) examined strategic initiatives geared to the actualization of rural electrification targets.

Moreover, the results of SREP2011 are reflected in the Ministry of Industry, Mines and Energy ordinance, the “Strategy and Plan for Development of Rural Electrification in the Kingdom of Cambodia (SPDRE).” Out of the sites in Ratana Kiri Province and Mondul Kiri Province, Table 3-26 shows the ones that were included in the lists examined in MP2006 and SREP2011. Figure 3-15 shows the location of potential sites and villages.

Table 3-26 Potential Micro Hydropower Sites for Rural Electrification

No.	Project Name	MP 2006		SREP 2011		MIME
		No.	Power (kW) (η=0.7)	No.	Power (kW)	Power (kW)
Mondul Kiri Province						
1	O Rang Tributary	68	5	----	< 50	
2	Prek Pua	69	49	46	49	
3	Prek So Long Tributary	70	11	----	< 50	
4	Prek So Long Upper	71	11	----	< 50	
5	Prek So Long Lower	72	42	----	< 50	
6	Prek Te	73	494	49	494	
7	Prek Te Tributary	74	41	----	< 50	
8	Prek Chhung	75	21	----	< 50	
9	O Bumpa	76	33	----	< 50	
10	O Long Mang	77	123	15	123	
11	O Dak Dam	78	2	----	< 50	
12	O Moleng	O&M	-----	----	-----	
13	O Romis	O&M	-----	----	-----	
14	Prek Dak Deurr	81	33	41	202	200
15	Prek Dak Deurr D/S	82	123	40	125	
35	Prek Dak Deurr (Meritec)	-----	-----	42	730	
36	Prek Dak Deurr (MIME)	-----	-----	43	112	110
16	Bu Sra	83	70	3	80	56
17	O Phlai (JICA)	84	91	18	91	
37	O Phali (MIME)	-----	-----	19	750	
38	O Phlai II	-----	-----	103	725	
39	O Yong Ngol	-----	-----	31	68	
18	Prek Rwei	85	27	----	< 50	
19	Prek Chbar Lower	86	66	39	66	
20	Prek Chbar Upper	87	33		< 50	
Ratanak Kiri Province						
21	O Kachan	108	32	12	82	220
22	O Katieng	109	40	14	223	330
23	O Katieng (D/S)	110	126	13	1076	
24	Ta Ang	111	12	----	< 50	10
25	Prek Banpong	112	42	----	< 50	
26	Tributary of prek Lalay	113	23	----	< 50	
27	O Houei Lalay	114	198	11	198	
28	Tributary of o Houei Lalay	115	14	----	< 50	
29	O Chum I	116	93	102	93	300-1000
40	O Chum III	-----	-----	10	74	
30	Bay Srok	117	66	1	66	130
31	O Ta Phlai	118	26	----	< 50	
32	O Pyol	119	11	----	< 50	
33	Prek Liang	120	768	45	768	
34	Stung Khampha	121	549		< 50	

Source: JICA Team

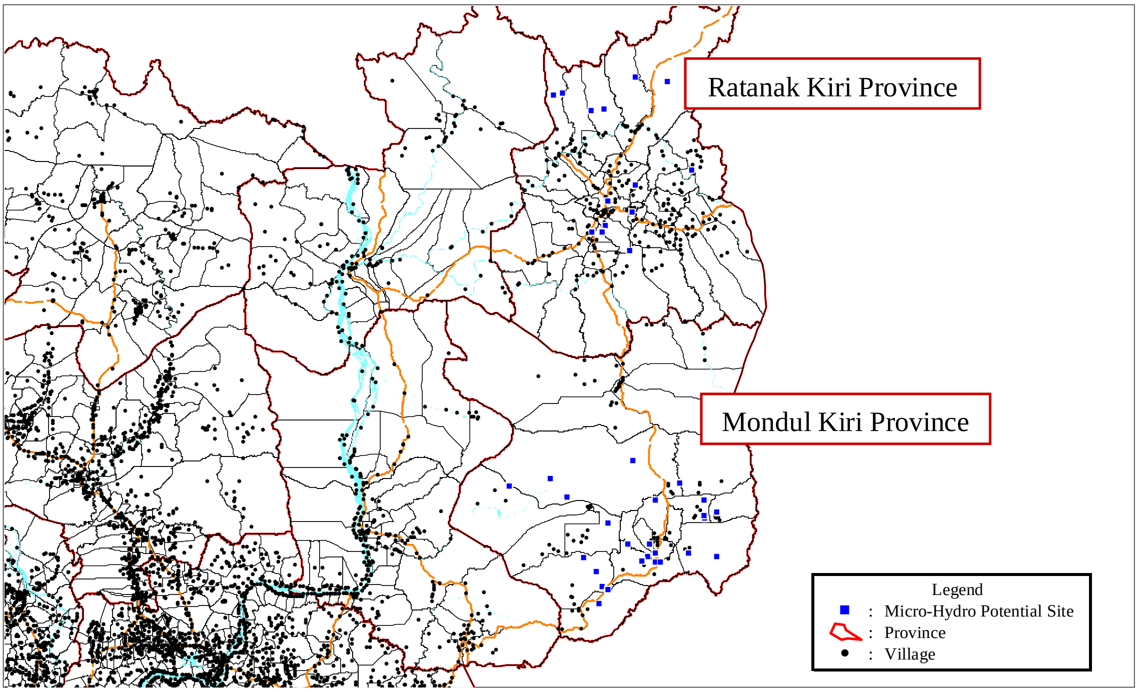


Figure 3-15 Potential Sites and Villages in Ratana Kiri and Mondul Kiri

b. Micro hydropower sites targeted for examination

In this latest update, the basic information has been renewed and consolidated upon selecting promising sites. Specifically, out of the sites indicated in Table 3-26, the sites that were regarded as potential micro hydropower mini grid sites in MP2006, the sites that were identified as potential micro hydropower supply sites in SREP2011 (sites identified in cases reflected in PRAKAS) and the sites currently owned by MIME, have been selected. The target sites are shown in Table 3-27.

Table 3-27 Selected Micro Hydropower Sites for Rural Electrification

No.	Project Name	MP2006	SREP2011	MIME
	(Mondul Kiri Province)			
5	Prek So Long Lower	x		
6	Prek Te		x	
10	O Long Mang		x	
14	Prek Dak Deurr	x		x
15	Prek Dak Deurr D/S	x	x	
36	Prek Dak Deurr (MIME)			x
16	Bu Sra	x	x	x
17	O Phlai (JICA)		x	
39	O Yong Ngol		x	
	(Ratanak Kiri Province)			
21	O Kachan			x
22	O Katieng	x		x
23	O Katieng (D/S)		x	
24	Ta Ang			x
29	O Chum I			x
40	O Chum III		x	
30	Bay Srok	x	x	x

c. Information updating

(a) Updating of village extraction conditions

As of January 2012, databases on villages in Cambodia comprise the National Census and the Community/Sangket Database (CDB).

The Community/Sangket Database (CDB) compiles data on villages in tandem with the Seila program (started in 1996 with a view to promoting decentralization and resident participation, this implemented support for infrastructure, health and education services, etc. on the administrative village level while mobilizing financial aid from donors). Concerning the CDB, the survey scope of village data was expanded from 1998 to 2001 and the system was established whereby survey could be implemented on the national scale between 2002 and 2005. From 2006 onwards, survey items were successively added, and today the data is updated by the Ministry of Planning. Since data if officially updated around August in the year following the actual survey, the latest data as of January 2012 is that obtained in 2010. Updating of the village data here was basically implemented based on the CDB.

The Census is updated once every 10 years. The latest data are from 2008. In the Study, information that couldn't be obtained from the CDB department in charge (village location information, etc.) was supplemented using the Census data.

In the evaluation of electrification level in MP 2006, firstly, in order to determine whether a given village has achieved electrification from connection to the grid, the following indicator is used: ① did the electrification rate (excluding battery power) for the village in question exceed 10% in 1998 according to the National Institute of Statistics (NIS) database. Furthermore, as the criteria for determining whether village electrification based on batteries is sufficiently disseminated and the level of village electrification by mini grid (including independent micro hydropower grid) is reached, the following indicator is used: ② In CDB2003, is the television diffusion rate more than 10%? Considering that batteries are being disseminated very rapidly, since it is inappropriate to depend on old 1998 data as indicator. ② is based on the assumption that a 10% diffusion rate of television is equivalent to a 50% battery diffusion rate (= the village is ready to be erectlified). Therefore, when the Seila data becomes disseminated, indicators ① and ② will be substituted with ③ Is the battery lighting diffusion rate more than 50%?

In the Study, verification was first conducted to determine whether the criteria of ① and ② can be substituted with ③.

Figure 3-16 shows the relationship between battery lighting diffusion rate and television diffusion rate in the 76 villages that were deemed to have potential for conducting electrification by micro hydropower development in MP2006 (Table 3-27). As a result, it was found that the number of villages which meet the fore-mentioned assumption was in only six. In other words, when it comes to selecting locations for village electrification based on micro hydropower in the future, it will be necessary to conduct further verification.

Therefore, in the Study, in order to grasp the electrified situation from the following viewpoint:

① Whether or not the electrification rate (excluding battery power) given in CDB2010 exceeded 10%;

② Whether or not the battery diffusion rate given in CDB2010 exceeded 50%

Moreover, in the Study, in order to roughly evaluate the possibility of electrification by micro hydropower, evaluation has been conducted according not to electrification rate of each village itself but average electrification of villages by each micro hydropower.

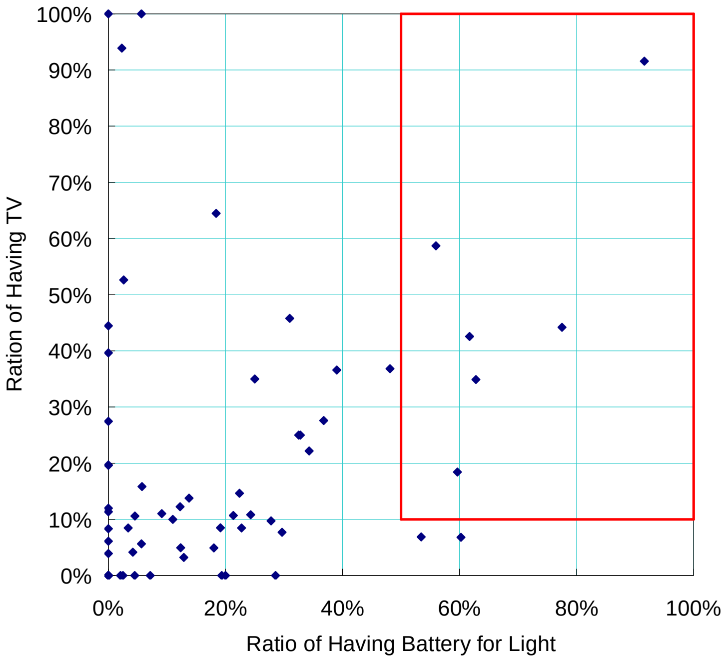


Figure 3-16 Correlation between Ration Having Battery for Light and Ratio of Having TV

(b) Updating of village data

Table 3-28 shows the latest basic data of villages that are targeted for electrification of the micro hydropower sites in Table 3-26. However, because it was possible to identify the villages targeted for electrification of the MIME recommended sites, this table only shows the villages mentioned in MP2006 and SREP2011. It can be seen that the number of households requiring electrification is increasing in many villages.

Table 3-29 shows the latest information on locations that were examined in Table 3-27. In Mondul Kiri Province, the electrification rate excluding batteries is higher than 10% at all locations, whereas conversely in Ratana Kiri Province, the electrification rate is slightly lower than 10% at all locations. In Ratana Kiri Province, the battery diffusion rate is higher than 50% at one location, however, grid electrification has already commenced in this area.

Table 3-28 Target Villages to be Electrified
(Mondul Kiri Province)

No.	Province	Scheme	River	MHP 2006 JICA					JICA 2011		SREP 2011				
				ID No. by Seila	Commune	Village name	Nos. of HHs	Nos. of HHs to be Electrified	Nos. of Houses	Nos. of Hs to be Electrified	ID No. by Seila	Village	Village name if change *use CDB ID	Nos. of Houses	Nos. of Hs to be Electrified
5	Mondul Kiri	Prek So Long Lower	Prek So Long			# Srelovi etc.	286	229	347	299					
				11010403	Srae Khtum	Srelovi			28	28					
				11010404	Srae Khtum	Sreampil			40	36					
				11010407	Srae Khtum	Srae Khtum			88	80					
				11010502	Srae Preah	Pu Char			49	49					
				11010505	Srae Preah	Srae Preah			142	106					
6	Mondul Kiri	Prek Te	Prek Te			# Chorkcha etc.	1101	881	894	734		# Pongol etc.		763	603
				11010302	Srae Chhuk	Chorkcha			131	131					
				11010201	Me Mang	Pongol			61	61	11010201	Pongol		61	61
				11010202	Me Mang	Pognov			29	29	11010202	Pognov		29	29
				11010203	Me Mang	Pocha			31	31	11010203	Pocha		31	31
				11010204	Me Mang	Pokes			56	56	11010204	Pokes		56	56
				11010205	Me Mang	Tourl			128	107	11010205	Tourl		128	107
				11010101	Chong Phlah	Potung			293	164	11010101	Potung		293	164
				11010102	Chong Phlah	Pohourn			103	93	11010102	Pohourn		103	93
				11010103	Chong Phlah	Kheng			62	62	11010103	Kheng		62	62
10	Mondul Kiri	O Long Mang	O Long Mang			* Ph Pu Cheng etc. but access difficult. 13km over mountains						# Pu Antraeng etc.		173	153
											11030101	Pu Antraeng		99	85
											11030102	Pu lao		74	68
12	Mondul Kiri	O Moleng	O Moleng	11050101	Monourom	* Already developed			* Already developed						
13	Mondul Kiri	O Romis	O Romis	11050102	Monourom	* Already developed	1434	1147	* Already developed						
14	Mondul Kiri	Prek Dak Deurr	Prek Dak Deurr	11050201	Sokh Dom	Mean Leaph									
15	Mondul Kiri	Prek Dak Deurr D/S	Prek Dak Deurr			# Daoh Kramom etc.	1434	1147	1340	457		# Chrey Saen etc.		330	202
				11050202	Sokh Dom	Daoh Kramom			152	33	11050102	Chrey Saen		152	33
				11050203	Sokh Dom	Svay Chek			87	37					
				11050204	Sokh Dom	Lao ka			9	0	11050204	Lao ka		9	0
				11050301	Spean Mean Chey	Ou Spean			124	0					
				11050302	Spean Mean Chey	Chambak			154	5					
				11050303	Spean Mean Chey	Kandal			294	0					
				11050304	Spean Mean Chey	Chamkar Tae			131	8					
				11050401	Romonea	Pu Trom *			139	124					
				11050402	Romonea	Pu Tang			41	41	11050402	Pu Tang		41	41
				11050403	Romonea	Pu Long *			128	128	11050401	Pu Trom		128	128
				11050404	Romonea	Srae I *			81	81					
36	Mondul Kiri	Prek Dak Deur (MIME List)	Prek Dak Deurr												
16	Mondul Kiri	Bu Sra	Prek Por			# Phum Lekh Muoy etc.	899	719	1061	720		# Pu Tit etc.		720	404
				11040401	Bu Sra	Phum Lekh Muoy			122	107	11040401	Phum Lekh Muoy	Pu Tit	122	107
				11040402	Bu Sra	Phum Lekh Pir			89	42	11040402	Phum Lekh Pir	Pu Rang	89	42
				11040403	Bu Sra	Phum Lekh Bei			107	74	11040403	Phum Lekh Bei	Bu Sra	107	74
				11040404	Bu Sra	Phum Lekh Buon			81	70					
				11040405	Bu Sra	Phum Lekh Pram			121	11	11040405	Phum Lekh Pram	Lam Mes	121	11
				11040406	Bu Sra	Phum Lekh Prammuoy			97	71	11040406	Phum Lekh Prammuoy	Pu Cha	97	71
				11040407	Bu Sra	Phum Lekh Prampir			184	99	11040407	Phum Lekh Prampir	Pu Lu	184	99
				11040301	Srae Ampum	Phum Lekh Muoy			66	52					
				11040302	Srae Ampum	Phum Lekh Pir			114	114					
				11040303	Srae Ampum	Phum Lekh Bei			80	80					
37	Mondul Kiri	O Phlai (JICA)										# Phum Krorng Kes etc.		553	513
											11040101	Phum Krorng Kes		104	104
											11040103	Phum Tram Kach		45	38
											11040104	Phum lou Rapet		63	55
											11040301	Phum Lekh Muoy	Pu Kroch	66	52
											11040302	Phum Lekh Pir	Pu Radeth	114	114
											11040303	Phum Lekh Bei	Pu Kreng	80	80
											11040404	Phum Lekh Buon	Pu Til	81	70
39	Mondul Kiri	O Yong Ngol										# Pu Hiem etc.		372	332
											11030201	Pu Hiem		281	241
											11030204	Pu rang		91	91

(Ratana Kiri Province)

No.	Province	Scheme	River	MHP 2006 JICA					JICA 2011		SREP 2011				
				ID No. by Seila	Commune	Village name	Nos. of HHs	Nos. of HHs to be Electrified	Nos. of Houses	Nos. of Hs to be Electrified	ID No. by Seila	Village	Village name if change *use CDB ID	Nos. of Houses	Nos. of Hs to be Electrified
21	Ratanak Kiri	O Kachan	O Kachan	16020102	Kachanh	Phum Pir	98	78	108	30					
22	Ratanak Kiri	O Katieng	O Katieng			# Ka Tieng etc.	295	236	321	307					
				16050303	La Bang Muoy	Ka Tieng			91	91					
				16050304	La Bang Muoy	Ka Lang			43	43					
				16050301	La Bang Muoy	Kam Phlenh			100	96					
				16050401	La Bang Pir	Ka Tieng			87	77					
23	Ratanak Kiri	O Katieng (D/S)	O Katieng									# Lon etc.		3122	2991
											16020301	Lon		110	110
											16020302	Phnum		42	42
											16020303	Sil		51	36
											16030403	Pa Yang		74	61
											16030602	Kab		71	66
											16040301	Ta Ang Ka Tae		155	152
											16040302	Ta Ang Pok		138	138
											16040303	Tus		121	105
											16040304	Sek		116	116
											16040305	Ta Kab		133	133
											16040401	Teun		244	231
											16040402	La En		149	145
											16040403	Ta Heuy		79	69
											16040404	Kam Bak		66	61
											16050301	Kam Phlenh		100	96
											16050302	Ka Tueng		50	48
											16050303	Ka Tieng		91	91
											16050304	Ka Lang		43	43
											16050401	Ka Tieng		87	77
											16050402	Ka Chanh		110	93
											16050502	Pruok		158	158
											16050503	Pa Tang		105	102
											16050504	Chang Rea		154	154
											16060101	Char Ung Ket		67	67
											16060102	Char Ung Chan		125	125
											16060103	Phlay Ampil		168	168
											16060104	Thuoy Tum		71	69
											16060105	Char Ung Kao		117	117
											16060301	Pa or		75	75
											16060504	L'eun Kreaeng		52	43
24	Ratanak Kiri	Ta Ang	O Cheng	16040304	Ta Ang	Sek	98	78	116	116					
29	Ratanak Kiri	O Chum I	O Chum			# Ou Chum etc.	278		330	322					
				16060501	Ou Chum	Ou Chum			129	127					
				16060501	Ou Chum	Tharang Chong			106	100					
				16060205	Ou Chum	Svay			95	95					
40	Ratanak Kiri	O Chum III	O Chum									# Tuy etc.		530	492
											16030601	Tuy		145	125
											16030604	Pa Nal		36	33
											16060302	Pa Chon Thum		247	232
											16060304	Krouch		102	102
30	Ratanak Kiri	Bay Srok	O Sien Ler (O Paling Thom)			# Bay Srok etc.	560	448	0	0		# Thmei etc.		459	429
				16050204	Ka Laeng	Bay Srok			-	-					
				16050205	Ka Laeng	New Ka Laeng			-	-					
				16050206	Ka Laeng	New Sayos			-	-					
											16050601	Thmei		172	149
											16050606	Nang Hai		160	160
											16050607	Sakmotr Kraom		127	120

Table 3-29 Village Data on Rural Electrification

No.	Project Name	Total Houses			Ratio of Electrified Houses		Ratio of Houses Having Battery		Ratio of Houses Having TV	
		JICA 2006	for VLLGs in JICA2006	for VLLGs in SREP2011	for VLLGs in JICA2006	for VLLGs in SREP2011	for VLLGs in JICA2006	for VLLGs in SREP2011	for VLLGs in JICA2006	for VLLGs in SREP2011
			CDB2010	CDB2010	CDB2010	CDB2010	CDB2010	CDB2010	CDB2010	CDB2010
(Mondul Kiri Province)										
5	Prek So Long Lower	286	**347**	-	14%	-	34%	-	22%	-
6	Prek Te	1,101	894 *1	763	18%	21%	36%	33%	26%	29%
10	O Long Mang	-	-	173	-	12%	-	5%	-	8%
14	Prek Dak Deurr	-	-	-	-	-	-	-	-	-
15	Prek Dak Deurr D/S	1,434	1,340	341	66%	42%	6%	10%	52%	41%
36	Prek Dak Deurr (MIME)	-	-	-	-	-	-	-	-	-
16	Bu Sra	899	1,061	720	32%	44%	10%	1%	5%	0%
17	O Phlai (JICA)	-	-	553	-	7%	-	18%	-	15%
39	O Yong Ngol	-	-	372	-	11%	-	39%	-	6%
(Ratanak Kiri Province)										
21	O Kachan	98	108	-	0%	-	0%	-	3%	-
22	O Katieng	295	**321**	-	4%	-	30%	-	17%	-
23	O Katieng (D/S)	-	-	3,122	-	4%	-	24%	-	15%
24	Ta Ang	98	116	-	0%	-	22%	-	15%	-
29	O Chum I	278	330	-	2%	-	58%	-	45%	-
40	O Chum III	-	-	530	-	7%	-	29%	-	13%
30	Bay Srok	560	- *2	459	-	7%	-	6%	-	7%

*1 Nos. of families is 1,198
*2 Villages' name are not identified in CDB2010

(c) Grid expansion plans

Figure 3-17 through Figure 3-20 show the current power supply areas of Mondul Kiri Province and Ratana Kiri Province and the planned grid expansion of EDC in 2020. In the SPDRE, consistent plans ranging from stand-alone power sources to grid expansion are formulated, and these include micro hydropower mini grids. According to these plans, rural electrification by micro hydropower is under the jurisdiction of MIME, while the EDC, which currently operates micro hydropower at three locations, is mainly in charge of rural electrification based on grid expansion. In the interviews conducted in the Study, emphasis is placed on rural electrification based on grid expansion in terms of the overall energy sector and it is inferred that concrete plans for rural electrification based on micro hydropower according to the SPDRE will be compiled from now on.

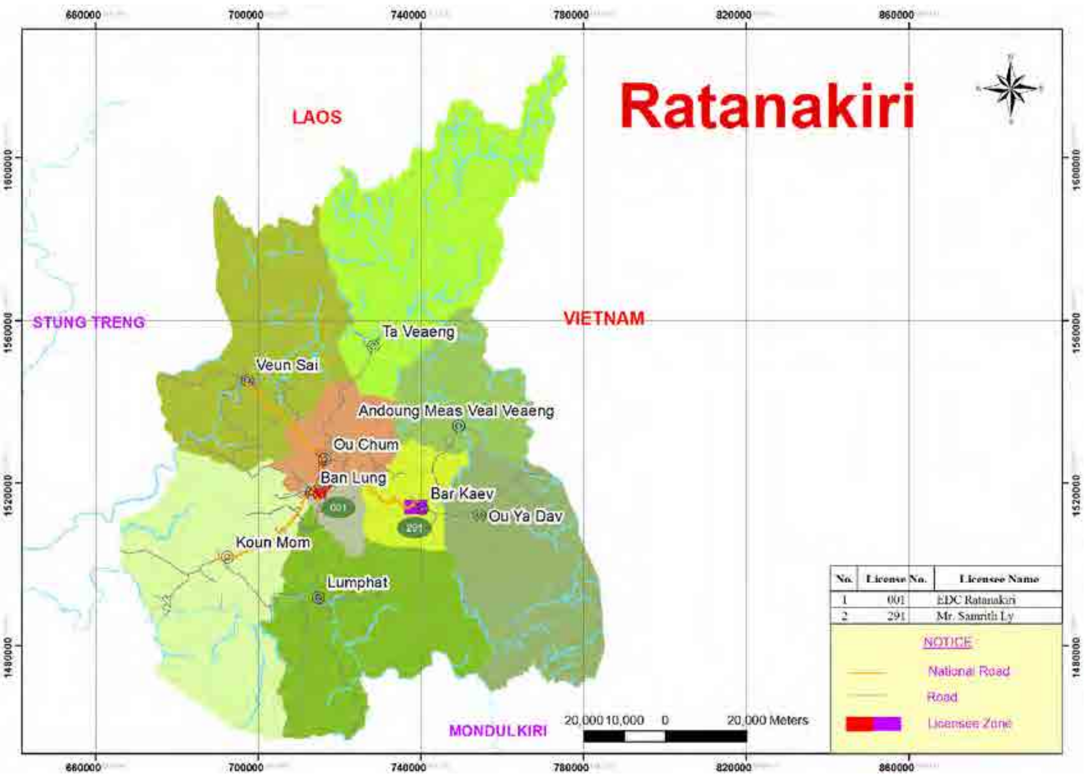


Figure 3-17 Present Supply Area (Ratana Kiri)

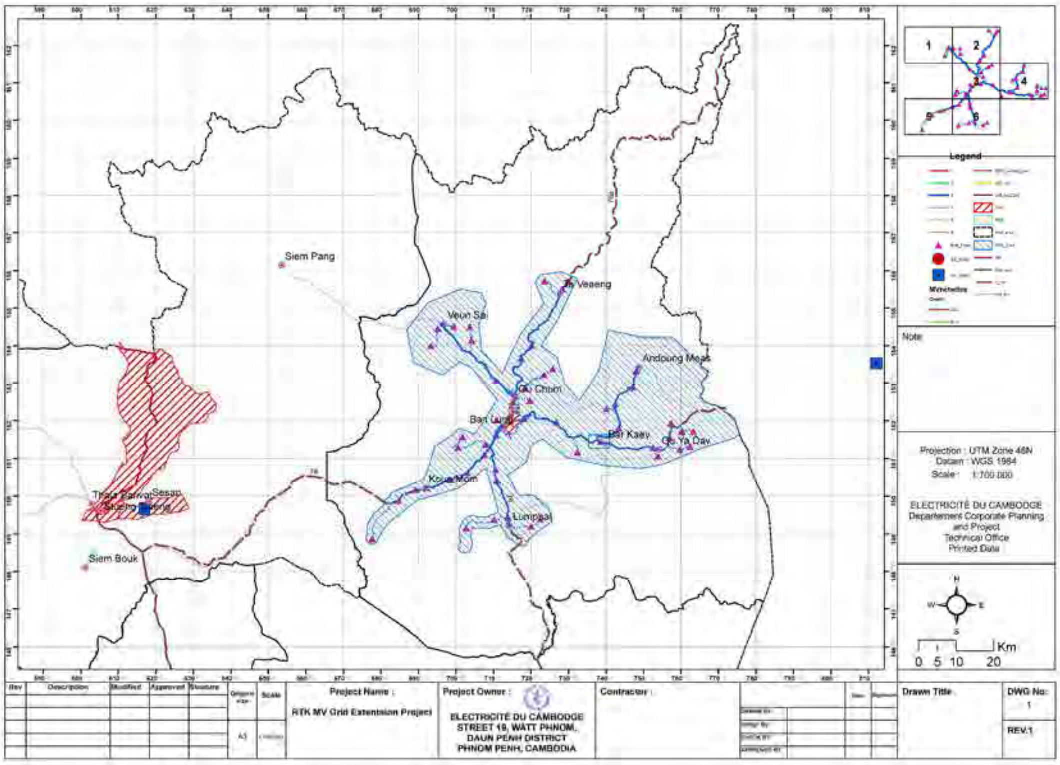


Figure 3-18 Future Grid Connection Area (Ratana Kiri)

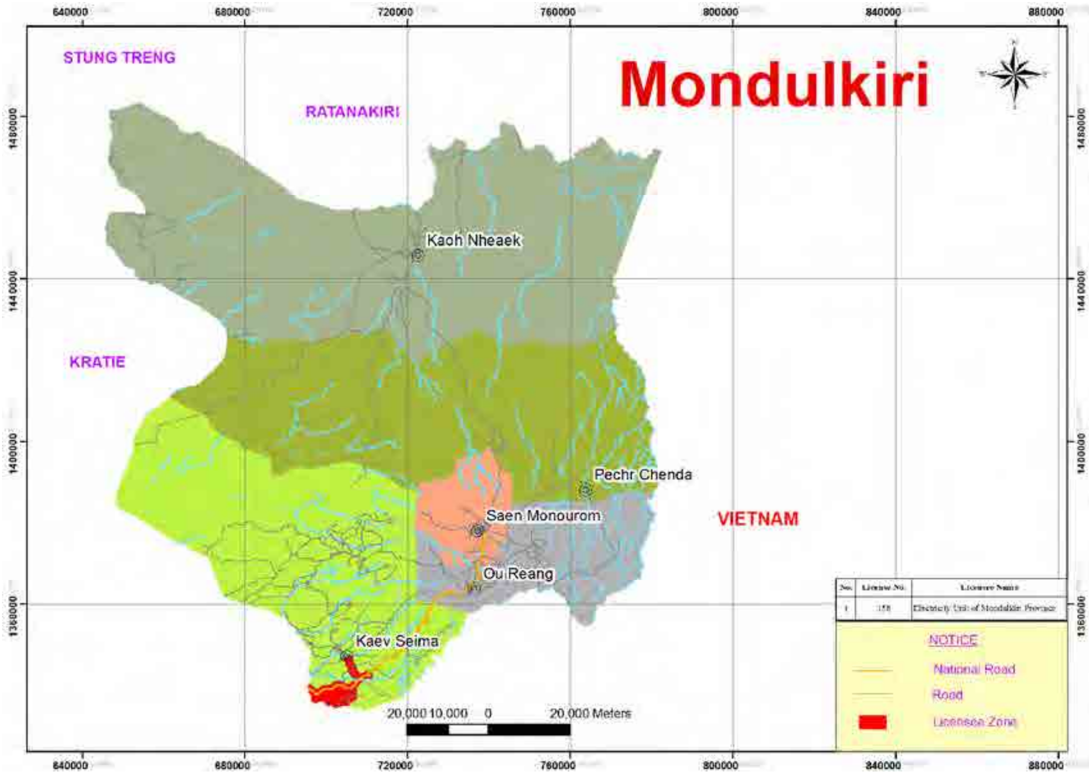


Figure 3-19 Present Supply Area (Mondul Kiri)

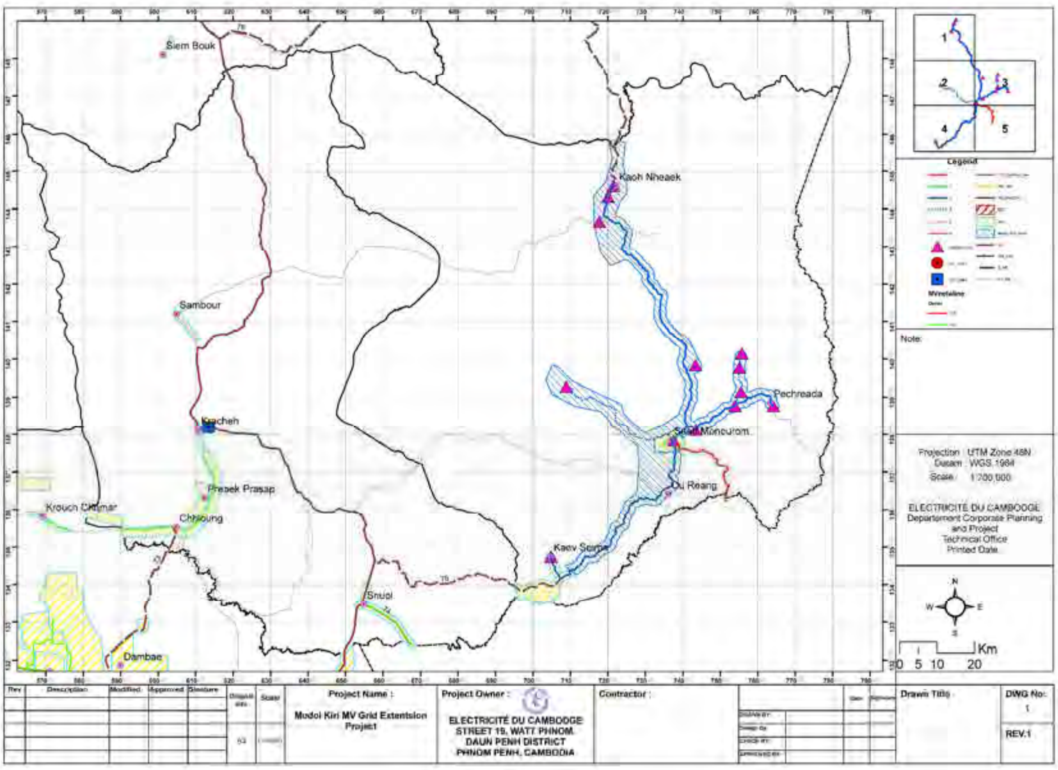


Figure 3-20 Future Grid Connection Area (Mondul Kiri)

Table 3-30 and Figure 3-21 and Figure 3-22 show the relationship between the planned scope of grid expansion (2020) and the promising sites. And Table 3-31 shows the situation according to each village.

Table 3-30 Village Data on Rural Electrification

No.	Project Name	Power (kW)			Connection to National Grid	
		MP2006	SREP2011	MIME	Expected Year of Connection in SREP2011	Relationship with EDC's Plan
	(Mondul Kiri Province)					
5	Prek So Long Lower	**42**	< 50			Ref. Figure for Mondul Kiri
6	Prek Te	494	494		2020 except 1 village =No connection	
10	O Long Mang	123	123		2018-2024	
14	Prek Dak Deurr	**33**	202	200		
15	Prek Dak Deurr D/S	**123**	125		2016-2025	
36	Prek Dak Deurr (MIME)	-----	112	110		
16	Bu Sra	**70**	80	56	2020	
17	O Phlai (JICA)	91	91		2020	
39	O Yong Ngol	-----	68		2020	
	(Ratanak Kiri Province)					
21	O Kachan	32	82	220		Ref. Figure for Ratanak Kiri
22	O Katieng	**40**	223	330		
23	O Katieng (D/S)	126	1076		No connection	
24	Ta Ang	12	< 50	10		
29	O Chum I	93	93	300-1000		
40	O Chum III	-----	74		2019	
30	Bay Srok	**66**	66	130	2018-2030 except 2 villages = No connection	

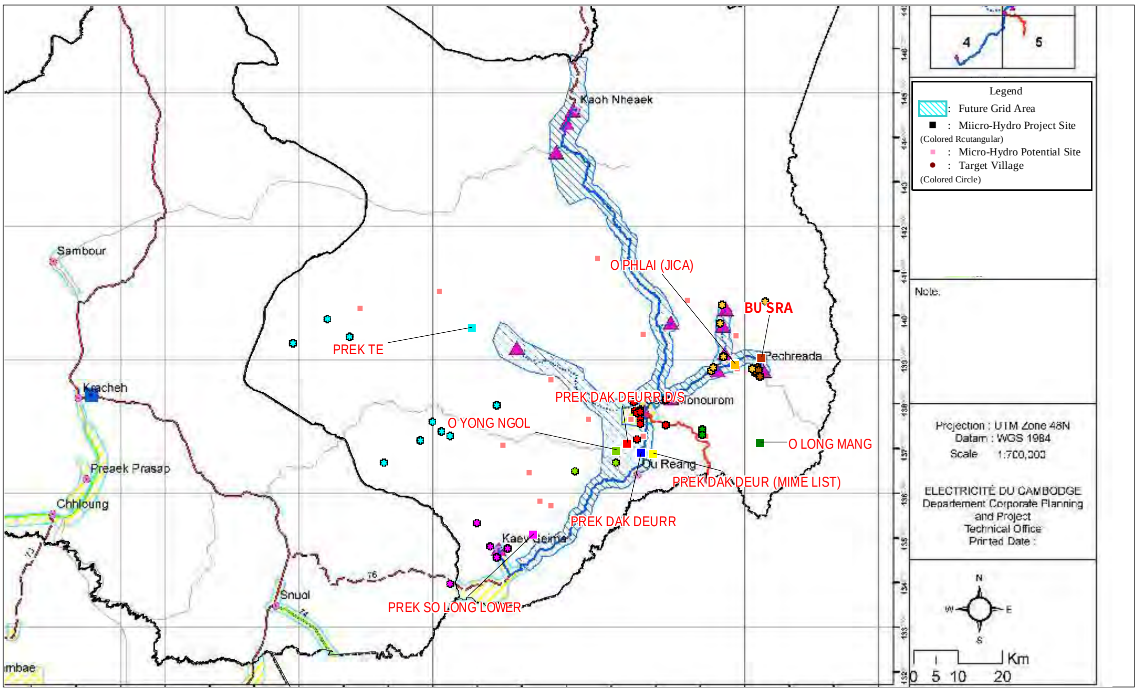


Figure 3-21 Target Villages and Grid Extension Plan by EDC (Mondul Kiri)

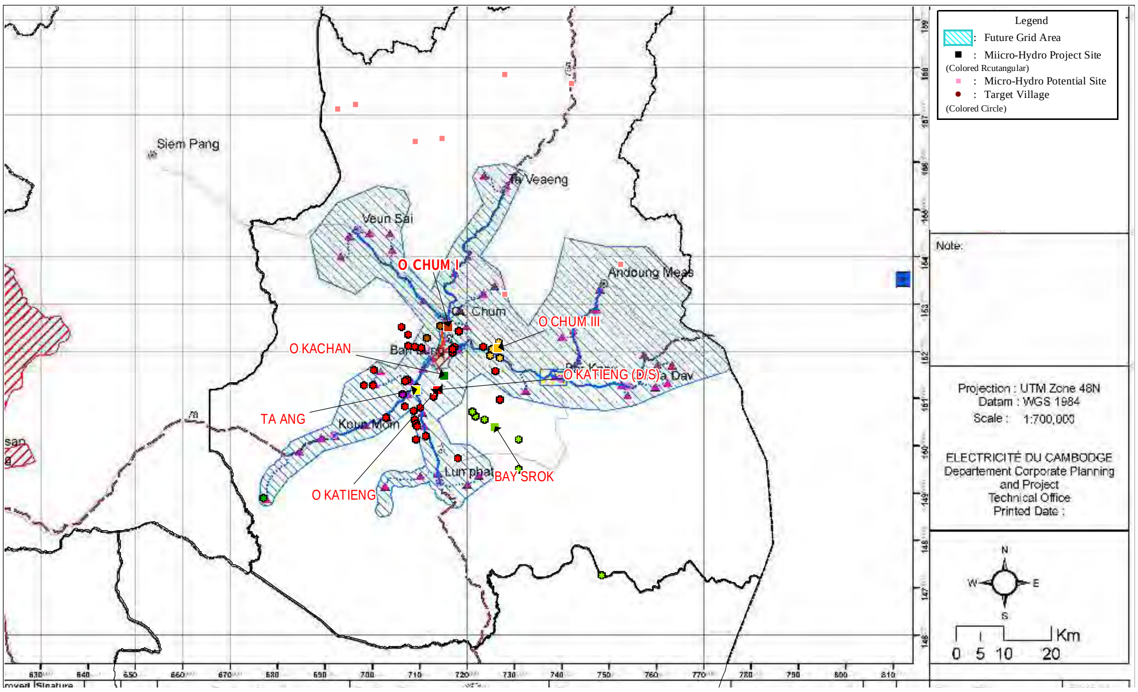


Figure 3-22 Target Villages and Grid Extension Plan by EDC (Ratana Kiri)

Table 3-31 Relationship between Micro Hydropower Location and Grid Area

(Mondul Kiri Province)

Legend
- (yellow hatched) Electricity is supplyed by REE as of now
- (blue hatched) Electricity grid is planned by EDC
- (grey) Electricity grid is not planned as of now

No.	Province	Scheme	River	MHP 2006 JICA					JICA 2011		SREP 2011				
				ID No. by Seila	Commune	Village name	Nos. of HHs	Nos. of HHs to be Electrified	Nos. of Houses	Nos. of Hs to be Electrified	ID No. by Seila	Village	Village name if change *use CDB ID	Nos. of Houses	Nos. of Hs to be Electrified
5	Mondul Kiri	Prek So Long Lower	Prek So Long			# Srelovi etc.	286	229	347	299					
				11010403	Srae Khtum	Srelovi			28	28					
				11010404	Srae Khtum	Sreampil			40	36					
				11010407	Srae Khtum	Srae Khtum			88	80					
				11010502	Srae Preah	Pu Char			49	49					
				11010505	Srae Preah	Srae Preah			142	106					
6	Mondul Kiri	Prek Te	Prek Te			# Chorkcha etc.	1101	881	894	734		# Pongol etc.		763	603
				11010302	Srae Chhuk	Chorkcha			131	131					
				11010201	Me Mang	Pongol			61	61	11010201	Pongol		61	61
				11010202	Me Mang	Pognov			29	29	11010202	Pognov		29	29
				11010203	Me Mang	Pocha			31	31	11010203	Pocha		31	31
				11010204	Me Mang	Pokes			56	56	11010204	Pokes		56	56
				11010205	Me Mang	Tourl			128	107	11010205	Tourl		128	107
				11010101	Chong Phlah	Potung			293	164	11010101	Potung		293	164
				11010102	Chong Phlah	Pohourn			103	93	11010102	Pohourn		103	93
				11010103	Chong Phlah	Kheng			62	62	11010103	Kheng		62	62
10	Mondul Kiri	O Long Mang	O Long Mang			* Ph Pu Cheng etc. but access difficult. 13km over mountains						# Pu Antraeng etc.		173	153
											11030101	Pu Antraeng		99	85
											11030102	Pu lao		74	68
12	Mondul Kiri	O Moleng	O Moleng	11050101	Monourom	* Already developed			* Already developed						
13	Mondul Kiri	O Romis	O Romis	11050102	Monourom	* Already developed	1434	1147	* Already developed						
14	Mondul Kiri	Prek Dak Deurr	Prek Dak Deurr	11050201	Sokh Dom	Mean Leaph									
15	Mondul Kiri	Prek Dak Deurr D/S	Prek Dak Deurr			# Daoh Kramom etc.	1434	1147	1340	457		# Chrey Saen etc.		341	198
				11050202	Sokh Dom	Daoh Kramom			152	33	11050102	Chrey Saen		152	33
				11050203	Sokh Dom	Svay Chek			87	37					
				11050204	Sokh Dom	Lao ka			9	0	11050204	Lao ka		9	0
				11050301	Spean Mean Chey	Ou Spean			124	0					
				11050302	Spean Mean Chey	Chambak			154	5					
				11050303	Spean Mean Chey	Kandal			294	0					
				11050304	Spean Mean Chey	Chamkar Tae			131	8					
				11050401	Romonea	Pu Trom *			139	124	11050401	Pu Trom		139	124
				11050402	Romonea	Pu Tang			41	41	11050402	Pu Tang		41	41
				11050403	Romonea	Pu Long *			128	128					
				11050404	Romonea	Srae I *			81	81					
36	Mondul Kiri	Prek Dak Deur (MIME List)	Prek Dak Deurr												
16	Mondul Kiri	Bu Sra	Prek Por			# Phum Lekh Muoy etc.	899	719	1061	720		# Pu Tit etc.		720	404
				11040401	Bu Sra	Phum Lekh Muoy			122	107	11040401	Phum Lekh Muoy	Pu Tit	122	107
				11040402	Bu Sra	Phum Lekh Pir			89	42	11040402	Phum Lekh Pir	Pu Rang	89	42
				11040403	Bu Sra	Phum Lekh Bei			107	74	11040403	Phum Lekh Bei	Bu Sra	107	74
				11040404	Bu Sra	Phum Lekh Buon			81	70					
				11040405	Bu Sra	Phum Lekh Pram			121	11	11040405	Phum Lekh Pram	Lam Mes	121	11
				11040406	Bu Sra	Phum Lekh Prammuoy			97	71	11040406	Phum Lekh Prammuoy	Pu Cha	97	71
				11040407	Bu Sra	Phum Lekh Prampir			184	99	11040407	Phum Lekh Prampir	Pu Lu	184	99
				11040301	Srae Ampum	Phum Lekh Muoy			66	52					
				11040302	Srae Ampum	Phum Lekh Pir			114	114					
				11040303	Srae Ampum	Phum Lekh Bei			80	80					
37	Mondul Kiri	O Phlai (JICA)										# Phum Krorng Kes etc.		553	513
											11040101	Phum Krorng Kes		104	104
											11040103	Phum Tram Kach		45	38
											11040104	Phum lou Rapet		63	55
											11040301	Phum Lekh Muoy	Pu Kroch	66	52
											11040302	Phum Lekh Pir	Pu Radeth	114	114
											11040303	Phum Lekh Bei	Pu Kreng	80	80
											11040404	Phum Lekh Buon	Pu Til	81	70
39	Mondul Kiri	O Yong Ngol										# Pu Hiem etc.		372	332
											11030201	Pu Hiem		281	241
											11030204	Pu rang		91	91

(Ratana Kiri Province)

Legend
- Electricity is supplyed by REE as of now
- Electricity grid is planned by EDC
- Electricity grid is not planned as of now

No.	Province	Scheme	River	MHP 2006 JICA: ID No. by Seila	MHP 2006 JICA: Commune	MHP 2006 JICA: Village name	MHP 2006 JICA: Nos. of HHs	MHP 2006 JICA: Nos. of HHs to be Electrified	JICA 2011: Nos. of Houses	JICA 2011: Nos. of Hs to be Electrified	SREP 2011: ID No. by Seila	SREP 2011: Village	SREP 2011: Village name if change *use CDB ID	SREP 2011: Nos. of Houses	SREP 2011: Nos. of Hs to be Electrified
21	Ratanak Kiri	O Kachan	O Kachan	16040202	Srae Angkrong	Phum Pir	98	78	108	30					
22	Ratanak Kiri	O Katieng	O Katieng			# Ka Tieng etc.	295	236	321	307					
				16050303	La Bang Muoy	Ka Tieng			91	91					
				16050304	La Bang Muoy	Ka Lang			43	43					
				16050301	La Bang Muoy	Kam Phlenh			100	96					
				16050401	La Bang Pir	Ka Tieng			87	77					
23	Ratanak Kiri	O Katieng (D/S)	O Katieng									# Lon etc.		3122	2991
											16020301	Lon		110	110
											16020302	Phnum		42	42
											16020303	Sil		51	36
											16030403	Pa Yang		74	61
											16030602	Kab		71	66
											16040301	Ta Ang Ka Tae		155	152
											16040302	Ta Ang Pok		138	138
											16040303	Tus		121	105
											16040304	Sek		116	116
											16040305	Ta Kab		133	133
											16040401	Teun		244	231
											16040402	La En		149	145
											16040403	Ta Heuy		79	69
											16040404	Kam Bak		66	61
											16050301	Kam Phlenh		100	96
											16050302	Ka Tueng		50	48
											16050303	Ka Tieng		91	91
											16050304	Ka Lang		43	43
											16050401	Ka Tieng		87	77
											16050402	Ka Chanh		110	93
											16050502	Pruok		158	158
											16050503	Pa Tang		105	102
											16050504	Chang Rea		154	154
											16060101	Char Ung Ket		67	67
											16060102	Char Ung Chan		125	125
											16060103	Phlay Ampil		168	168
											16060104	Thuoy Tum		71	69
											16060105	Char Ung Kao		117	117
											16060301	Pa or		75	75
											16060504	L'eun Kreaeng		52	43
24	Ratanak Kiri	Ta Ang	O Cheng	16040304	Ta Ang	Sek	98	78	116	116					
29	Ratanak Kiri	O Chum I	O Chum			# Ou Chum etc.	278		330	322					
				16060501	Ou Chum	Ou Chum			129	127					
				16060502	Ou Chum	Tharang Chong			106	100					
				16060503	Ou Chum	Svay			95	95					
40	Ratanak Kiri	O Chum III	O Chum									# Tuy etc.		530	492
											16030601	Tuy		145	125
											16030604	Pa Nal		36	33
											16060302	Pa Chon Thum		247	232
											16060304	Krouch		102	102
30	Ratanak Kiri	Bay Srok	O Sien Ler (O Paling Thom)			# Bay Srok etc.	560	448	0	0		# Thmei etc.		459	429
				16050204	Ka Laeng	Bay Srok			-	-					
				16050205	Ka Laeng	New Ka Laeng			-	-					
				16050206	Ka Laeng	New Sayos			-	-					
											16050601	Thmei		172	149
											16050606	Nang Hai		160	160
											16050607	Sakmotr Kraom		127	120

As can be clearly seen from Figure 3-21 and Figure 3-22,, the micro hydropower development sites are divided into three types; ① sites included in the scope of EDC grid expansion, ② sites that are partially included, and ③ sites located outside of the scope of expansion.

Moreover, according to the EDC, expected power sources following grid expansion in Mondul Kiri Province and Ratana Kiri Province are as follows.

Mondul Kiri Province

The importation of electric power via the 22kV transmission line running from Vietnam to Mondul Kiri was scheduled to begin in January 2012. Given the agreement between EDC and Vietnamese side, it can be assumed that the capacity will be approximately 3MW. Bearing in mind that peak demand in the Sen Monorom grid is around 0.5MW, it would appear that the supply capacity should be ample to meet demand even after the grid is expanded.

Ratana Kiri Province

There is high potential for power supply from outside the province. Possible options are as follows: A. Importing electric power from Vietnam (via the 230kV transmission line from Vietnam to Stung Treng); B. Importing electric power from Laos (via the 230kV transmission line from Laos through Stung Treng to Phnom Penh); C. Obtaining electric power from the Se San hydroelectric power facility (from Se San hydroelectric power plant to Stung Treng). Regardless of which option is chosen, the installation of transmission lines and transformer substations between Stung Treng and Banlung will be necessary.

In consideration of the above points, concerning development in Ratana Kiri Province, in the case of micro hydropower development of the villages indicated in ①, this can be expected to enhance the feasibility of the grid expansion plans being vigorously advanced by the Government of Cambodia based on the advance construction of distribution lines in the scope of expansion. In the case of the type ③ development, this can be expected to electrify villages where there are no plans for electrification. Concerning type ②, this can be expected to simultaneously fill both the roles of ① and ③. Concerning Mondul Kiri Province, doubts possibly exist over the need for micro hydropower development concerning types ① and ②, and it is thought that only sites that serve the function of type ③ away from the Sen Monorom grid can make a major contribution to rural electrification.

(d) Check of scale
Here, it is roughly checked to determine whether or not micro hydropower output is appropriate to the demand for rural electrification. Concerning the amount of power consumption per household, in MP2006, 100 W/family is adopted as a mean value taken from the range of 30 to 200 W/family that is used for considering rural electrification. Meanwhile, in SREP2011, the value of 200 W/household is adopted upon referring to the EDB basis for calculation. On referring to the operating performance in the Mondul Kiri rural electrification project, the peak demand per contract was around 300 W in the first year but the latest value in the third year is approximately 450 W. In the Study, since only a rough check is conducted, based on the assumption that the terms family, household and contract refer to the same thing, a figure of 200 W/household is adopted in the Study. Table 3-32 shows the results of examination.

Table 3-32 Evaluation Capacity of Micro HP to Estimated Demand

No.	Project Name	Households to be electrified* (Nos.)	Estimated Maximum Demand** (kW)	Maxmum Power of MHP* (kW)	Evaluation
	(Mondul Kiri Province)				
5	Prek So Long Lower	347	69	42	× Too Short
6	Prek Te	894	179	494	O Enogh
10	O Long Mang	173	35	123	O Enogh
14	Prek Dak Deurr	---	---	202	---
15	Prek Dak Deurr D/S	1,340	268	125	× Too Short
36	Prek Dak Deur (MIME List)	---	---	112	---
16	Bu Sra	1,061	212	80	× Too Short
17	O Phlai (JICA)	553	111	91	Δ A Little Shorter
39	O Yong Ngol	372	74	68	Δ A Little Shorter
	(Ratanak Kiri Province)				
21	O Kachan	108	22	220	O Enogh
22	O Katieng	321	64	330	O Enogh
23	O Katieng (D/S)	3,122	624	1,076	O Enogh
24	Ta Ang	116	23	12	× Too Short
29	O Chum I	330	66	93	O Enogh
40	O Chum III	530	106	74	× Too Short
30	Bay Srok	459	92	130	O Enogh

(e) Evaluation in terms of environment
According to Cambodian environmental impact assessment criteria, in cases where the hydropower plant capacity exceeds 1 MW in micro hydropower plans and 5 MW in thermal power generation (diesel and biomass) plans, an environmental impact assessment (EIA) is required. Concerning installation of distribution lines, environmental impact assessment is not

required for mini grid connections. Since all the micro hydropower projects for adoption in rural electrification proposed in this survey are less than 1 MW in size, the EIA is not required.

In Cambodia, environmental protection districts are established. In micro hydropower development projects located in such protection districts (Bu Sra site, etc.), it is first necessary to implement environmental screening. Figure 3-23 shows the relationship between micro hydropower sites and environmental protection districts. Looking at these results, it can be seen that almost all the sites in Mondul Kiri Province are located inside environmental protection districts, however, the sites in Ratana Kiri are not located in environmental protection districts.

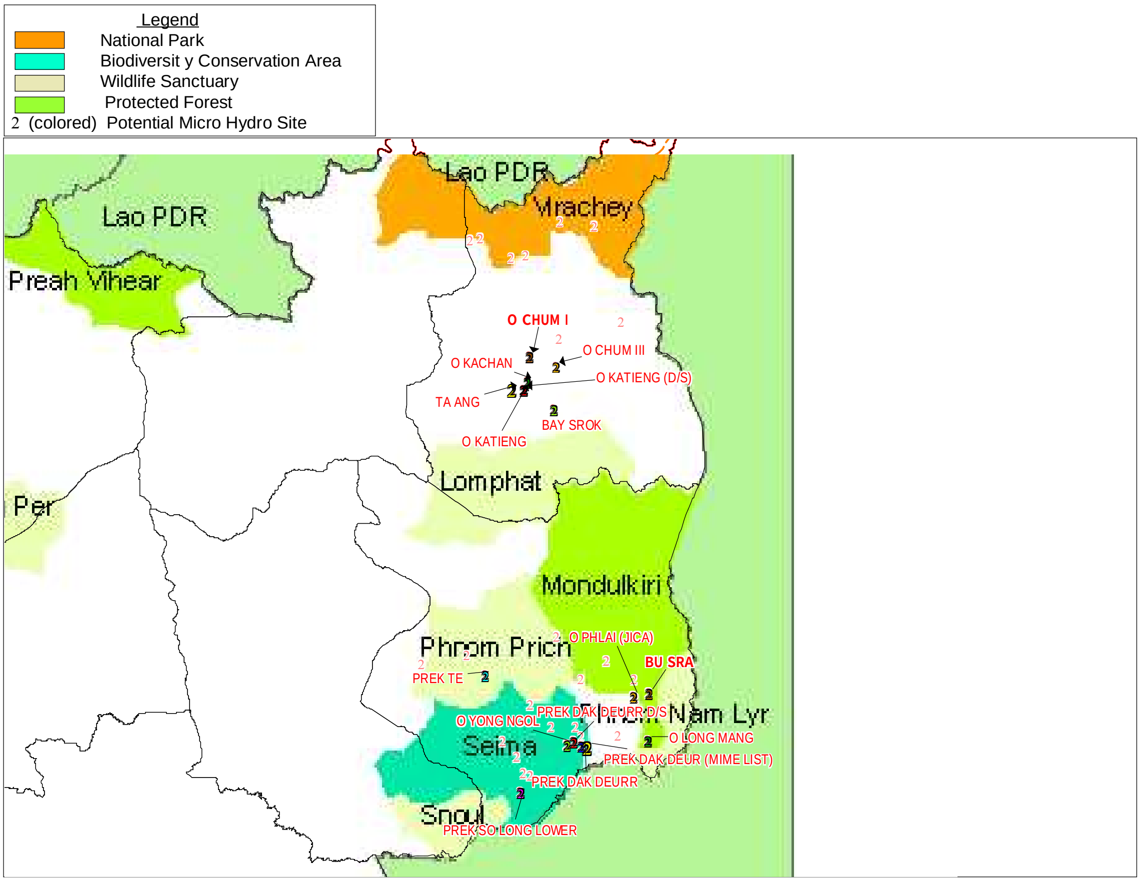


Figure 3-23 Protected Area in Mondul Kiri and Ratana Kiri

(f) Promising sites

Since hydropower plants represent a purely domestic natural form of energy, even if an independent mini grid based on micro hydropower is connected with the NGD, it is generally hard to imagine that micro hydropower (a renewable energy) will be stopped. In particular, for a country such as Cambodia that is deficient in energy resources, from the viewpoint of energy security, there is hardly any chance of that happening.

Both MIME and EDC discount the possibility of this happening. In the Mondul Kiri grid, in which distribution lines have recently been connected with the Vietnamese system, considering that the micro hydropower plants at O'Moleng and O'Romis are continuing to operate, there is very little likelihood that connecting the micro hydropower mini grid with the NGD will lead to the abolition of the said micro hydropower.

Moreover, as the existing grid in the northeastern provinces is extremely small, installation of micro hydropower will contribute to rural electrification through one of the two following patterns:

① Contribution to expansion of the existing EDC rural grid as new power sources, or
② Direct realization of rural electrification through installation of a new independent grid based on hydropower.

The characteristics of each type are indicated below:

① Power supply to the existing rural grid

Merits

- ✓ Energy security will be improved.
- ✓ Through developing power sources close to demand areas, power quality on the existing grid will be improved.
- ✓ Through acquiring supply capacity, incentive will be provided to promote grid expansion plans (electrification in areas around the grid).
- ✓ Since the maintenance setup is in place, it is highly likely that maintenance will be carried out appropriately.
- ✓ Access for works and maintenance is easy and there are small impediments to maintenance.

Demerits

- ✓ If the goal is only to achieve electrification, it is just as effective to increase the amount of imported power from the neighboring country or develop large-scale power sources.
- ✓ Since power can be imported from the neighboring country, development appears to be unnecessary from the viewpoint of supplying power in the short term.

② Establishment of a new mini grid

Merits

- ✓ Areas where electrification is not currently planned can be electrified.

Demerits

- ✓ The new grid often is located further away from the existing grid, and this sometimes creates issues in terms of building the maintenance organization and procuring maintenance materials.

Moreover, concerning ②, as JICA has already achieved success in the Mondul Kiri rural electrification project, there are thought to be no barriers to development in Cambodia in particular.

Table 3-33 collates the information obtained from various kinds of evaluation. Concerning the sites in Mondul Kiri Province, except for O Long Mang, as was mentioned above, since the sites are located close to the grid of the Mondul Kiri rural electrification project that was implemented by JICA and it appears that the area around development sites will be able to receive ample power supply along the transmission lines from Vietnam, the comparative effect would be minor when viewed in terms of rural electrification.

On the other hand, all the micro hydropower sites in Ratana Kiri Province have high potential for contributing to rural electrification, whether they be incorporated into existing grid expansion or are developed as new mini grids. However, when it comes to developing micro hydropower in Ratana Kiri Province, except for Bay Srok, since construction of the transmission line between Stung Treng and Banlung will be highly significant as a rural electrification project, it will be necessary to carefully monitor the progress (including existence of plans and so on).

Table 3-33 Evaluation of Micro HP Potential Sites

No.	Project Name	Benefit of Residents		Type of Contribution toRural		Environment*	Info.
		Nos. of HH	Supply ability	Grid Ext.	Mini-Grid		
	(Mondul Kiri Province)						
5	Prek So Long Lower	347	× Too Short	Δ		BD(Seima)	
6	Prek Te	894	O Enogh	Δ		WS (Phnom Prich)	
10	O Long Mang	173	O Enogh		O	F (Mondul Kiri)	
14	Prek Dak Deurr	---	---	Δ		BD(Seima)	
15	Prek Dak Deurr D/S	1,340	× Too Short	Δ		BD(Seima)	
36	Prek Dak Deurr (MIME)	---	---	Δ			
16	Bu Sra	1,061	× Too Short	Δ		X (Mondul Kiri) Fall	
17	O Phlai (JICA)	553	Δ A Little	Δ		X (Mondul Kiri)	
39	O Yong Ngol	372	Δ A Little	Δ			
	(Ratanak Kiri Province)						
21	O Kachan	108	O Enogh	O			EDC is trying with CLV bufget Bridge funded by ADB was installed for sightseeing
22	O Katieng	321	O Enogh	O			
23	O Katieng (D/S)	3,122	O Enogh	O			
24	Ta Ang	116	× Too Short	O			
29	O Chum I	330	O Enogh	O			
40	O Chum III	530	× Too Short	O			
30	Bay Srok	459	O Enogh		O		

(g) Summary

While the collected information presented above will require more detailed examination by means of site surveys, etc., it would appear that, as of this point in time, the site where rural electrification should be most effective is Bay Srok, which is not included within the scope of planned system expansion by 2020. This site was omitted from the potential targets in MP2006 (it also doesn't exist in the CDM2010 list) because the target village is founded on precious stone mining and it will probably fall into decline after the mining is finished. However, in SREP2011, since the villages that are included on the CDM2010 list are targeted, unlike MP2006, these are thought to be comparatively promising for rural electrification projects.

In the Mondul Kiri Province micro hydropower rural electrification project, the number of households was originally estimated as approximately 1,200, however, due to increase in the number of contracts following the start of operation, there are now more than 1,400 households. Since the number of electrified households around the Bay Srok site is around 500, a possible approach to realizing rural electrification on a similar scale would be to simultaneously develop multiple micro hydropower sites in the same way as in the Mondul Kiri Province micro hydropower rural electrification project. Since the other sites in Ratana Kiri Province are not very far from the Bay Srok site, it should be possible to enhance the rural electrification effect through combining with one of the other sites. However, further investigation will be required to select the site. Currently, if integrated development is sought with the O'Chum Hydropower Redevelopment Project that was requested as a grant aid undertaking by the Cambodian side in 2010 (see Figure 3-24 , this development entails combining rehabilitation of the O'Chum II hydropower plant currently operated by EDC with the new development at O'Chum I, and examination of optimum redevelopment including O'Chum I is included), a synergistic effect can be expected and the most rational and effective form of rural electrification for the Cambodian side can be realized.

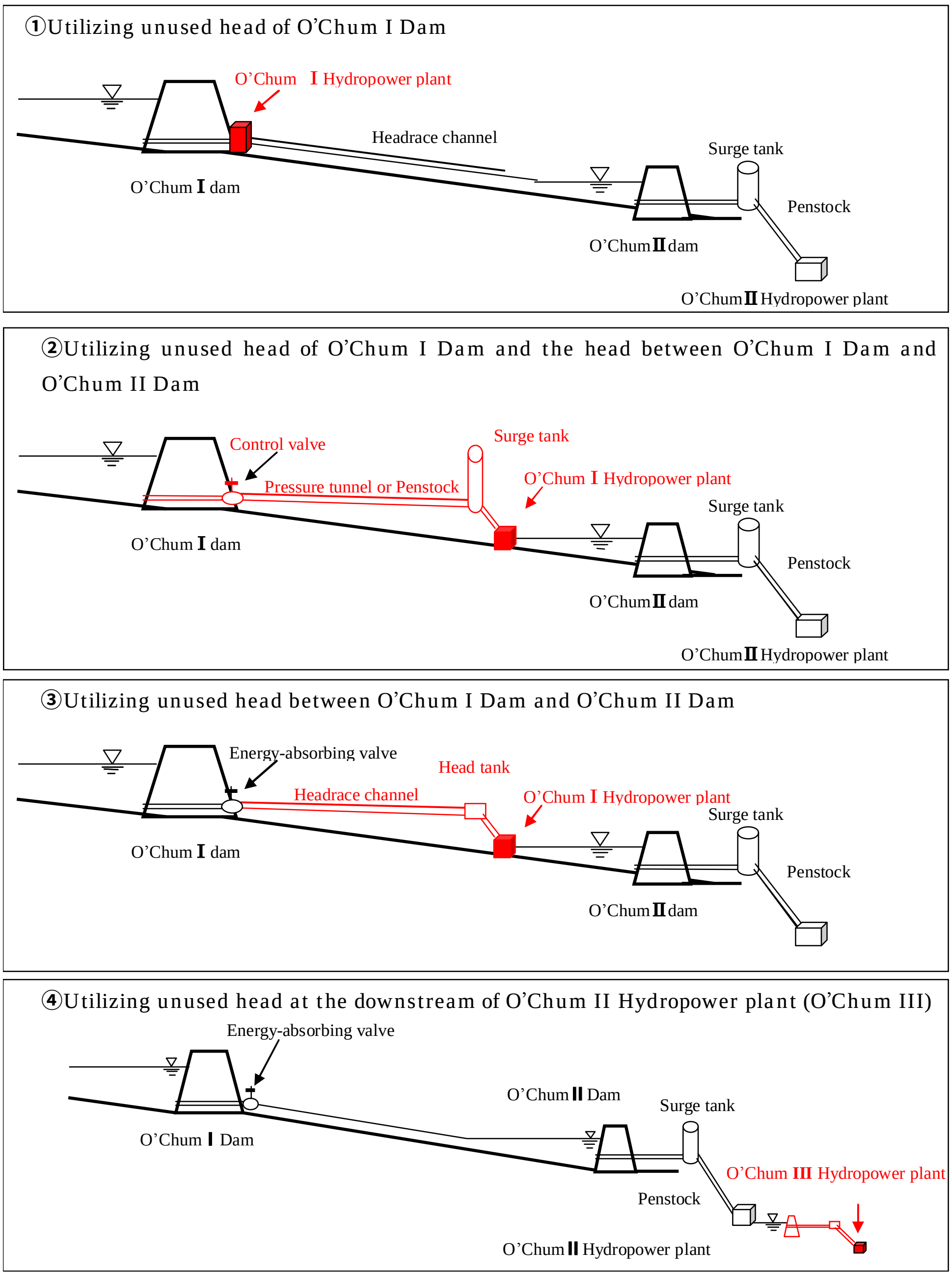


Figure 3-24 Rehabilitation Plans of O'Chum Site

3.4.2 Hydropower Potential Utilizing Irrigation Channels

In order to grasp the possibility of the small hydropower on the irrigation system, potential sites in the area of the West Tonle Sap Lake and near Phnom Penh are investigated. The target sites were selected based mainly on the information collected in advance and information from the Kandal Province Irrigation Facilities and Kandal Stueng Irrigation Facilities projects implemented under Japanese assistance (both in the Phnom Penh area) and the Tonle Sap Western Basin Irrigation Facilities Rehabilitation Project currently being implemented as well as information garnered through interviews with REF and MOWRAM. Field surveys were also conducted to confirm new sites on the ground.

(1) Results of advance site information collection

Based on the information provided by REF and MOWRAM, information was collected on unexploited water head differences that could become potential sites in irrigation facilities to the west of Tonle Sap Lake and in the area around Phnom Penh. Table 3-34 shows the collected information.

Table 3-34 Unexploited Head in Irrigation System near Phnom Penh and in the West of Tonle Sap Lake

No.	Project Name	Source	Province	Irrigation	Category
1	Koun Sat	1)	Kampot		Out of study
2	Bos S'am	REF interview	Pilin		West of Tonle Sap Lake
3	Kamping Puoi	1)	Battambang		West of Tonle Sap Lake
4	Moung Russei weir	3)	Battambang		West of Tonle Sap Lake
5	Ream Kon gate	3)	Battambang	Ream Kon	West of Tonle Sap Lake
6	Por gate	3)	Battambang	Por	West of Tonle Sap Lake
7	Basak Resevoir	4)	Battambang		West of Tonle Sap Lake
8	Basak	1)	Battambang		West of Tonle Sap Lake
9	Bovel	MOWRAM interview	Battambang		West of Tonle Sap Lake
10	Kong Hot	MOWRAM interview	Battambang		West of Tonle Sap Lake
11	Stung Koe	MOWRAM interview	Battambang		West of Tonle Sap Lake
12	Wat Tre irrigation weir	3)	Pursat		West of Tonle Sap Lake
13	Damnak Ampil dam	3)	Pursat		West of Tonle Sap Lake
14	Presak Chik	1)	Pursat		West of Tonle Sap Lake
15	Bamnak	1)	Pursat		West of Tonle Sap Lake
16	Steung Moung No.1	1)	Pursat		West of Tonle Sap Lake
17	Steueng Boribour	1)	Unknown		West of Tonle Sap Lake
18	Lum Hach Weir	3)	Kampong Chnnang	Lum Hach	West of Tonle Sap Lake
19	Lpeak	1)	Kampong Cham		West of Tonle Sap Lake
20	Prek Pol Gate	1)	Kandal		Near Phunom Penh
21	Prek Yourn Gate	1)	Kandal		Near Phunom Penh
22	Prek Chrey Gate	1)	Kandal		Near Phunom Penh
23	Koki Thom	1)	Kandal		Near Phunom Penh
24	Samrong Thom	1)	Kandal		Near Phunom Penh
25	Prek Kampong Phnom	1)	Kandal		Near Phunom Penh
26	7th January Weir	1)	Kandal		Near Phunom Penh
27	Tuk Thla Regulating	1)	Kandal		Near Phunom Penh
28	Deum Russ Regulator	1)	Kandal		Near Phunom Penh
29	Roleng Chery Gate	MOWRAM interview	Kampong Spue		Near Phunom Penh
30	Stung Chinit	MOWRAM interview	Kampong Tom		Near Phunom Penh
31	Stung Tas Sal 25-2	MOWRAM interview	Kandal		Near Phunom Penh
32	Batheay Irrigation 25-1	4)			Near Phunom Penh
33	Tamouk Reservoir 34-3	4)			Near Phunom Penh

Source: 1) Basic Survey to Support and Establishment of a New Master Plan on Renewable Energy Utilization in Kingdom of Cambodia, NEDO, 2005
2) Rehabilitation of the Kandal Stung Irrigation System in the Lower Prek Thnot Basin, JICA, 2004
3) The Basic Design Study on the Project for the Improvement of the Facilities of the Colmatage Systems in Kandal Province along the Mekong River, JICA, 1998
4) Irrigation Development in Cambodia, Status as of March 2011, MORAM (Supported by JICA), 2011

(2) Potential sites

Out of 33 potential sites, field confirmation was carried out at 10 sites whose positions could be identified. Table 3-35 shows the summary of the field survey results, while Appendix 2 shows the detailed survey forms for each site. In Table 3-35, the peak output provisionally calculated on the assumption of operation even in the dry season is indicated. There are 20 survey locations (total maximum output 390 kW), and the maximum output is more than 10 kW at eight of these sites (13 - 180 kW).

The main features of the survey sites are as follows:

- ✓ The survey sites are located at dam sites or on irrigation channels.

- ✓ Since the survey was conducted at the start of the dry season, reservoir water levels were high and the flow rate inside channels was small.
- ✓ Since there is possibility that the flow rate in the dry season will be very small, it is necessary to implement detailed investigation of flow rate in order to confirm potential.
- ✓ Since areas around the surveyed sites have not been electrified, development of the sites will contribute to promoting electrification.

Figure 3-25 shows the chart for selecting water turbine generators that can be used when examining the candidate sites. In this, ⑤ and ⑥ are unique to Japan. Figure 3-26 shows actual examples of the type ⑤ water turbine and unique Japanese turbines not stated in the selection chart. Any of these examples can be adopted at the sites that were surveyed.

Table 3-35 Micro Hydropower Station Development Confirmed by Site Survey

No.	Name	Condition / Donnor etc.	Province	Region	Info source *0	Dimension CA	Q	He	P	Survey result Location X	Y	Survey date
						km²	m³/s	m	kW	X	Y	
1	Wat Tre irrigation weir	Weir Broken	Pursat	West Tonle Sap	JICA Survey 2009		0.03 *1	1.8 *a	0.4	362433	1397105	Nov-2011
2	Moung Russei head works	Broken	Battambang		JICA Survey 2009		0.03 *1	3.5	0.0	332800	1413160	Nov-2011
3	Ream Kon irrigation gate	Broken	Battambang		JICA Survey 2009		2.86 *2	1.5	30.0	332700	1414155	Nov-2011
4	Po Intake	Broken	Battambang		JICA Survey 2009		2.74 *2	2.7	58.0	332019	1412909	Nov-2011
5	Damnak Anpil Weir	Usable MOWRAM 2006	Pursat		JICA Survey 2009 / MOWRAM 2011	4,480 *0	5.60 *2	4.0	180.0	370423	1380719	Nov-2011
6	Wat Loung Weir	-	Kampong Chhnang		JICA Survey 2009				-	-	-	-
7	Bos S'am Irrigation Weir	Usable New weir	Pailin		REF 2011		2.03 *1	2.5	39.8	239846	1434394	Nov-2011
8	Kamping Puoy Dam	Usable Gate old	Battambang		NEDO		0.37 *1	4.5	13.1	281093	1446241	Nov-2011
9	Basak reservir 27-1	Usable JPN 2010	Battambang		NEDO / MOWRAM 2011	598 *0	0.77 *2	5.9	35.6	318080	1389957	Nov-2011
10	Moung Russei irrigation gate 1	Usable	Battambang		New		0.03	0.8	0.2	334558	1396349	Nov-2011
11	Moung Russei irrigation gate 2	Usable	Battambang		New		0.03	0.9	0.2	331379	1396984	Nov-2011
12	Moung Russei irrigation gate 3	Usable	Battambang		New		0.03	1.8	0.4	328453	1397589	Nov-2011
13	Moung Russei irrigation gate 4-1	Usable	Battambang		New		0.00	0.0	0.0	325383	1398377	Nov-2011
14	Moung Russei irrigation gate 4-2	Usable	Battambang		New		0.73	2.9	16.6	325458	1398375	Nov-2011
15	Moung Russei irrigation gate 4-3	Usable	Battambang		New		0.03	0.9	0.2	325475	1398181	Nov-2011
16	Moung Russei irrigation gate 4-4	Gate removed	Battambang		New		0.03	0.1	0.0	325399	1398222	Nov-2011
17	Moung Russei irrigation gate 5	Usable	Battambang		New		4.00	0.5	15.7	324988	1398218	Nov-2011
18	Kandaɾ Stung 34-1 - 7th January	Usable JPN 2007	Kanral	Near Phnm Penh	JICA2004		-	7.0	-	377287	1411675	Jan-2012
19	Kandaɾ Stung 34-1 -Tuk Thla	Usable JPN 2007	Kanral		JICA2004		-	6.0	-	377295	1412012	Jan-2012
20	Kandaɾ Stung 34-1 - Deum Russ Regulator	Usable JPN 2007	Kanral		JICA2004		-	2.0	-	377253	1411289	Jan-2012
21	Kandaɾ Stung 34-1 - 7th January	Usable JPN 2007	Kanral		JICA2004		-	0.0	-	377271	1411365	Jan-2012
	--Potential Sites--											
22	Batheay Irrigation 25-1	KR 2010			MOWRAM 2011							
23	Stung Tas Sal 25-2	IND Under porep.	Kampang Spue		MOWRAM 2011	495 *0	9.00 *3	13.6	750.0	398271	1289862	-
24	Tamouk Reservoir 34-3	KR 2004			MOWRAM 2011							
	Total				Total				1,140.2			

*0 JICA Survey 2009: Master Plan of Rehabilitation of Irrigation and Drainage System, JICA, 2009
JICA 2004:Rehabilitation of the Kandal Stung Irrigation System in the Lower Prek Thnot Basin, JICA, 2004
REF 2011: Interview with REF, November 2011
NEDO: Renewable Energy Master Plan Study, 2004
MOWRAM 2011: Interview with MOWRAM, November and December 2011
New: Found during the site survey
*1 River flow rate estimated in the site survey of the JICA Team in December x (100% / 30%) from November 2011 to January 2012.
*2 Maximum Design flow of irrigation canal shown in existing report.
*3 Design Engineering Report STUNG TASCAL DAM PROJECT,WAPCOS,2008

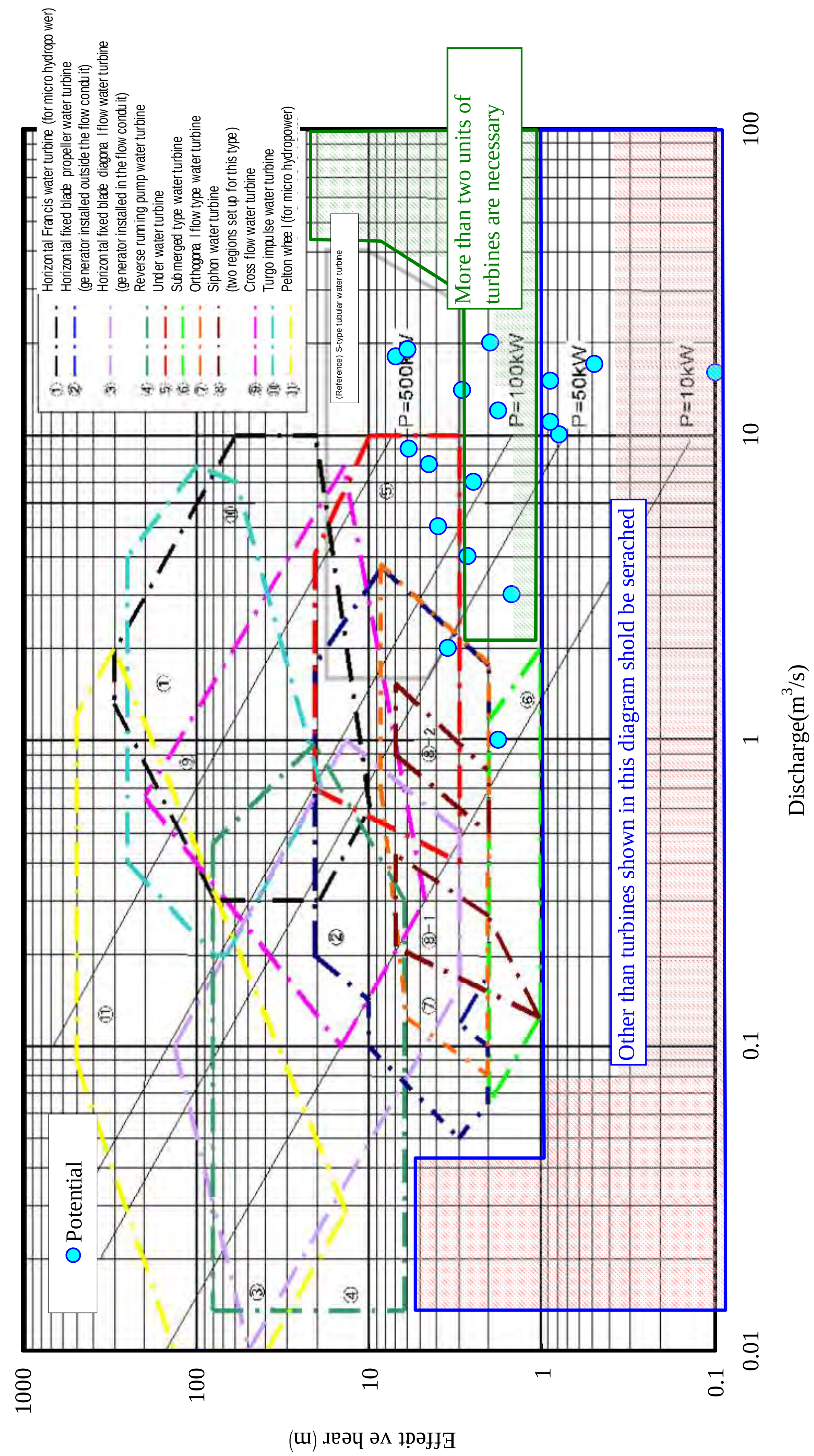
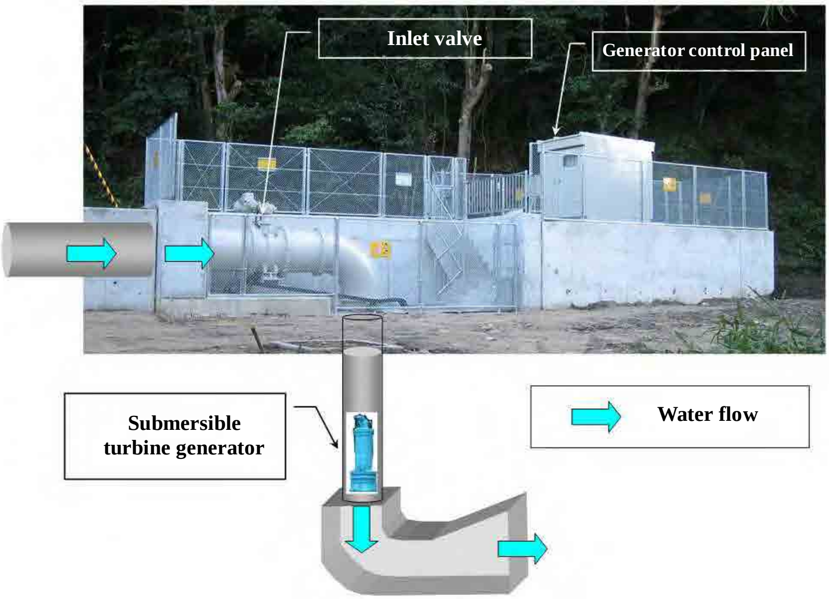


Figure 3-25 Selection Sheet of Water Turbine

Ring turbine
(Tsuyama Municipal Water Department unit)

Pump reverse running turbine
(Kawasaki Plant Systems experimental)



Submersible Turbine (Chugoku EPCO)
Figure 3-26 Examples of Unique Micro Hydropower Generators in Japan

(3) Development candidates

In cases of hydropower projects utilizing agricultural channels, either the electric power sector or the agricultural sector can act as the development management. Since agricultural channels are important infrastructure for supporting the daily lives of people in rural areas, in cases where irrigation is managed by special groups or communities, such groups and communities can also become operation and maintenance entities.

Table 3-36 shows possible operating entities for hydropower projects on existing agricultural channels, obtained as a result of interviews with MIME and MOWRAM, etc.

Table 3-36 Main Groups operating Hydropower in Irrigation Systems

Name	Explanation
Electricité Du Cambodge (EDC)	A wholly state-owned limited liability company to generate, transmit and distribute electric power though-out Cambodia. EDC is a juridical organization with administrative, financial and managerial authority. EDC is responsible for its profit and losses and liable for its debts to the extent of the value of its assets.
Rural Electricity Enterprise (REE)	REE is a private group and supplies rural villages with basic electricity services.
Farmer Water Users Committee (FWUC)	FWUC manages the using water in irrigation systems and to operate and maintain the irrigation systems. Water users in the irrigation system are obligated to pay Irrigation Service Fee (ISF).
Private company	It means IPP

Moreover, the following information was obtained via preliminary survey, field survey and interviews.

- ✓ An agreement was signed in 2000 between MIME and irrigation-related agencies concerning the division of supervision duties in dam development;
  a) Dam development with the goal of independent power development: MIME
  b) Development of multipurpose dams: MOWRAM
  However, MOWRAM so far possesses no experience of conducting hydropower development. The previously mentioned two micro hydropower projects financed by a loan from South Korea were the first of their kind for MOWRAM.
- ✓ Since the locations where field survey was conducted are only separated from the existing grid by no more than around 20 kilometers, REE is likely to consider it more attractive to make connections and distribution from the grid, which entails less initial investment than hydropower development.

Bearing in mind all the above points, the development candidate sites will be as follows:

1) The most feasible sites at present are the three micro hydropower locations operated by the EDC.
2) Farmer Water Users Committee (FWUC) can also be a hydropower development and operation entity as a REE. Depending on how the two sites developed under the Korean loan are operated by FWUC and how the operating results turn out, it will become clear whether or not FWUC can function as the development and operating entity for hydropower plants using agricultural water channels.

3.4.3 Problems to Realize Micro Hydropower Development in Cambodia

(1) Rural Electrification based on Exploitation of Renewable Energy (Micro Hydropower)

In November 2011, the concrete strategy and plan concerning rural electrification (SPDRE) was compiled as a Ministry of Mining and Energy ordinance (PRAKAS). The basic examination for this (SREP2011) included proposals for the specific sites and schedule of micro hydropower rural electrification. However, the SPDRE does not specify the specific order and method of development for micro hydropower site plans. Moreover, since the SPDRE has only just gone into effect, MIME, which is the implementing entity for micro hydropower rural electrification, is unable to propose a concrete order of priority for development.

① First of all, the Cambodian side needs to sort out the specific order of priority with which it will carry out micro hydropower development.

② In light of this plan, it is necessary to once more conduct detailed examination of the concrete sites.

In the Study, as a result of collecting information on the latest conditions surrounding rural electrification after MP2006 and the latest village data and conducting examination assuming the current conditions and expansion plans of the grid, it was deemed that the micro hydropower sites in

Ratana Kiri Province can have a high rural electrification effect. Moreover, the Bay Srok site, which is proposed for mini grid development in SREP2011, received the best evaluation. However, other sites also have ample potential for contributing to rural electrification through grid expansion and it is still possible that these sites could be even more effective as mini grid locations depending on the level of actualization of the grid expansion plans. At the present time, depending on the results of further detailed evaluation from the aspects of implementation appropriateness and level of contribution concerning the development of multiple sites around Banlung including Bar Srom, it may become necessary to shuffle around the candidate sites. Specifically, the survey items requiring survey in the future are as follows.

① Survey concerning compatibility between micro hydropower development plans and this development plan based on the SPDRE
② Reconsolidation of status consistent with the level of realization of EDC grid expansion plans
③ Identification of areas targeted for electrification and survey of social and economic conditions
④ Detailed survey concerning power supply and demand in areas targeted for electrification
⑤ Formulation of power generating plans and electrification plans in consideration of the level of development of related infrastructure and hydrological data
⑥ Survey of awareness of residents regarding electrification and setting of electricity tariff plans based on this
⑦ Discussions with MIME, REF and EDC concerning the Project operation and maintenance setup and methods
⑧ Survey of impacts on the natural and social environment
⑨ Outline cost estimation of the Project and target works

(2) Hydropower Potential utilizing Agricultural Channels

Agricultural sector development is a major policy issue for Cambodia; as such, the ongoing implementation of irrigation projects over the past few years can be expected to continue into the future. While irrigation projects often involve the construction of dams, many of these dams are located in areas distant from the grid. Micro hydropower facilities attached to dams and agricultural irrigation channels can serve as sources of power for dam water level control gates, etc. (currently, diesel generators or manual operation are being used for this purpose); however, at present, there are only two micro hydropower facilities of this type in Cambodia, both of which are still under construction. In order to achieve multi-purpose development, where electricity generation is given the same level of importance as flood control and agricultural irrigation management, the results obtained in the operation of these two sites will need to be used as the basis for developing more complex adjustment of irrigation facilities.

Given that the establishment of hydropower facilities on agricultural irrigation channels can permit the sharing of facilities to achieve a variety of different goals, careful coordination is required not only at the level of the authorities which will play the main role in developing these facilities, but also at the national level, with respect to the laws, regulations and standards etc. relating to matters such as the priority order for irrigation facility utilization, the allocation of dam development costs, etc.

(3) The Framework for Management of Micro Hydropower Plants

Toeuk Char Hydropower Station in Kampong Cham Province was established as a NEDO demonstration research facility in 2004. Although this was originally intended as a photovoltaic, etc. dispersed system demonstration research facility (photovoltaic + small hydropower), it actually became Cambodia's first small hydropower rural electrification project on an irrigation channel. However, it fell into a state of disuse soon after coming into operation in 2005.
The Cambodian side has reported the following as the primary reasons for the suspension of operation.

① Failure of battery charge and discharge unit
(Master side: 2005/5/28, slave side: 2005/10/6 failure occurrence)
② Drop in storage battery voltage due to failure of the battery charge and discharge unit
(Because the control power supply was rendered useless, operation of the micro hydropower plant is impossible)
③ Inability to pay wages to operators (from December 2005 onwards)
④ Dissatisfaction among consumers about hikes in the electricity tariff (October 1, 2005), resulting in refusal to pay tariffs

Usually, when disputes arise over electricity tariffs as in ④, the EAC acts to mediate, however, resolution couldn't be realized at this time because the local management board, which is elected to operate the utility from consumer representatives based on the public participation project management approach, had not obtained the necessary license from the EAC.
Meanwhile, in the Mondul Kiri Province micro hydropower rural electrification project that started operation in 2009, the EDC (the Electricity Unit of Mondul Kiri Province (EUMP) at the start of development) has stably supplied power to target areas for 24 hours a day. In the target areas, the number of contract households is increasing steadily and by the end of December 2011 there were 1,463 households or 140% or more of the design value that were purchasing power.

Table 3-37 Number of Electrified Households and Electrified Ratio in the Area where Electricity is Supplied by Mondul Kiri Rural Electrification Project

	Estimated value at time of Basic Design (BD)*1			Actual Performance*2			
	Total number of households	Number of electrified households	Electrification rate	Total number of households[1]	Number of electrified households	Electrification rate	Remarks
Start of power supply	1,264	448	35%	(Same as left)			At time of BD in December 2004
(Ditto)				1,560	465	30%	Survey at time of start of electrification in September 2008
1 year after power supply	1,327	928	70%	1,645	1,180	72%	End of November 2009: 1 year after power supply
2 years after power supply	1,383	996	72%	1,710	1,275	75%	End of August 2010: 1 year 10 months after power supply
3 years after power supply	1,410	1,043	74%		1,463		End of December 2011: 3 years 1 month after power supply

*1: However, Figures for before the start of power supply were confirmed by field survey.

The differences between the aforementioned project and this project are deemed to be as follows: 1) based on ample prior survey and adjustment, a structure has been established to satisfy consumer needs while the implementing agency makes appropriate profits, and 2) consideration is given to aspects ranging from human resources development in the project operator (EUMP) to the environment surrounding the Project. The actual contents of initiatives include the following:

① Appropriate tariff settings and adherence to the tariff setting policy

- ✓ Electricity tariffs are at a level that is acceptable to residents
- ✓ The tariff settings are appropriate to conditions in that country
- ✓ Appropriate budget for operation and maintenance (overhaul fund in readiness for large-scale repairs and a fund for drought countermeasures) is secured

② Human resources development
- ✓ Human resources development including the construction phase and operating period
- ✓ Building of a situation in which the Japanese experts can conduct measures over a longer term

③ Assignment of human resources for operation and maintenance
- ✓ Rather than seeking basic knowledge on electricity and the electric utility, the assignment of human resources who can seriously get to work following recruitment

④ Conformance with direction of the implementing body
- ✓ The project is in conformance with the policy direction of the implementing entity

Therefore, if appropriate operation is carried out, the following effects similar to those achieved in the Mondul Kiri Province micro hydropower rural electrification project can be anticipated in the rural electrification project:

① Improvement in the household electrification rate and stable supply of electricity
② Creation of employment opportunities
③ Economic vitalization in the target areas, in particular development of the tourism industry (in the Mondul Kiri Province micro hydropower rural electrification project, electrification via the project combined with improved access enabled by repairs to Route 76 has resulted in a rapid increase in people moving to Sen Monorom and an increase in the number of tourists, which has in turn led to an increase in the number of tourism facilities)
④ Nurturing of atmosphere in electrified villages
⑤ Human resources development (transmission and distribution engineers, and also grid engineers and hydropower engineers who are lacking in Cambodia)
⑥ Contribution to energy security
⑦ Improvement in the living standard of minorities
⑧ Mitigation of forest cutting

3.5 Electricity Tariffs

(1) Structure of electricity tariffs

The large proportion of electricity tariffs comprises generating costs including fuel expenses. Since roughly 93% of generated electricity in Cambodia in 2010 was generated from diesel or heavy oil, the power generating cost is greatly influenced by fluctuations in crude oil prices. Therefore, the EAC has introduced the Fuel Cost Adjustment (FCA) mechanism. Through using this mechanism, it becomes necessary to stage public hearings in order to revise conventional power tariffs.
Commercial, industrial and government budget consumers on the Phnom Penh system are invoiced by the EDC based on a certain tariff added to the average amount of electricity purchased from the IPP in the previous month. Table 3-38 and Figure 3-27 show movements in West Texas Intermediate (WTI) in addition to the actual performance from 2007 to 2010. Up until 2009, electricity tariffs fluctuated almost in line with the WTI, however, sensitivity to fuel price changes declined in 2010 due to an increase in the amount of cheap power purchased from Vietnam.

Table 3-38 Tariff of EDC for Phnom Penh and Kandal Province and Provincial Town of Kampong Speu for Commercial, Industrial and Government Budget Consumers and WTI from 2007 to 2010

Category of Consumers	2007											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Small	16.93	16.64	17.02	17.47	18.06	18.40	18.59	18.48	18.73	19.11	19.63	21.12
Medium	16.13	15.84	16.22	16.67	17.26	17.60	17.79	17.68	17.93	18.31	18.83	20.32
Big	15.73	15.44	15.82	16.27	16.86	17.20	17.39	17.28	17.53	17.91	18.43	19.92
MV	15.33	15.04	15.42	15.87	16.46	16.80	16.99	16.88	17.13	17.51	18.03	19.52
WTI	54.24	59.25	60.60	63.94	63.45	67.49	74.14	72.38	79.91	85.90	94.76	91.36

Category of Consumers	2008											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Small	22.06	22.10	22.03	22.50	23.38	24.58	25.97	27.32	26.60	24.77	21.69	18.09
Medium	21.26	21.30	21.23	21.70	22.58	23.78	25.17	26.52	25.80	23.97	20.89	17.29
Big	20.86	20.90	20.83	21.30	22.18	23.38	24.77	26.12	25.40	23.57	20.49	16.89
MV	20.46	20.50	20.43	20.90	21.78	22.98	24.37	25.72	25.00	23.17	20.09	16.49
WTI	92.98	95.38	105.47	112.62	125.37	133.93	133.38	116.64	103.94	76.61	57.29	41.44

Category of Consumers	2009											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Small	16.41	17.16	17.28	17.35	18.36	19.49	19.75	20.51	21.45	21.23	21.91	22.99
Medium	15.61	16.36	16.48	16.55	17.56	18.69	18.95	19.71	20.65	20.43	21.11	22.19
Big	15.21	15.96	16.08	16.15	17.16	18.29	18.55	19.31	20.25	20.03	20.71	21.79
MV	14.81	15.56	15.68	15.75	16.76	17.89	18.15	18.91	19.85	19.63	20.31	21.39
WTI	41.74	39.15	47.98	49.81	59.12	69.58	64.14	71.06	69.44	75.77	78.00	74.49

Category of Consumers	2010											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Small	22.99	20.26	20.05	19.90	20.21	19.92	19.57	19.21	19.32	19.25	19.50	19.68
Medium	22.19	19.46	19.25	19.10	19.41	19.12	18.77	18.41	18.52	18.45	18.70	18.88
Big	21.79	19.06	18.85	18.70	19.01	18.72	18.37	18.01	18.12	18.05	18.30	18.48
MV	21.39	18.66	18.45	18.30	18.61	18.32	17.97	17.61	17.72	17.65	17.90	18.08
WTI	78.36	76.42	81.26	84.47	73.74	75.35	76.35	76.60	75.29	81.90	84.23	89.15

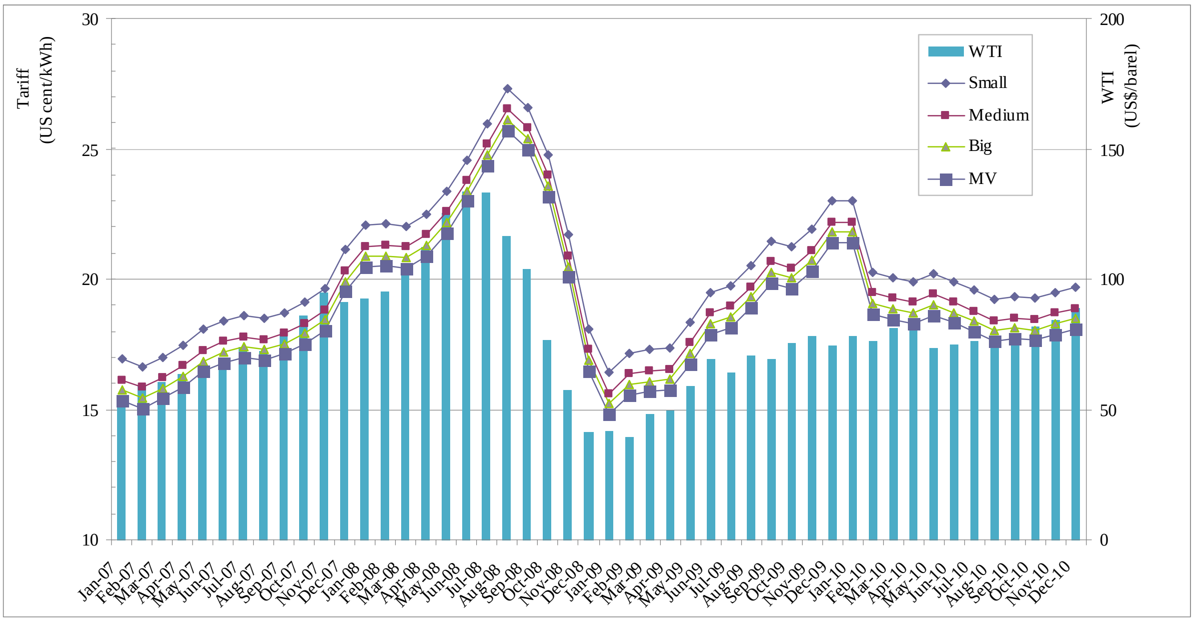


Figure 3-27 Procedure of Tariff of EDC for Phnom Penh and Kandal Province and Provincial Town of Kampong Speu for Commercial, Industrial and Government Budget Consumers and WTI from 2007 to 2010

(2) Prospective power purchase cost arising from changes in the composition of power sources

As is indicated in Figure 3-27, power generating costs fluctuate greatly as the composition of power sources (power suppliers) changes. Power purchasing costs were estimated based on consideration of the power source development (only the power sources indicated in Table 2-38(p.2-82)) that is planned regarding the NGD power demand shown in Table 3-8. The projected results are shown in Figure 3-28. The EDC power purchasing plans are referred to for the period from 2010 to 2012, while it is assumed that cheap hydropower development is maximized from 2013 onwards. Also, it is assumed that fuel prices for imported power from Vietnam and Thailand, heavy oil, coal, etc. increase at a rate of 5% per year.

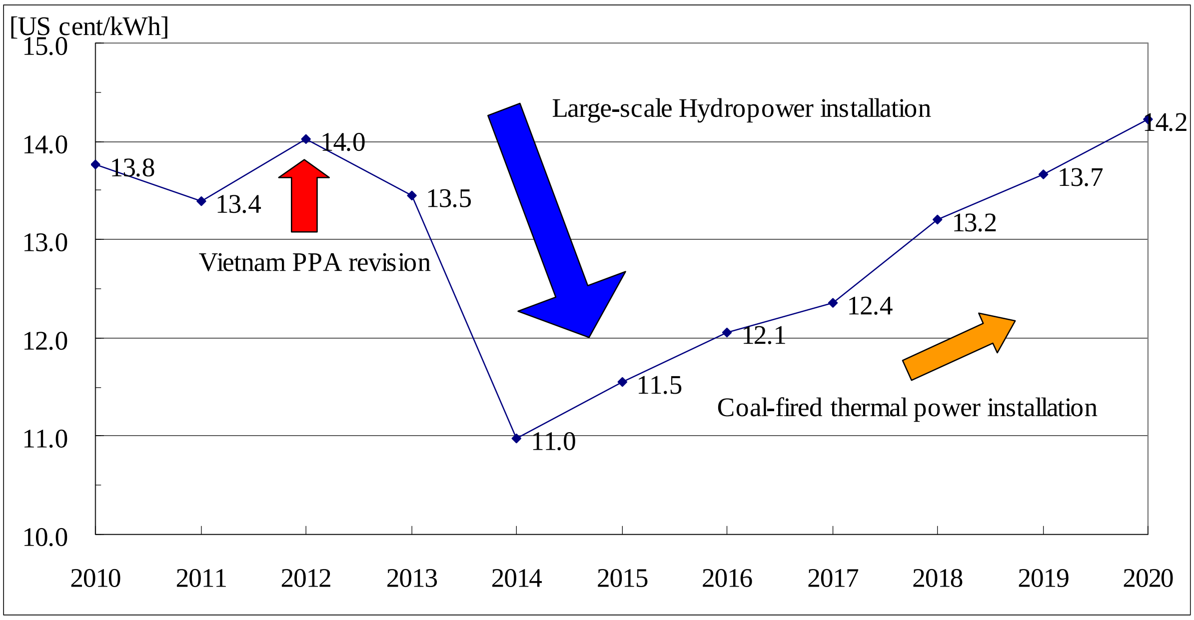


Figure 3-28 Energy Purchase Cost Forecast

There is a major factor triggering increase in the purchase price in 2012; that is PPA revision will result in a 30% or so price hike for power from Vietnam, which accounts for the largest portion of purchased power, however, the amount of inflation is compressed due to the commissioning of Kamchay Hydropower Station and Kirirom III Hydropower Station. With the successive commissioning of large-scale hydropower stations from 2013 onwards, it is forecast that purchase prices will fall up to 2014, after which they will steadily rise again. This is because the ratio of coal-fired thermal power, for which fuel costs are increasing, will become larger, and hydropower plants that are indicated in Table 2-39(p.2-82) but are still in the planning stage have not been included in the projection.
As may be gathered from the above points, in order to reduce power purchasing costs, it is important to advance the phased development of cheap power sources including imported power.

3.6 Organization, Personnel, Capacity and Financial Condition of Related Agencies

MIME has so far received technology transfer based on technical training primarily by JICA individual experts. However, due to the low level of staff salaries in MIME, it was found in interviews that some staff members work in the morning and seek side jobs in the afternoon, or staff who have received overseas training switch to the private sector after returning to Cambodia and so on. Accordingly, it is necessary to consider improving salaries, giving incentives and taking other steps to improve the motivation of staff.

Concerning the EAC and EDC, leaving aside the question of capability, both organizations have sufficient numbers of staff to carry out their roles. In the EAC, which is soon to commence operation of large-scale hydropower plants, since there are no staffs capable of conducting inspections according to hydropower technology standards, the EAC will employ one hydropower engineer from now on. However, following the initial inspection, it will be necessary to increase the number of engineers upon determining how many personnel are required from now on. Moreover, the EDC doesn’t have engineers capable of conducting operation and maintenance from the viewpoints of preventive maintenance and accident prevention in transmission and substation facilities, and it will be necessary to determine how many people with what level of capacity will be required from now on.

3.7 Grid Stability and Power Quality

In terms of the current situation regarding power quality, there is a pressing need to resolve numerous power interruptions caused by lack of supply capacity. A number of large-scale power sources are about to go into operation, however, in Cambodia, where there is a rainy season and dry season, since many of these are hydropower plants, the major issue concerns how to secure supply capacity during the dry season.

In terms of the grid, a major issue concerns strengthening of the Phnom Penh system. When future growth in demand and failures are taken into consideration, since power interruptions have to be resorted to because of the limited capacity of transformers, it will be necessary to boost capacity on the Phnom Penh system in order to secure reliability. The details are described in section 3.2.

Moreover, in order for Cambodia to promote the attraction of factories and so on, it requires power supply with good quality (frequency and voltage, etc.), however, it currently has to rely on Vietnam, which has large grid capacity, in order to conduct frequency adjustment. In the future, if Thailand, Cambodia and Phnom Penh become interconnected as a single system, the overall system capacity will become larger and frequency will become more stable, however, it will be necessary for the countries concerned to hold discussions on maintaining frequency and set wide area rules concerning common target values and each country’s role according to system size. Concerning adjustment of generator output, NCC will continue to issue all output commands by telephone and wireless as it has done so until now. Currently, since the Cambodian grid system is small and load fluctuations are minor, no major problems are occurring, however, if the system and load fluctuations become larger in the future, telephone-based generator commands, which lack immediacy, may become a problem from the viewpoint of maintaining frequency.

Concerning maintenance of frequency, the NCC, which is about to commence operation, also issues all its commands concerning generator output adjustment to substations by telephone and wireless. When the system and load fluctuations become larger in the future, since telephone-based generator commands may become a problem from the viewpoint of maintaining frequency due to the lack of speed, it will be necessary to have a power source to enable direct operations from the NCC. Since it is not realistic for the NCC to directly conduct output operations for all IPP, which account for the large majority of power sources in Cambodia, it will become necessary for the EDC to possess its own power sources for adjustment purposes. For reference, Figure 3-29 shows the image of frequency adjustment techniques in Japan.

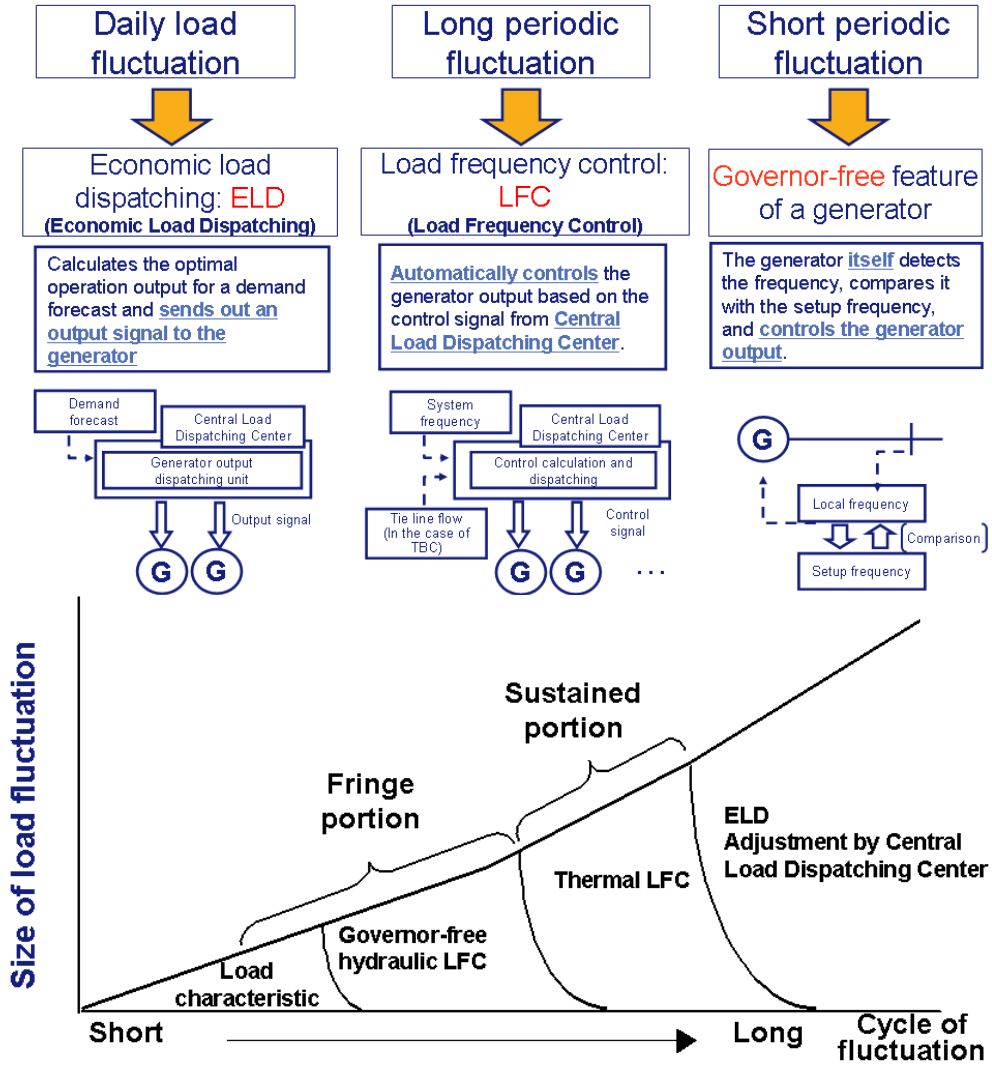


Figure 3-29 Image of frequency adjustment in Japan

3.8 Issues concerning International Interconnection

In the Phnom Penh system, because the generated electrical energy of power stations in the power system is less than the demand for power, a large proportion of the power supply (around 40%) is purchased from Vietnam and the international interconnected line with Vietnam is key to stable supply. In other words, if ample power cannot be supplied from Vietnam, the operator is forced to conduct planned outages, and if the power supply from Vietnam is suddenly suspended for some reason or other, there is a high possibility of blackouts occurring. Figure 3-30 illustrates this situation. As transmission lines continue to be built and the systems in Thailand, Cambodia and Vietnam become interconnected in the future, supply reliability will be enhanced. Even though realizing wide area interconnection has advantages in terms of stabilizing the power supply and frequency and securing economic merits, as is indicated in Figure 3-31, there is a possibility that failure in one country will spread to the entire system and cause large-scale power interruption. Therefore, it is necessary to take measures to prevent failures from spreading.

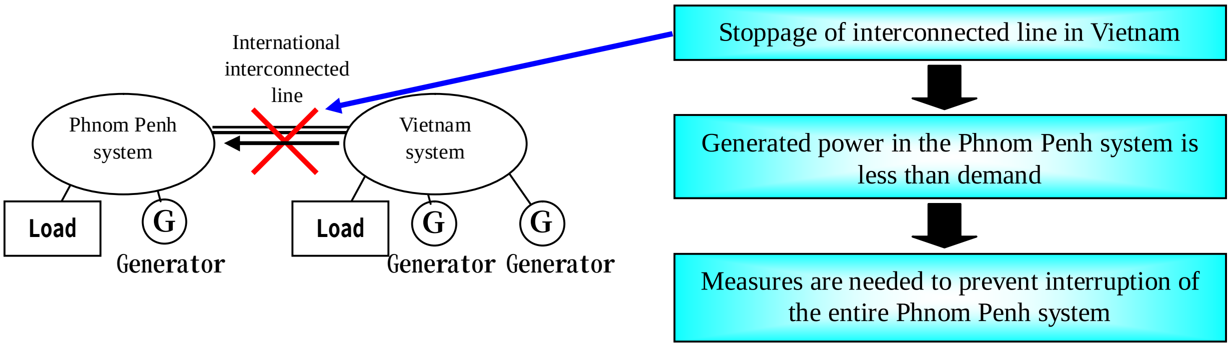


Figure 3-30 Example of Failure on Interconnected Line (current system)

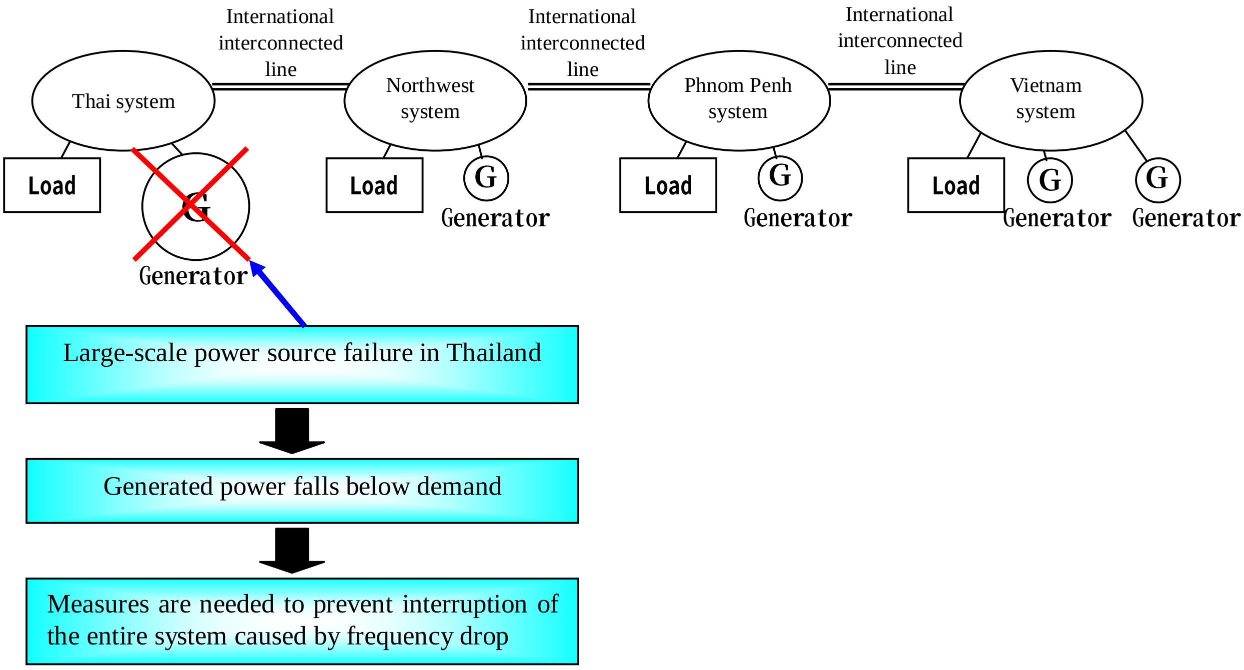


Figure 3-31 Example of Generator Failure (Future System)

Concerning problems in terms of international interconnection system stability, there is currently a risk that the Phnom Penh system could blackout if supply from Vietnam was suspended. When it comes to actual introduction, detailed system analysis and so on will be required, however, a possible solution is load shedding based on a system stabilizing Controller (SSC). Through incorporating system information in advance, computing the appropriate load shedding amount and immediately shedding load as soon as a projected failure (suspension of the interconnection line from Vietnam) occurs, the SSC can prevent major drops in frequency. For conducting calculation, since online information concerning flow values and system recognition, etc. is required from each electric facility, the system becomes relatively large-scale. There are more simple systems instead of SSC, such as Transfer Trip Equipment and Frequency Relay. The former is that when interconnection transmission lines trips, feeders will be tripped based on the current of interconnection transmission lines and the latter is that feeders will be tripped based on frequency. Moreover, in the case where the Phnom Penh system is interconnected with Thailand in the future, the above risk will be remedied, however, there is a possibility that a failure in one country could spread and cause power outages through the entire system. In order to prevent failures from spreading, it is necessary to set interconnected line operating targets in consideration of conditions for frequency, voltage and stability and, in the event where frequency displays major fluctuation, to separate the interconnection and recover the situation in each individual system in order to prevent the failure from spreading. Additionally, in order to further utilize the merits of wide area interconnection, it is also important to prepare a mechanism for mutually advancing power between countries to counter tight supply and demand conditions caused by power supply troubles, etc. For making equivalent rules with these neighboring countries, it is important for Cambodia to have a negotiation skill based on high technique of power system.

3.9 Verification of Optimum Generating Equipment Operation considering Stable Supply and Economy

Figure 3-32 and Figure 3-33 show the daily demand curve and breakdown of supply capacity in the Phnom Penh system during the rainy season and dry season. Based on cheap imported power from Vietnam, hydropower is the base power during the rainy season, while during the dry season, it is used to generate power only during daytime when demand is high and the remainder is supplied by generators that burn expensive heavy oil, etc. Planned outages are also constantly implemented due to the lack of supply capacity. Figure 3-34 shows the operating condition of Kirirom I hydropower station during the dry season. Priority is given to the generation of power during the daytime when demand is high, however, further fine-tuned operation needs to be conducted from the viewpoint of supply stability because generation is happening during lunch times and other times when demand is low and no planned outages are occurring, or conversely there are times when no generation is conducted even though planned outages are happening. In particular, large-scale hydropower plants are expected to go into operation in the future, so the operation of hydropower stations is becoming extremely important from the viewpoint of securing supply capacity during the dry season.
Therefore, in order to conduct the optimum operation of power generating facilities, the most important thing will be the role of the NCC, which is responsible for issuing operation commands to the IPP power plants.

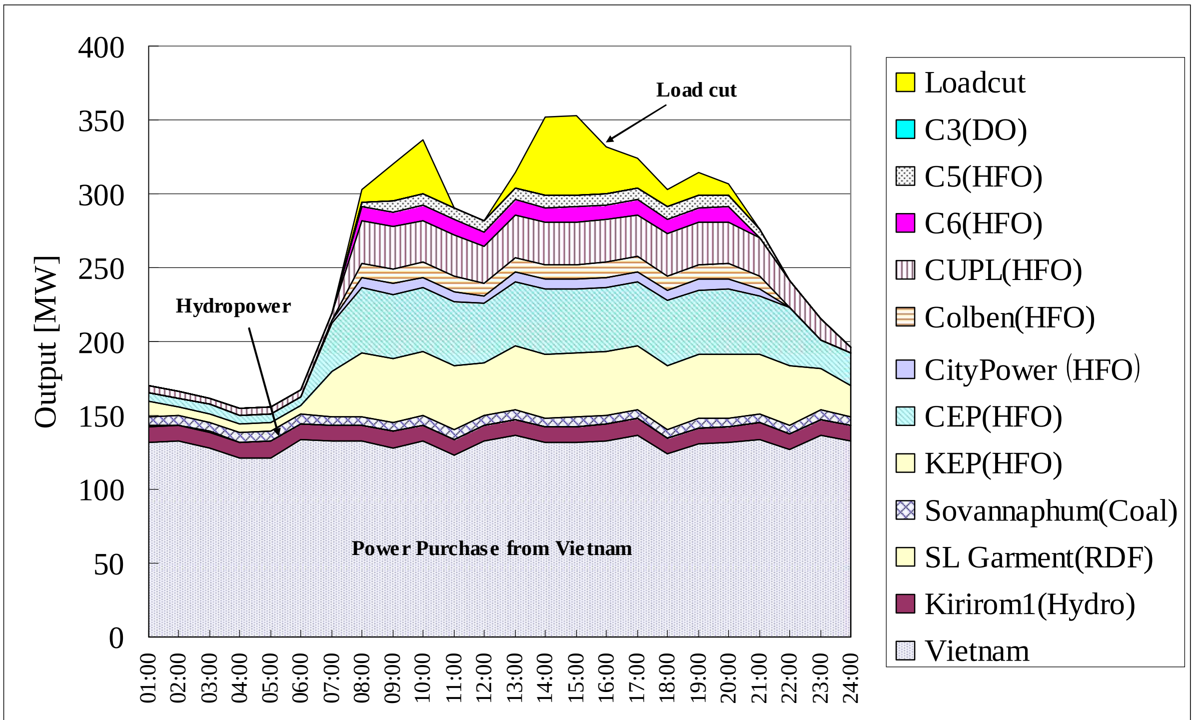


Figure 3-32 Demand Curve and Supply Capacity Breakdown in the Rainy Season (October 24, 2011)

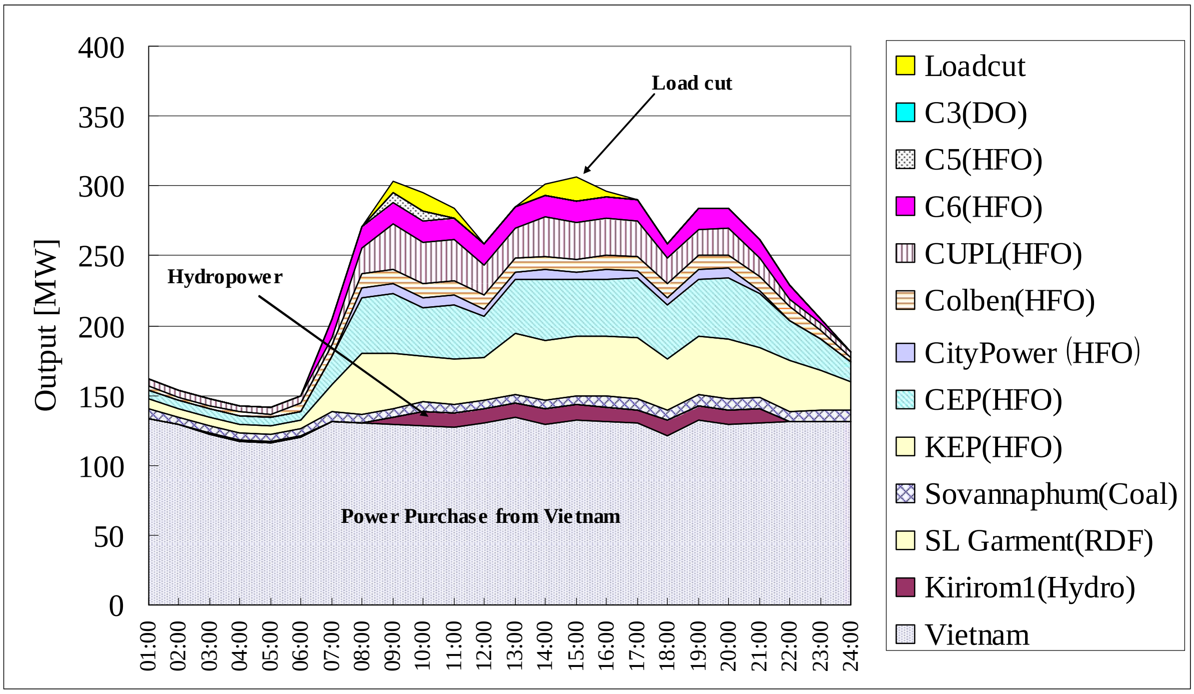


Figure 3-33 Demand Curve and Supply Capacity Breakdown in the Dry Season (April 12, 2011)

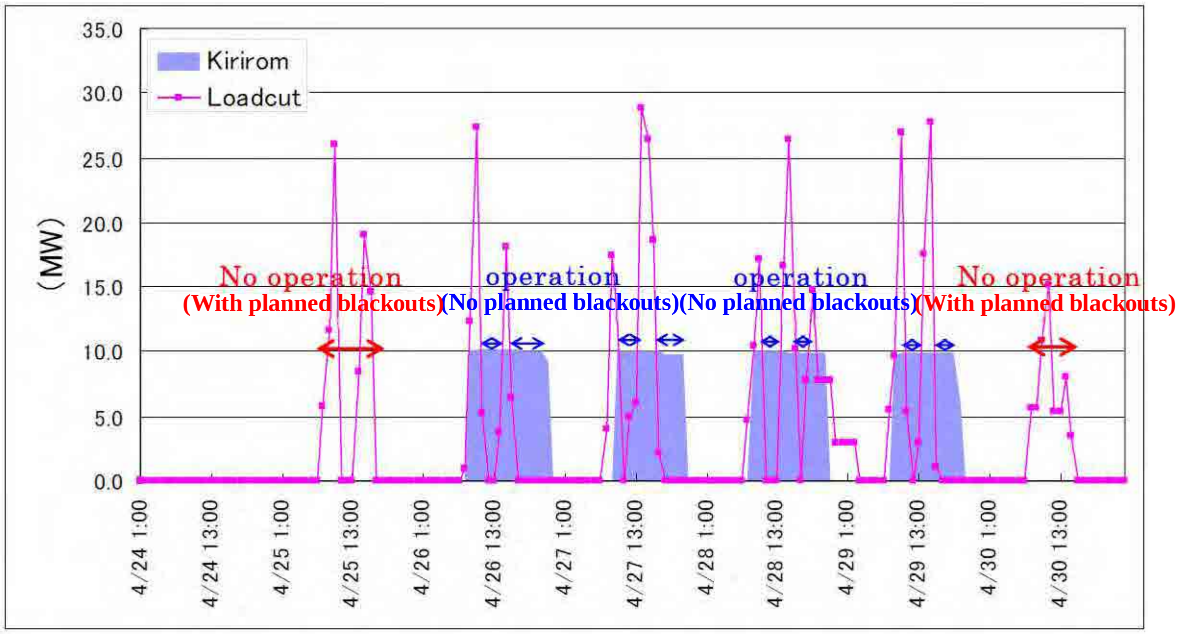


Figure 3-34 Operating Condition of Hydropower Plant (Kirirom I) in the Dry Season

In Cambodia, numerous large-scale hydropower plants are scheduled to successively go into operation from now on, and the ratio of hydropower in the power source composition will expand. Moreover, as it is difficult to secure 100% supply capacity from hydropower plants during the dry season, the key to securing supply capacity at this time will be to conduct the planned operation of reservoirs upon conducting accurate flow rate forecasting and compiling annual plans based on statistical data. The annual utilization rate of newly commissioned hydropower plants is expected to be around 30 to 40%, but this will be even lower during the dry season. During the dry season, since conditions will become harsh in terms of supply, important points in reservoir operation will be ① to maintain as high a water level as possible before entering the dry season while considering the dam discharge risk based on appropriate inflow forecast, and ② to give priority to power generation during the times when demand is high and to limit generation when this won't hinder supply. Meanwhile, during the rainy season, since there will be times when the hydropower plant utilization rate is 100% and situations of excess power arise, it will be necessary to bind a contract for selling power to Vietnam via interconnected line.

Table 3-39 Maximum Output and Capacity Factor of Hydropower Plant (Expected)

Power Plant	Max Output (MW)	Capacity factor (%)
Kamchay	194.1	29.3
Kirirom III	18.0	49.8
Stung Atay	120.0	44.3
Stung Tatay	246.0	39.4
Lower Russey Churum	338.0	34.4

Table 3-40 Expected Monthly Generating Quantity and Capacity Factor of Kamchay Power Plant in 2012

Month	Monthly generation quantity (GWh)	Capacity factor (%)
January	39.76	27.5
February	13.55	10.4
March	17.37	12.0
April	8.46	6.1
May	14.58	10.1
June	33.76	24.2
July	146.05	100.0
August	146.05	100.0
September	17.13	12.2
October	34.39	23.8
November	24.99	17.9
December	2.54	1.9
Total	**498.63**	**29.3**

Source: Annual Generation Plan for Year 2012, Kamchay by EDC

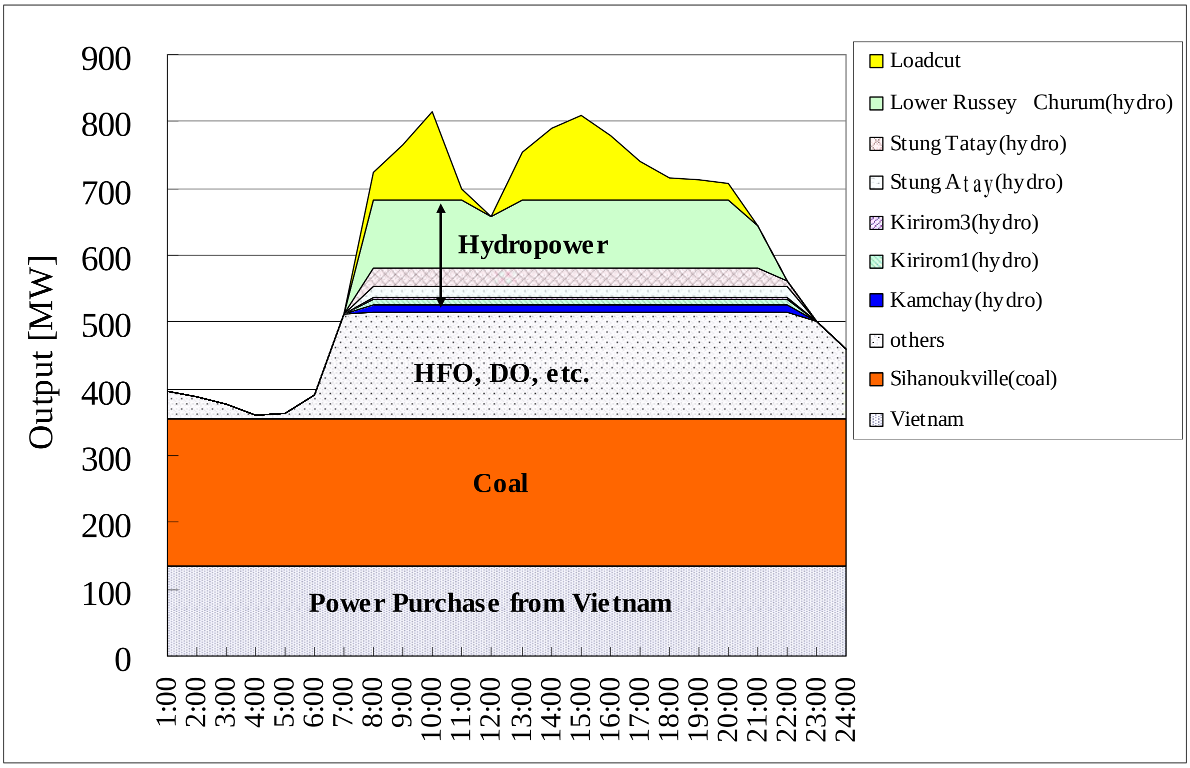


Figure 3-35 Image of Supply and Demand Balance in the Dry Season 2015

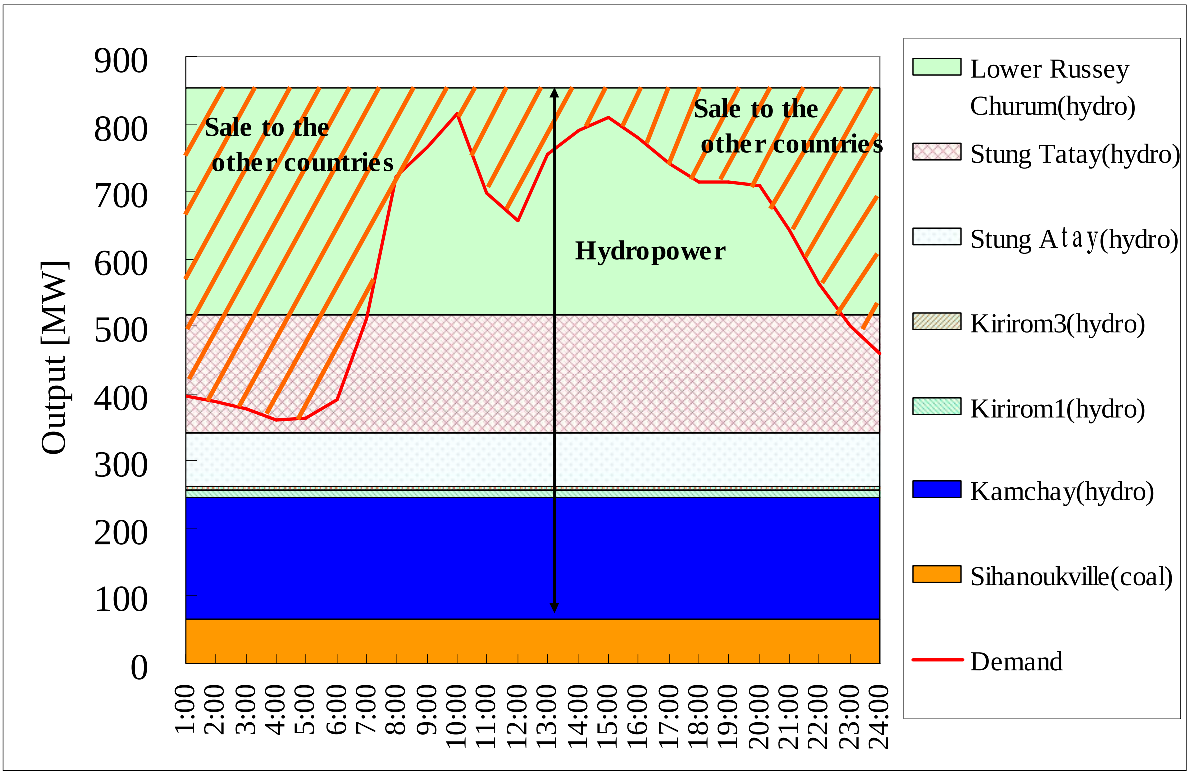


Figure 3-36 Image of Supply and Demand Balance in the Rainy Season 2015

3.10 Summary

The priority issues that need to be tackled by the electric power sector in Cambodia can be summarized as follows.

In the short term, against the background of expansion of the power system based on expansion of transmission and substation grids and introduction of large-scale power sources, a pressing issue is the training of human resources in the EDC and NCC, which are responsible for operation of the nationwide power grid and economic power supply, and human resources who can carry out the maintenance of transmission and substation facilities. Moreover, in order to enhance supply capacity, reliability and stability in the Phnom Penh system, which is the most important, it is necessary to expand new substations, underground transmission lines and distribution grid and enhance protection systems.

In the long term, in order to achieve the stable supply of cheap electric power in Cambodia, which has few natural resources, and respond to the high demand for power in the Mekong region, it will be necessary to further develop the domestic resource of hydropower and introduce highly efficient thermal power plants.

Proposals to tackle above mentioned issues that are described in the chapter 3 can be summarized as follows.

○Proposals to tackle the short-term issues

・Capacity Building
- Capacity building for NCC and maintenance of transmission and substation facilities in EDC
- Enhancement of the training program for maintenance of transmission and substation facilities at Training Center in EDC
- Capacity building for generating technology in the electric power sector

・Facility strengthening
- Improvement of the Phnom Penh System Transmission and Distribution Network
  Establishment of new indoor grid substations
  Construction of 115kV underground transmission lines
  Improvement of the 115kV relay system
  Adoption of a Distribution Automation System
  Adoption of a System Stabilizing Controller
- 115kV transmission line connection between CPTL grid substation and Cambodia Power Grid one

・Enhancement of supply capacity in the dry season
- Construction of thermal power plant or expansion of power import

○Proposals to tackle the middle-term and long-term issues

・Power Generation Development
- Planning of exporting energy in the GMS
- Development of hydropower plants
- Installation of high-efficiency thermal power plants
- Construction of a power plant in order to adjust frequency owned by EDC

・System Development
- To early organize the NGD
- To connect the NGD to Thai system by 230kV transmission line

・Capacity building
- Improvement of technical capabilities and capacity of MIME officials