PART IV POWER BALANCE

Chapter 11 Power Development Plan

11.1 Power demand forecast

The power demand forecast is an important factor in the formulation of a future power development plan (PDP). It is not very difficult to find the most efficient way to develop facilities to meet the forecast demand.

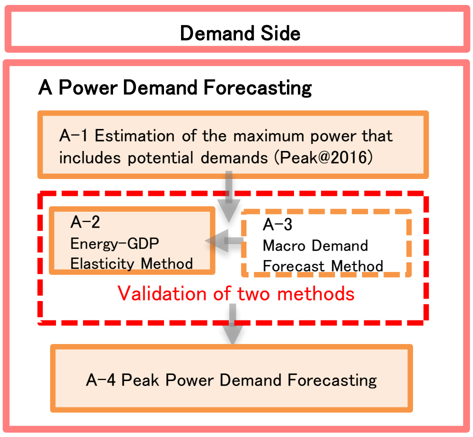
However, the accuracy of the actual demand forecast is at such a level that it is difficult to forecast even the demand for the next day accurately and, in fact, it is almost impossible to accurately forecast the power demand for several years or longer.

Because of this unreliability of the demand forecast, it is not advisable to formulate a PDP optimal for a certain condition in future and promote actual power development in accordance with this PDP. In other words, it is very important in formulating a future PDP to consider all the elements, including the demand variables in the estimation, conduct a sensitivity analysis while changing these variables within their respective reasonable ranges for a certain system, and analyze the relationship between power generating facilities in the system and the economic, environmental and energy security values of the system.Therefore, a long-term vision for the power source composition created by making a rough estimation of the future demand based on a scenario of the macro economic growth, simulating a demand/supply operation somewhat simply using the estimated demand scenario as a variable and formulating the optimal PDP is presented as a recommendation in this chapter.

11.2 Peak demand projection

11.2.1 Implementation flow

As for the methodology of peak demand projection for PSMP2016, this study adopted the "GDP elasticity method", which is an easier approach and thus easy for technology transfer to local counterpart agencies who are expected to take over the work in a rolling plan. However, it has to be noted that this methodology disregards various factors that may also affect the power demand; hence, the results may differ significantly from other methodologies. This study therefore also tried the peak demand projection based on the "Sectorial analysis method" to confirm the appropriateness of the "GDP elasticity method". This peak demand projection referred to the economic development projection that was discussed in Chapter 5. Following the aforementioned, this study compared the results of the peak demand projection with the projection for energy supply and demand balance that was discussed in Chapter 6 to check consistency, and then integrated both projections and completed a unified "energy & power supply-demand projection"[1]. The following shows the flow chart for power demand forecasting.



Source: JICA Study Team

Figure 11-1 Power demand forecasting flow

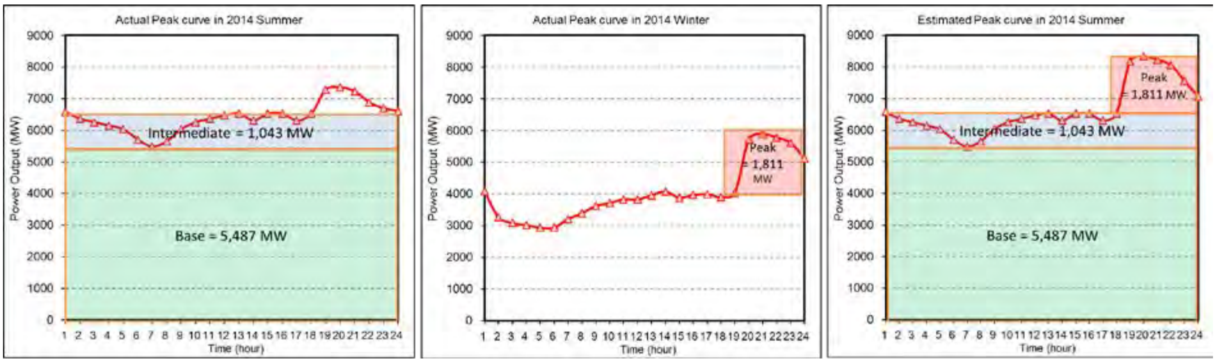
[1] The energy supply and demand projection in Chapter 6 shows the results after comparing the peak demand projection in this chapter and confirming the consistency between them.

11.2.2 Assumptions

Deciding the level at which the baseline is to be set is an important factor in peak power demand forecasting. Because of the particular situation in Bangladesh whereby rolling blackouts have been used as a measure to circumvent power shortages at the peak hours, the recorded maximum power consumption does not include such potential power demand. Therefore, an accurate forecast of the maximum demand including the potential demand requires a theoretical estimation of load curves from the daily operational data with particular attention on the characteristics of the seasonal changes in the daily load curve and the frequency and durations of rolling blackouts.

Because rolling blackouts have been relatively rare on weekends and holidays in the winter (between November and January), a daily load curve gives an actual peak load (at the hours of the peak power consumption for lighting) that is quite accurate. A daily load curve in the summer gives estimates of the base and intermediate loads close to the recorded values.

Therefore, a composite daily load curve representing the peak power demand was created from the daily load curve in the summer with part of the peak hours replaced by the same part of the daily load curve in the winter as shown in the figure below. The peak power demand in FY 2014, which was used as the baseline for the peak demand forecast, was set at 8,039 MW by adding the base and intermediate load in the summer (5,487 MW and 1,043 MW, respectively) and the peak load in the winter (1,811 MW) recorded in FY 2015. The peak power demand in FY 2016 was estimated at 8,921 MW in the same way and this value was used as the reference value in the peak power demand forecast.



Source: JICA Study Team

Figure 11-2 Estimated Composite Daily Load Curve in the summer in Bangladesh

The table below shows the results of the maximum load analysis. The maximum load recorded in FY 2015 was 7,500 MW, while a maximum load of approximately 8,921 MW was estimated from the estimated base load of 6,170 MW, the potential intermediate and peak-hour loads and the actual net/gross ratio. Therefore, the 8,291 MW obtained in this analysis was used as the reference value in the long-term demand forecast up to 2041.

Table 11-1 Peal load estimation 2005-2015

Fiscal Year	Estimated Base Load (MW)	Estimated Intermediate Load (MW)	Estimated Base Over Peak Load (MW)	Estimated Peak Load (MW)	Actual Net/Gross	Estimated Net Peak Load (MW)	Growth (%)	Actual Net Peak Load (MW)	Growth (%)
2005	3,097	-	1,379	4,476	0.95	4,230		3,900	
2006	3,600	-	1,413	5,013	0.95	4,737	12.0%	4,200	7.7%
2007	4,050	-	1,063	5,113	0.95	4,832	2.0%	4,500	7.1%
2008	4,190	-	1,484	5,674	0.95	5,362	11.0%	4,600	2.2%
2009	4,150	-	1,500	5,650	0.95	5,339	-0.4%	5,050	9.8%
2010	4,300	817	1,462	6,579	0.95	6,258	16.4%	5,550	9.9%
2011	4,400	836	1,496	6,732	0.95	6,411	2.3%	5,550	0.0%
2012	5,000	950	1,700	7,650	0.96	7,326	13.6%	6,600	18.9%
2013	5,300	1,007	1,802	8,109	0.96	7,764	6.0%	6,600	0.0%
2014	5,487	1,043	1,811	8,341	0.96	8,039	2.9%	7,356	11.5%
2015	6,170	1,111	1,974	9,255	0.96	8,921	11.0%	7,500	2.0%

Source: JICA Study Team

11.3 Peak demand projection using gdp elasticity method

The peak demand up to 2041 was estimated by multiplying the GDP projection based on the economic development prospects in Chapter 5 by the GDP elasticity of peak demand, taking also into consideration the effect of peak demand reduction referring to the Bangladesh government's target for energy efficiency.

11.3.1 Economic development projection

The projection for GDP discussed in Chapter 5 was adopted regarding the economic development prospects. Not only the "Base Scenario" but also the "High-growth scenario" and the "Low-growth scenario" were referred to in the simulation. All of these scenarios assumed that the GDP growth target up to 2020 as stipulated in the Seventh Five-Year Plan would be achieved. After the 2020s, when the growth rate becomes gradually more moderate in the course of maturity of economic development, the pace of the declining growth rate is relatively slow in the "High-growth Scenario", whereas in the "Low-growth Scenario" it is relatively rapid.
As a result, whereas the "Base Scenario" assumed that the average growth rate of GDP (real price) from 2036 to 2041 becomes 4.4% p.a., the "High-growth scenario" assumed 5.0% p.a. and the "Low-growth Scenario" assumed 4.0% p.a.

Table 11-2 Real GDP Growth Rate Projection (constant at 2005 price)

	2010	2015	2020	2025	2030	2035	2041
Base Scenario	6.1%	6.3%	7.4%	7.4%	6.3%	5.3%	4.4%
High-growth Scenario	6.1%	6.3%	7.4%	7.5%	6.6%	5.7%	5.0%
Low-growth Scenario	6.1%	6.3%	7.4%	7.3%	6.1%	4.9%	4.0%

Source: JICA Survey Team

Table 11-3 Nominal GDP Growth Rate Projection (current price)

		2010	2015	2020	2025	2030	2035	2041
Base Scenario	USD	10.7%	11.0%	11.9%	11.4%	10.0%	8.6%	7.3%
	BDT	13.3%	13.7%	13.3%	12.7%	11.1%	9.5%	8.0%
High-growth scenario	USD	10.7%	11.0%	11.9%	11.6%	10.3%	9.1%	7.9%
	BDT	13.3%	13.7%	13.3%	12.8%	11.4%	9.9%	8.6%
Low-growth Scenario	USD	10.7%	11.0%	11.9%	11.4%	9.8%	8.3%	6.9%
	BDT	13.3%	13.7%	13.3%	12.7%	10.9%	9.1%	7.6%

Source: JICA Survey Team

11.3.2 Validation of gdp elasticity

The table below shows the historical trend for GDP elasticity of power demand in Bangladesh for the last 10 years, and the average was 1.27. Considering that the elasticity in some other ASEAN countries (Thailand, Indonesia, Malaysia) also fell in the range between 1.1 and 1.3, this study assumes that this 1.27 will continue in the BAU (business-as-usual) case.

Table 11-4 Historical Trend of GDP Elasticity of Power Demand in Bangladesh

Year	GDP at Constant Market Price (Million Taka)	GDP Growth Rate (%)	Actual Net Energy Generation (GWH)	Energy Not served	Forecasted Net Generation (GWH)		GWH Growth	Elasticity
2005	2,669,740		21,408	260	21,668	21,798		
2006	2,846,726	6.6%	22,978	843	23,821	24,243	7.3%	1.1
2007	3,029,709	6.4%	23,268	2,264	25,532	26,664	1.3%	0.2
2008	3,217,855	6.2%	24,946	1,107	26,053	26,606	7.2%	1.2
2009	3,406,524	5.9%	26,533	1,363	27,896	28,577	6.4%	1.1
2010	3,608,450	5.9%	29,247	1,829	31,076	31,991	10.2%	1.7
2011	3,850,500	6.7%	31,355	1,899	33,254	34,204	7.2%	1.1
2012	4,090,530	6.2%	35,118	1,647	36,765	37,588	12.0%	1.9
2013	4,337,200	6.0%	38,229	1,070	39,299	39,834	8.9%	1.5
2014	4,601,770	6.1%	42,195	515	42,710	42,968	10.4%	1.7
								1.27

Source: JICA Survey Team and BPDB

Table 11-5 Actual Energy-GDP Elasticity in ASEAN Countries

Thailand	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	GDP (constant 2005 US$)	170,956,863,507	181,708,833,946	189,318,499,954	198,723,685,564	209,524,501,833	213,140,198,921	211,566,627,910	227,448,322,637	229,344,519,381	246,139,191,582	
	Electricity consumption (GWh)	106,959	115,044	121,229	127,811	133,178	135,450	135,209	149,320	148,700	161,749	
	(A) GDP growth	7.2%	6.3%	4.2%	5.0%	5.4%	1.7%	-0.7%	7.5%	0.8%	7.3%	
	(B)Electricity growth	6.8%	7.6%	5.4%	5.4%	4.2%	1.7%	-0.2%	10.4%	-0.4%	8.8%	
	(A)/(B)	0.94	1.20	1.28	1.09	0.77	0.99	0.24	1.39	-0.50	1.20	
	(A') 5-year average GDP	5.2%	5.5%	5.4%	5.8%	5.6%	4.5%	3.1%	3.7%	2.9%	3.3%	
	(B') 5-year average Electricity	5.9%	7.2%	6.6%	6.7%	5.9%	4.8%	3.3%	4.3%	3.1%	4.0%	
	(A')/(B')	1.1	1.3	1.2	1.2	1.0	1.1	1.1	1.1	1.1	1.2	1.1
Indonesia	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	GDP (constant 2005 US$)	257,516,488,195	270,471,818,103	285,868,619,206	301,594,114,117	320,730,327,692	340,018,098,955	355,757,098,753	377,898,901,817	401,214,448,583	425,407,883,059	
	Electricity consumption (GWh)	90,441	100,097	107,705	113,415	121,614	128,810	136,053	147,972	159,867	175,329	
	(A) GDP growth	4.8%	5.0%	5.7%	5.5%	6.3%	6.0%	4.6%	6.2%	6.2%	6.0%	
	(B)Electricity growth	3.9%	10.7%	7.6%	5.3%	7.2%	5.9%	5.6%	8.8%	8.0%	9.7%	
	(A)/(B)	0.81	2.12	1.34	0.96	1.14	0.98	1.21	1.41	1.30	1.60	
	(A') 5-year average GDP	3.7%	4.6%	4.7%	5.1%	5.5%	5.7%	5.6%	5.7%	5.9%	5.8%	
	(B') 5-year average Electricity	6.7%	7.0%	6.4%	6.1%	6.9%	7.3%	6.3%	6.6%	7.1%	7.6%	
	(A')/(B')	1.8	1.5	1.3	1.2	1.3	1.3	1.1	1.1	1.2	1.3	1.3
Malaysia	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	GDP (constant 2005 US$)	127,611,641,758	136,268,098,017	143,534,102,611	151,550,262,734	161,096,089,356	168,879,881,704	166,323,572,126	178,674,711,521	188,133,365,986	198,430,759,593	
	Electricity consumption (GWh)	73,420	77,252	80,755	84,573	89,358	92,881	102,920	110,853	111,852	120,637	
	(A) GDP growth	5.8%	6.8%	5.3%	5.6%	6.3%	4.8%	-1.5%	7.4%	5.3%	5.5%	
	(B)Electricity growth	6.6%	5.2%	4.5%	4.7%	5.7%	3.9%	10.8%	7.7%	0.9%	7.9%	
	(A)/(B)	1.14	0.77	0.85	0.85	0.90	0.82	-7.14	1.04	0.17	1.43	
	(A') 5-year average GDP	5.3%	5.4%	4.7%	5.8%	6.0%	5.8%	4.1%	4.5%	4.4%	4.3%	
	(B') 5-year average Electricity	6.6%	6.6%	5.7%	5.4%	5.3%	4.8%	5.9%	6.5%	5.8%	6.2%	
	(A')/(B')	1.3	1.2	1.2	0.9	0.9	0.8	1.5	1.5	1.3	1.5	1.2

Source: JICA Survey Team

11.3.3 Assumption of the effects of peak demand reduction

As discussed in Chapter 6, “Energy Efficiency and Conservation Master Plan up to 2030” (EECMP) was published by the Sustainable and Renewable Energy Development Authority (SREDA) and Power Division in March 2015 with technical assistance by JICA. This master plan set a target for energy efficiency to “reduce the energy intensity of GDP by 15% by 2021 and by 20% by 2030, compared to 2014”.

The energy efficiency target in EECMP is in terms of energy consumption (ktoe), but calculating the effect of achieving this target on the reduction of peak power demand (MW) requires a complicated conversion considering the electrification rate and annual load factor (= annual electricity consumption/peak demand) on a timeline.

Following discussion with the Power Division and BPDB, this study therefore set a more simplified target of “reducing the peak power demand by 20% from the BAU case (GDP elasticity = 1.27) referring to EECMP” and formulated the projection of peak power demand. Then, the results were compared with the primary energy supply and demand projection that was discussed in Chapter 6, and adjustments made if there were inconsistencies between them.

11.3.4 Peak demand projection using gdp elasticity method

The peak demand projections considering the aforementioned factors are shown in the following tables.

Table 11-6 Peak Demand Projection Using GDP Elasticity Method (base cases)

Model	GDP Elasticity Method								Sectorial Analysis Method
FY	GDP growth rate	Elasticity	Electricity growth rate	Total Demand without EE&C	Effect of EE&C	Total Demand with EE&C	Captive power to the grid	GDP Elasticity Method	Sectorial Analysis Method
2015	6.5%	1.27	8.3%	8,920	0.0%	8,920	-	8,920	8,900
2016	7.0%	1.27	8.9%	9,713	1.3%	9,583	-	9,584	9,500
2017	7.2%	1.27	9.1%	10,601	2.7%	10,318	-	10,400	10,400
2018	7.4%	1.27	9.4%	11,597	4.0%	11,134	-	11,200	11,300
2019	7.6%	1.27	9.7%	12,717	5.3%	12,039	-	12,100	12,300
2020	8.0%	1.27	10.2%	14,009	6.7%	13,075	149	13,300	13,400
2021	7.8%	1.27	9.9%	15,394	8.0%	14,163	297	14,500	14,600
2022	7.6%	1.27	9.6%	16,875	9.3%	15,300	446	15,800	15,800
2023	7.4%	1.27	9.4%	18,453	10.7%	16,485	594	17,100	17,100
2024	7.2%	1.27	9.1%	20,129	12.0%	17,714	743	18,500	18,500
2025	6.9%	1.27	8.8%	21,903	13.3%	18,983	891	19,900	19,900
2026	6.7%	1.27	8.5%	23,776	14.7%	20,288	1,040	21,400	21,400
2027	6.5%	1.27	8.3%	25,744	16.0%	21,625	1,188	22,900	22,900
2028	6.3%	1.27	8.0%	27,806	17.3%	22,986	1,337	24,400	24,500
2029	6.1%	1.27	7.7%	29,959	18.7%	24,367	1,486	25,900	26,000
2030	5.9%	1.27	7.5%	32,198	20.0%	25,759	1,634	27,400	27,700
2031	5.7%	1.27	7.2%	34,520	20.0%	27,616	1,634	29,300	29,400
2032	5.5%	1.27	6.9%	36,916	20.0%	29,533	1,634	31,200	31,100
2033	5.3%	1.27	6.7%	39,381	20.0%	31,505	1,634	33,200	32,900
2034	5.0%	1.27	6.4%	41,906	20.0%	33,525	1,634	35,200	34,600
2035	4.8%	1.27	6.1%	44,483	20.0%	35,587	1,634	37,300	36,400
2036	4.6%	1.27	5.9%	47,101	20.0%	37,681	1,634	39,400	38,200
2037	4.4%	1.27	5.6%	49,750	20.0%	39,800	1,634	41,500	39,900
2038	4.4%	1.27	5.6%	52,526	20.0%	42,021	1,634	43,700	41,800
2039	4.4%	1.27	5.5%	55,436	20.0%	44,349	1,634	46,000	43,700
2040	4.3%	1.27	5.5%	58,486	20.0%	46,789	1,634	48,500	45,700
2041	4.3%	1.27	5.5%	61,681	20.0%	49,345	1,634	51,000	47,800

EE&C: Energy Efficiency and Conservation

Source: JICA Survey Team and BPDB

Table 11-7 Peak Demand Projection Using GDP Elasticity Method (high cases)

Model	GDP Elasticity Method								Sectorial Analysis Method
FY	GDP growth rate	Elasticity	Electricity growth rate	Total Demand without EE&C	Effect of EE&C	Total Demand with EE&C	Captive power to the grid	GDP Elasticity Method	Sectorial Analysis Method
2015	6.5%	1.27	8.3%	8,920	0.0%	8,920	-	8,920	8,900
2016	7.0%	1.27	8.9%	9,713	1.3%	9,583	-	9,600	9,500
2017	7.2%	1.27	9.1%	10,601	2.7%	10,318	-	10,400	10,400
2018	7.4%	1.27	9.4%	11,597	4.0%	11,134	-	11,200	11,300
2019	7.6%	1.27	9.7%	12,717	5.3%	12,039	-	12,100	12,300
2020	8.0%	1.27	10.2%	14,009	6.7%	13,075	149	13,300	13,500
2021	7.8%	1.27	9.9%	15,401	8.0%	14,169	297	14,500	14,700
2022	7.6%	1.27	9.7%	16,896	9.3%	15,319	446	15,800	15,900
2023	7.5%	1.27	9.5%	18,499	10.7%	16,526	594	17,200	17,200
2024	7.3%	1.27	9.3%	20,212	12.0%	17,787	743	18,600	18,700
2025	7.1%	1.27	9.0%	22,040	13.3%	19,101	891	20,000	20,100
2026	6.9%	1.27	8.8%	23,984	14.7%	20,466	1,040	21,600	21,700
2027	6.8%	1.27	8.6%	26,045	16.0%	21,878	1,188	23,100	23,300
2028	6.6%	1.27	8.4%	28,225	17.3%	23,333	1,337	24,700	25,000
2029	6.4%	1.27	8.1%	30,525	18.7%	24,827	1,486	26,400	26,700
2030	6.2%	1.27	7.9%	32,945	20.0%	26,356	1,634	28,000	28,500
2031	6.1%	1.27	7.7%	35,484	20.0%	28,387	1,634	30,100	30,400
2032	5.9%	1.27	7.5%	38,139	20.0%	30,512	1,634	32,200	32,300
2033	5.7%	1.27	7.3%	40,910	20.0%	32,728	1,634	34,400	34,300
2034	5.5%	1.27	7.0%	43,791	20.0%	35,033	1,634	36,700	36,300
2035	5.4%	1.27	6.8%	46,780	20.0%	37,424	1,634	39,100	38,400
2036	5.2%	1.27	6.6%	49,871	20.0%	39,896	1,634	41,600	40,500
2037	5.0%	1.27	6.4%	53,057	20.0%	42,445	1,634	44,100	42,700
2038	5.0%	1.27	6.3%	56,424	20.0%	45,139	1,634	46,800	44,900
2039	5.0%	1.27	6.3%	59,982	20.0%	47,986	1,634	49,700	47,300
2040	4.9%	1.27	6.3%	63,741	20.0%	50,993	1,634	52,700	49,800
2041	4.9%	1.27	6.2%	67,710	20.0%	54,168	1,634	55,900	52,400

EE&C: Energy Efficiency and Conservation

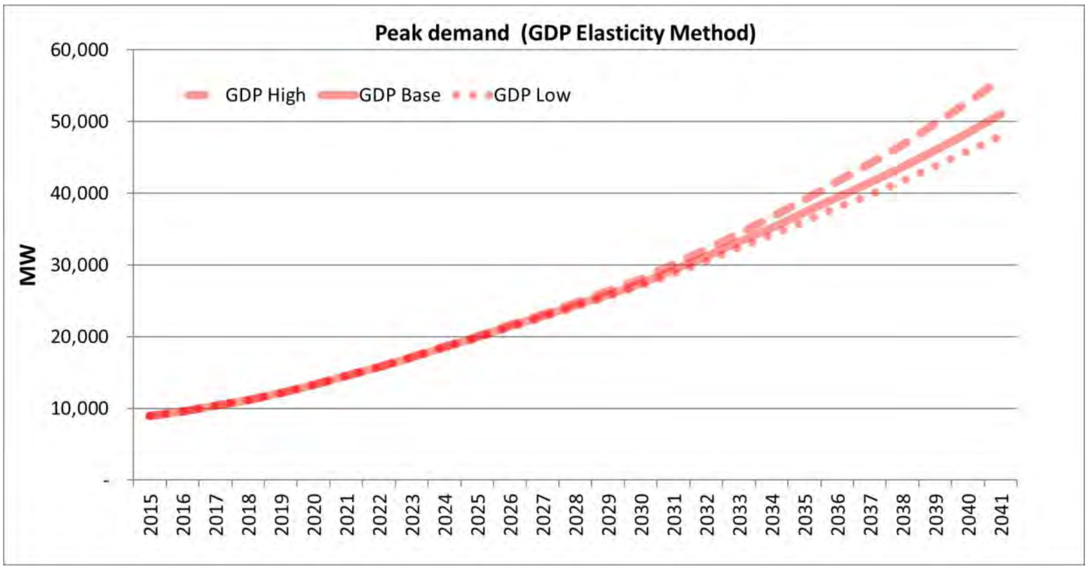
Source: JICA Survey Team and BPDB

Table 11-8 Peak Demand Projection Using GDP Elasticity Method (low cases)

Model	GDP Elasticity Method								Sectorial Analysis Method
FY	GDP growth rate	Elasticity	Electricity growth rate	Total Demand without EE&C	Effect of EE&C	Total Demand with EE&C	Captive power to the grid	GDP Elasticity Method	Sectorial Analysis Method
2015	6.5%	1.27	8.3%	8,920	0.0%	8,920	-	8,920	8,900
2016	7.0%	1.27	8.9%	9,713	1.3%	9,583	-	9,600	9,500
2017	7.2%	1.27	9.1%	10,601	2.7%	10,318	-	10,400	10,300
2018	7.4%	1.27	9.4%	11,597	4.0%	11,134	-	11,200	11,200
2019	7.6%	1.27	9.7%	12,717	5.3%	12,039	-	12,100	12,200
2020	8.0%	1.27	10.2%	14,009	6.7%	13,075	149	13,300	13,300
2021	7.8%	1.27	9.9%	15,390	8.0%	14,159	297	14,500	14,400
2022	7.5%	1.27	9.6%	16,861	9.3%	15,288	446	15,800	15,600
2023	7.3%	1.27	9.3%	18,423	10.7%	16,458	594	17,100	16,900
2024	7.1%	1.27	9.0%	20,074	12.0%	17,665	743	18,500	18,200
2025	6.8%	1.27	8.7%	21,813	13.3%	18,904	891	19,800	19,500
2026	6.6%	1.27	8.4%	23,638	14.7%	20,171	1,040	21,300	20,900
2027	6.4%	1.27	8.1%	25,545	16.0%	21,458	1,188	22,700	22,300
2028	6.1%	1.27	7.8%	27,529	17.3%	22,758	1,337	24,100	23,800
2029	5.9%	1.27	7.5%	29,586	18.7%	24,063	1,486	25,600	25,300
2030	5.6%	1.27	7.2%	31,709	20.0%	25,367	1,634	27,100	26,700
2031	5.4%	1.27	6.9%	33,890	20.0%	27,112	1,634	28,800	28,300
2032	5.2%	1.27	6.6%	36,120	20.0%	28,896	1,634	30,600	29,800
2033	4.9%	1.27	6.3%	38,391	20.0%	30,713	1,634	32,400	31,300
2034	4.7%	1.27	6.0%	40,691	20.0%	32,553	1,634	34,200	32,900
2035	4.5%	1.27	5.7%	43,010	20.0%	34,408	1,634	36,100	34,400
2036	4.3%	1.27	5.4%	45,334	20.0%	36,267	1,634	38,000	36,000
2037	4.0%	1.27	5.1%	47,652	20.0%	38,121	1,634	39,800	37,500
2038	4.0%	1.27	5.1%	50,068	20.0%	40,054	1,634	41,700	39,000
2039	4.0%	1.27	5.0%	52,587	20.0%	42,069	1,634	43,800	40,700
2040	3.9%	1.27	5.0%	55,211	20.0%	44,169	1,634	45,900	42,300
2041	3.9%	1.27	5.0%	57,946	20.0%	46,356	1,634	48,000	44,000

EE&C: Energy Efficiency and Conservation

Source: JICA Survey Team and BPDB



Source: JICA Survey Team and BPDB

Figure 11-3 Peak Demand Projection Using GDP Elasticity Method (case comparision)

11.4 Verifying the peak demand projection using sectorial analysis method

Next, this study also attempted an estimation of peak demand by projecting the total sum of power consumption in each sector. To serve for this, Simple.E software, which is an add-in module for MS-Excel, was used as the simulation program.

11.4.1 Steps in power demand projection

This program forecasts the energy demand for each sector using autocorrelation analysis on the energy intensity of GDP for each sector (and energy consumption per capita for the residential sector) while setting upper and lower limitations, and then formulates the future projection for peak demand.

Step 1 Sectoral energy consumption (A)
= Sectoral energy consumption intensity
× Sectoral GDP (Population for residential sector)
Step 2 Sectoral power demand (B)
= Sectoral total energy consumption (A) × Electrification ratio
× Power tariff elasticity × EE&C factor (Energy efficiency & conservation)
Step 3 Final electricity consumption (C)
= Sum of (B) for each sector, e.g. agriculture, industrial, commercial & public services and residential
Step 4 Electricity sent from the grid (net generation) (D)
= Final electricity consumption (C) + Transmission & distribution losses
Step 5 Peak demand (E)
= Electricity sent from the grid (D) / Load factor / 24 hours / 365 days

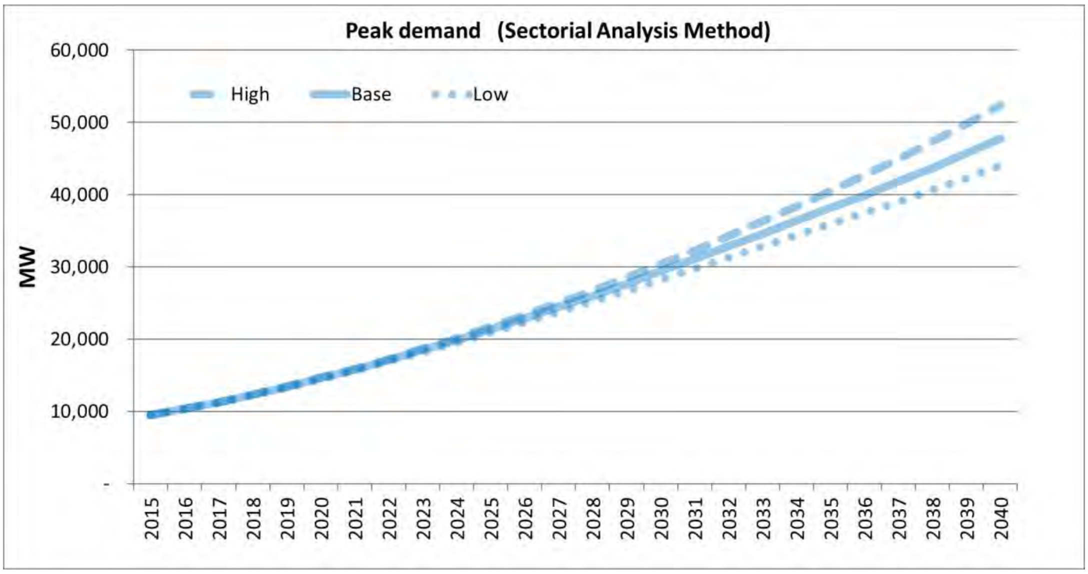
11.4.2 Peak Demand Projection Using Sectorial Analysis Method

The results of peak demand projection in “High-growth Scenario”, “Base Scenario” and “Low-growth Scenario” are shown in Table 11-9 and Figure 11-4. While the average GDP growth rates from 2015 to 2041 are 6.4% in the “High-growth”, 6.1% in the “Base” and 5.9% in the “Low-growth” scenarios, the peak demand in each scenario in 7.0% p.a. in “High-growth”, 6.7% p.a. in “Base” and 6.3% p.a. in “Low-growth”.

Table 11-9 Peak Demand Projection for Each Scenario Using Sectorial Analysis Method

	Unit	2015	2020	2025	2030	2035	2040	2041
High	MW	8,920	13,400	20,100	28,500	38,400	49,800	52,400
Base	MW	8,900	13,400	19,900	27,700	36,400	45,700	47,800
Low	MW	8,900	13,200	19,500	26,700	34,400	42,300	44,000
	Unit	2015/10	2020/15	2025/20	2030/25	2035/30	2040/35	2041/15
High	%	7.3	8.5	8.4	7.2	6.1	5.3	7.0
Base	%	7.3	8.5	8.2	6.8	5.6	4.7	6.7
Low	%	7.3	8.5	8.1	6.5	5.2	4.2	6.3

Source: JICA Survey Team



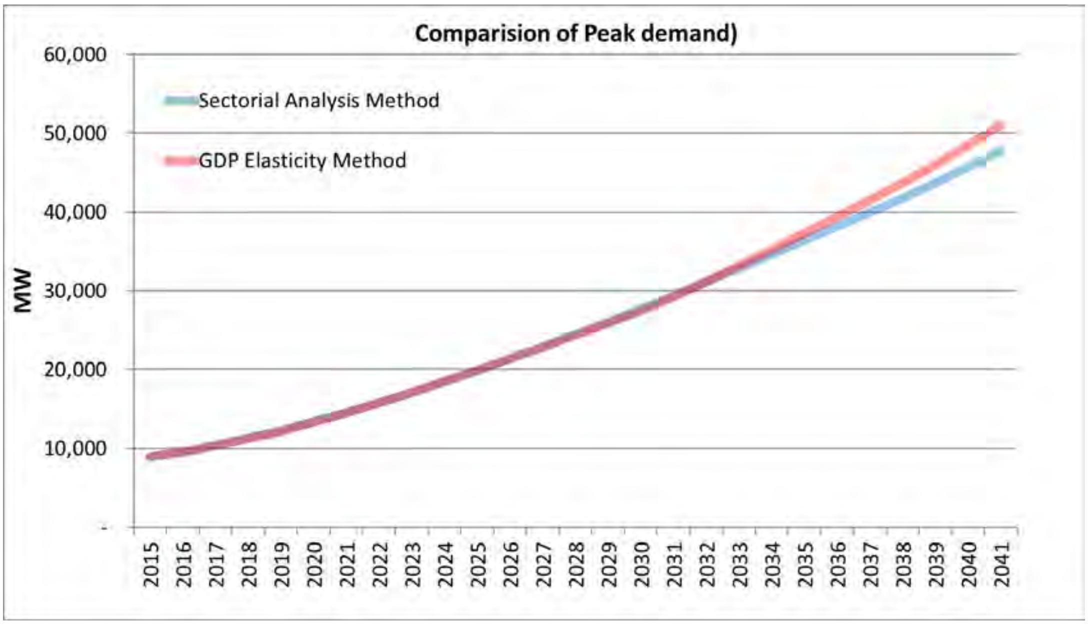
Source: JICA Survey Team

Figure 11-4 Peak Demand Projection for Each Scenario Using Sectorial Analysis Method

11.5 Verifying the peak demand forecasting model

11.5.1 Peak demand for PSMP 2016

In comparing the power demand projection between the “GDP elasticity method” and the “Sectorial analysis method”, this study concluded that the results are almost identical, though the latter exceeded the former by about 5%. Therefore, this study adopted a peak demand projection using the "GDP elasticity method”, which is an easier approach and thus easy for technology transfer to local counterpart agencies who are expected to take over the work in a rolling plan.



Source: JICA Survey Team

Figure 11-5 Comparison of Peak Demand Projection Results

11.5.2 Integration of peak power demand projection and energy supply-demand projection

Following the projection of peak power demand as formulated above, this study calculated the available electricity supply from the power grid by multiplying the annual load factor, and then compared this with the projection of total electricity consumption that was discussed in chapter 6 in the projection of primary energy supply and demand. The results are shown in Table 11-10 and 6. Because the "Total electricity consumption (B)" includes the factories' own consumption from captive power generation, it becomes larger than the "Available supply from the grid (A)". (C), which is the difference between (B) and (A), indicates the own consumption of electricity from captive power generation.

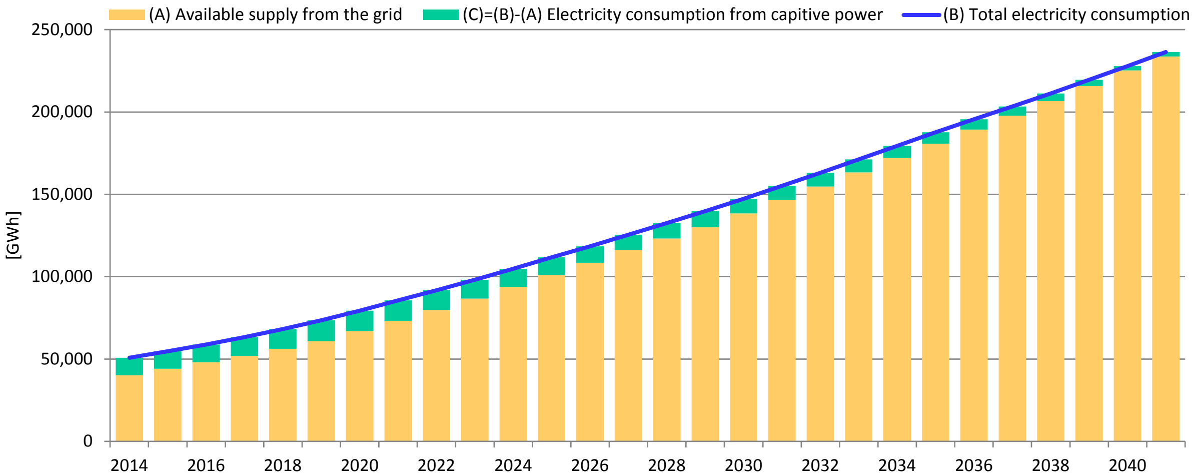
As discussed in chapter 6, this study confirmed that the electricity consumption using captive power generation accounts for a considerable share in the industrial sector at this moment because of the insufficient supply from the grid and the low price of natural gas. It is desired that, in the future, utilization of captive power generation will decline and shift to electricity purchase from the grid, , except for the case of factories using a highly efficient cogeneration system, as the supply capacity of the grid will be strengthened and the revision of gas price for captive power. In order to achieve this, the supply capacity of the grid needs be expanded beyond the growth of total electricity demand.

As shown in the following table and figure, the gap between the "Available supply from the grid (A)" and the "Total electricity consumption (B)" including the own consumption from captive power will be narrowed after 2020, which implies that the grid will gradually gain capacity to absorb the captive consumption. This study therefore confirms, by overviewing the "energy & power supply-demand projection", which is the integration of the power demand projection in this chapter, and the energy supply and demand projection in chapter 6, that this power demand projection complies with the long-term policy of the GoB to reduce the dependence on captive power generation by expanding and modernizing the electricity supply from the grid.

Table 11-10 Projection of Available Power Supply from the Grid, Total Electricity Consumption and Consumption from Captive Power Generation

		2015	2020	2025	2030	2035	2041
(A) Available supply from the grid		**44,171**	**66,937**	**101,036**	**138,439**	**180,715**	**233,677**
(B) Total electricity consumption		**54,743**	**79,370**	**111,735**	**147,274**	**187,721**	**236,391**
	Residential	19,636	26,500	34,658	42,429	51,984	62,800
	Industrial	30,103	46,302	68,511	94,297	122,958	158,246
	Commercial and public services	3,165	4,305	5,738	7,183	8,915	10,946
	Others (agriculture etc.)	1,839	2,263	2,828	3,365	3,864	4,399
(C)=(B)-(A) Electricity consumption from captive power		**10,572**	**12,433**	**10,699**	**8,835**	**7,006**	**2,715**

Source: JICA Survey Team



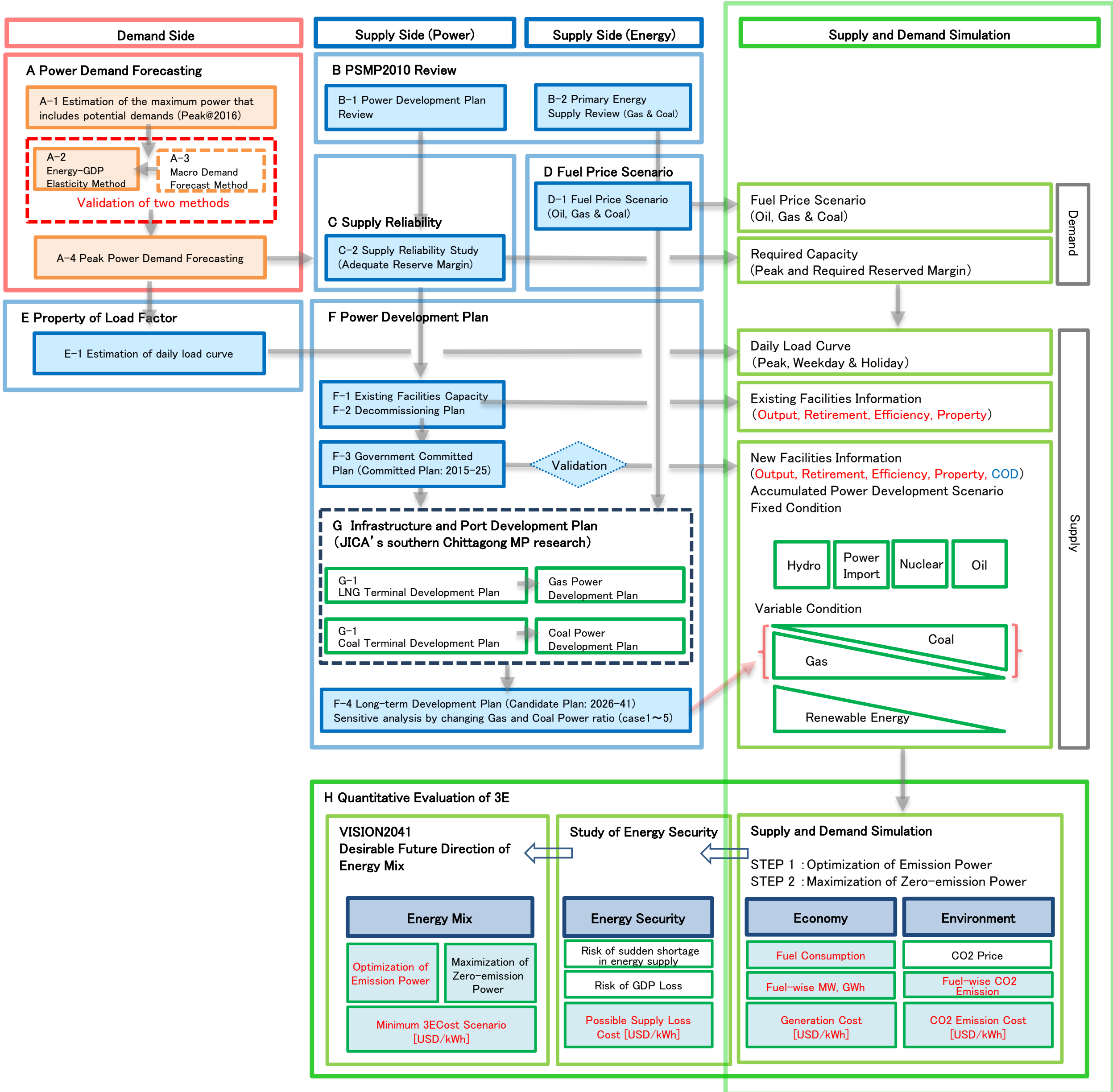
Source: JICA Survey Team

Figure 11-6 Projection of Total Electricity Consumption
(Power Supply from the Grid, Total Electricity Consumption and Consumption from Captive Power Generation)

11.6 Power development planning

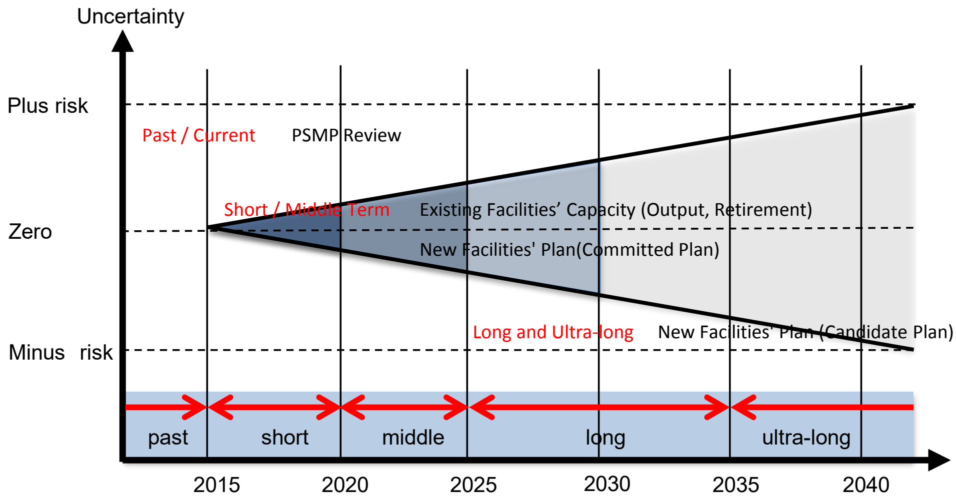
Short-term and medium-term power development plans are to be formulated after verifying the appropriateness of matters with a little short-term uncertainty (the state and retirement plans of the existing facilities and the plans approved by the Government) in the formulation of a long-term power development plan. The basic CODs of the gas and coal power plants in the long-term and candidate plans are to be determined in conformity with the port and fuel depot infrastructure development plan to be formulated separately in the "Data Collection Survey on Integrated Development for Southern Chittagong Region (Southern Chittagong MP Survey)."

The optimum power source composition is to be determined in the preparation of the future vision of the power source composition by conducting a quantitative evaluation of the economic, environmental and energy security (3E) values of scenarios with different composition ratios for the gas and coal power generation. Different composition ratios for the gas and coal power generation within ranges that are consistent with the infrastructure development plan in the Southern Chittagong MP Survey are to be used in the scenarios, particularly for the highly unpredictable periods for the long-term and candidate plans. The figure below shows the actual flow for the evaluation.



Source: JICA Survey Team

Figure 11-7 Power Development Planning flow



Source: JICA Survey Team

Figure 11-8 Relationship between the Time Scale and the Change in Risk in the Formulation of the Power Development Plan

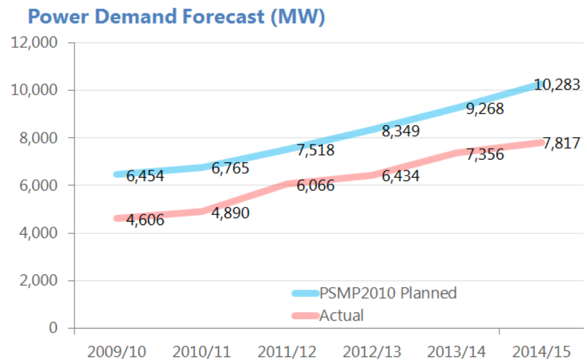
11.7 Review of PSMP 2010

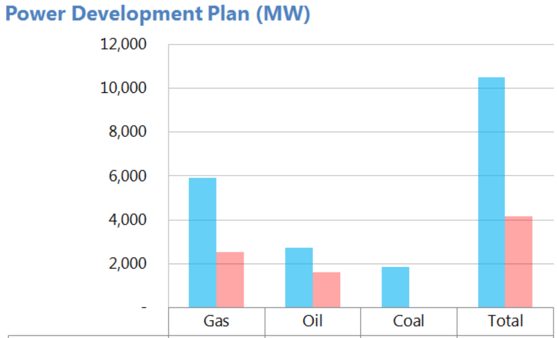
11.7.1 Review of the power development plan

The figure below shows the five-year power demand forecast in PSMP 2010 and the actual power demand. When PSMP 2010 was formulated five years ago, the demand was estimated to increase to around 10,000 MW by 2015. However, the actual demand in 2015 was approximately 80% of the estimate, around 8,000 MW.

The increase in the power demand, including potential demand driven by the rapid economic development in recent years, is expected to continue. The shortage of supply is considered to be the main cause of the continuation of this imbalance between the supply and demand. The figure below shows that the actual outputs of the gas and coal thermal power generation were only at 40% and 60% of the outputs described in PSMP 2010, respectively. In the case of the coal thermal power generation, a very important base load power source in the energy mix, while the output in 2015 was forecast at 1,850 MW in PSMP 2010, even the construction of coal power plants has not been commenced five years after the formulation of the plan. The lack of integrated planning and implementation for the construction of large-scale port facilities, indispensable for the stable import of fuel, and the construction of the power plants and the increased difficulty in fundraising for such a large-scale infrastructure development are considered to be major factors in the failure to develop power generating facilities as planned.

Therefore, it is considered necessary for the Energy Division and the Power Division to develop an organizational structure and operating system more integrated than before. They must also make concerted efforts to formulate a joint infrastructure development plan, to raise funds in the public-private partnership and to develop infrastructure systematically in order to achieve a stable energy supply, a source of future economic development.





	Gas	Oil	Coal	Total
PSMP2010 Planned	5,893	2,743	1,850	10,486
Actual	2,546	1,598	-	4,144

Source: JICA Survey Team

Figure 11-9 Review of the power development plan

11.7.2 Review of gas supply

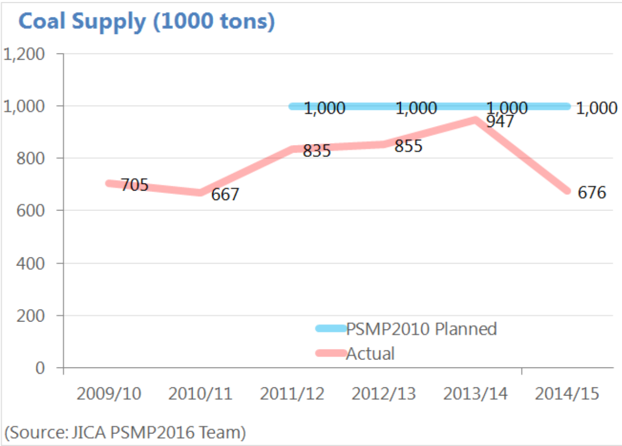
5-year gas supply projection in the PSMP 2010 was reviewed against the actual supply records from 2009/10 through to 2014/15. The results show that the actual supply figure is 15 points lower than that of the projected figures. The projection was made based on the gas reserve data by Hydrocarbon Unit (HCU) (2011); however, the projection did not reflect the gas field development plan or investment plan for new and/or existing gas fields after 2010/11. There are also differences in the gas reserve data between Hydrocarbon Unit (HCU) (2011) and USGD/Petrobangla. Hydrocarbon Unit (HCU) (2011) uses P90/P50/P10 while USGD/Petrobangla uses P95/Mean/P05 for gas reserve assessment; hence, the USGD/Petrobangla gas reserve appears smaller. The difference between the projection and actual is considered a combination of all these factors.

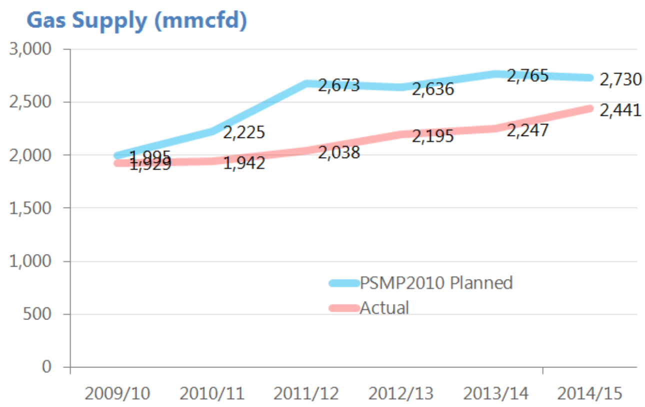
11.7.3 Review of coal supply

The figure and table below show the performance and the forecast for coal production in PSMP 2010. Annual production of 1 million tons will be possible using existing facilities. New long-wall mining equipment called LTCC (Long-wall Top Coal Caving) for thick coal seams was introduced in May 2013 from China and the mining was height increased from 3 meters to about double this. Actual mining height is not clear, but mining efficiency was obviously improved. The coal production in 2013/14 achieved 0.947million tons. However, in 2014/15, the figure decreased to 0.676 tons. The main reason was the delay in withdrawal and installation of the new equipment at sites. It is normal for it to take time for people to become skilled in the use of new equipment. If they can master the operation technology of the new facilities, it is surmised that 1,000,000t is quite possible.

11.7.4 Relationship between fuel consumption in power and primary energy balance

In this Manter Plan, it is very much important to establish a link between the energy balance and the power balance taken into account in order to maintain consistency between the fuel consumption expected in the power development plan up to 2041 and the energy balance described in detail in the previous chapter.





Source: JICA Survey Team

Figure 11-10 Review of the coal and gas supply

11.8 Examination of existing generation capacity

11.8.1 Existing capacity (Total)

The installed capacity of existing plants was determined as described below after discussions with the organizations concerned in Bangladesh. The installed capacity of existing plants is 10,895MW as of 2015. Lists of existing plants for each fuel type are shown below.

Table 11-11Existing capacity as of FY2015 [MW]

Gas	Existing	6,780
Oil	Existing	3,202
Coal	Existing	182
Sub Total	Existing	10,165
Hydro	Existing	230
Power Imports	Existing	500
Grand Total	Existing	10,895

Source: JICA Survey Team

11.8.2 Gas-based power

The list of existing gas-fired power plants is as follows and the total capacity is 6,780MW.

Table 11-12 Existing gas-based capacity as of FY2015 [MW]

No.	Gas Plant (Existing)	Type			COD	Retirement	Operation Period	Output (MW)
1	Raojan (Chittagong) 2x210 MW	Public	ST	Gas	1993	2023	31	166
2	Raojan (Chittagong) 2x210 MW	Public	ST	Gas	1993	2023	31	166
3	SIKALBAHA (Chittagong) (60 MW)	Public	ST	Gas	N/A	2016	-	39
4	Shikalbaha 150 MW PP	Public	GT	Gas	2010	2030	21	147
5	Ashuganj (B.Baria) 2x64 MW ST	Public	ST	Gas	1970	2017	48	89
6	Ashuganj (B.Baria) 3x150 MW ST	Public	ST	Gas	1986	2021	36	366
7	Ashuganj (B.Baria) 56 MW GT)	Public	CC	Gas	1986	2017	32	39
8	Ashugonj 50 MW Engine	Public	RE	Gas	2011	2031	21	44
9	Ashugonj 225 CCPP	public	GT	Gas	N/A	2040	-	218
10	Chandpur 150 MW CCPP	Public	CC	Gas	2012	2038	27	158
11	Ghorasal (Polash, Norshindi) 2x55 MW ST 1&2	Public	ST	Gas	1974	2019	46	78
12	Ghorasal (Polash, Norshindi) 210 MW ST 3,4,5&6	Public	ST	Gas	1986	2026	41	672
13	SIDDHIRGANJ (210 MW)	Public	ST	Gas	2004	2035	32	138
14	SIDDHIRGANJ 2x120 MW)	Public	GT	Gas	2012	2032	21	206
15	HARIPUR (96 MW) (Narayangonj)	Public	GT	Gas	1987	2017	31	59
16	Haripur 412 MW CCPP (EGCB)	Public	CC	Gas	2014	2039	26	400
17	TONGI (105 MW) (Dhaka)	Public	GT	Gas	2005	2025	21	103
18	Shahjibazar (Hobigonj) 2x35 MW GT 8&9	Public	GT	Gas	N/A	2019	-	65
19	Lump GT Publick Gas ~30MW (SYLHET (20 MW)）	Public	GT	Gas	1986	2018	33	19
20	SYLHET (150 MW) PP	Public	GT	Gas	2012	2018	7	139
21	Fenchuganj 97 & 104 MW CC BPDB	Public	CC	Gas	2011	2020	10	165
22	p GT Publick Gas ~100MW (Baghabari (Sirajgonj) 71 MW	Public	GT	Gas	1991	2020	30	69
23	Baghabari (Sirajgonj) 100 MW GT	Public	GT	Gas	2001	2025	25	98
24	Sirajgonj 210 MW CCPP (1st Unit)	Public	GT	Gas	N/A	2037	-	204
25	RPCL (Mymenshing) (210 MW)	Private		Gas	2006	2031	26	202
26	Haripur Power Ltd. (360 MW)	Private		Gas	2001	2026	26	360
27	Meghnaghat power Ltd. (450 MW)	Private		Gas	2002	2027	26	450
28	Ghorasal 108 MW IPP (Regent Power))	Private		Gas	2014	2029	16	108
29	Ashugonj 195 MW Modular PP	Private		Gas	N/A	2035	-	195
30	Bibiana-II 341 MW CCPP (Summit)	Private		Gas	N/A	2040	-	341
31	Bogra 15 Years RPP (GBB)	Private		Gas	2009	2023	15	22
32	Kumargoan, Sylhet RPP (Energyprima)	Private		Gas	N/A	2018	-	50
33	Shahjibazar 15 Yrs RPP (Shahjibazar Power)	Private		Gas	2009	2024	16	86
34	Shahjibazar RPP (Energyprima)	Private		Gas	2008	2017	10	50
35	Tangail SIPP (Doreen)	Private		Gas	2008	2024	17	22
36	Feni SIPP (Doreen)	Private		Gas	2009	2024	16	22
37	s Rental ~50 MW (Kumkargoan, Sylhet 15 Years RPP (Des	Private		Gas	2009	2024	16	10
38	Barobkundo SIPP (Regent Power)	Private		Gas	2009	2024	16	22
39	Bhola 3 Years RPP (Venture)	Private		Gas	2009	2017	9	33
40	Jangalia, Comilla SIPP (Summit))	Private		Gas	2009	2024	16	33
41	Fenchuganj 15 Years RPP (Barakatullah)	Private		Gas	2009	2024	16	51
42	Ashugong 55 MW RPP (Precision Energy))	Private		Gas	2010	2018	9	55
43	Fenchugonj RPP (Energy Prima)	Private		Gas	2012	2017	6	44
44	Ghorasal 45 MW QRPP (Aggreko)	Private		Gas	2010	2018	9	45
45	Ghorasal 100 MW QRPP (Aggreko)	Private		Gas	2012	2018	7	100
46	B. Baria 70 MW QRPP (Aggreco)	Private		Gas	2011	2017	7	85
47	p Gas Rental ~100 MW (Ghorasal 78 MW QRPP (Max Po	Private		Gas	2011	2020	10	78
48	Ashugonj 80 MW QRPP (Aggreko)	Private		Gas	2011	2016	6	95
49	Ashugonj 53 MW QRPP (United Power)	Private		Gas	2011	2019	9	53
50	Shajahanullah Power Com. Ltd.	Private		Gas	2010	2020	11	25
51	Summit Power(REB)	Private		Gas	1984	2022	39	105
52	Bogra RPP (Energy Prima)	Private		Gas	2011	2024	14	20
53	Lump SIPP Gas (Hobiganj SIPP (REB) (Confi-Energypac)	Private		Gas	2011	2024	14	11
54	Ullapara SIPP (REB) (Summit)	Private		Gas	2009	2024	16	11
55	Narsindi SIPP (REB) (Doreen)	Private		Gas	2008	2024	17	22
56	Feni SIPP (REB) (Doreen)	Private		Gas	2008	2024	17	11
57	Mouna, Gazipur SIPP (REB) (Summit)	Private		Gas	2009	2024	16	33
58	Rupganj , Narayanganj SIPP (REB) (Summit)	Private		Gas	2009	2024	16	33
59	Ashugonj 51 MW IPP (Midland)	Private		Gas	N/A	2028	-	51
							Total MW	6,780

Source: JICA Survey Team

11.8.3 Coal-based power

The list of existing coal-fired power plants is as follows and the total capacity is 182MW.

Table 11-13Existing coal-based capacity as of FY2015 [MW]

No.	Coal Plant (Existing)	Type	COD	Retirement	Operation Period	Output (MW)
1	Barpapukuria 250MW (Unit 1&2)	Coal Domestic	2000	2036	37	182

Source: JICA Survey Team

11.8.4 Oil-based power

The list of existing oil-fired power plants is as follows.

Table 11-14Existing oil-based capacity as of FY2015 [MW]

No.	Oil Plant (Existing)	Type			COD	Retirement	Operation Period	Output (MW)
1	Hathazari 100 MW Peaking PP	Public	RE	F.oil	2011	2032	22	96
2	Sangu, Dohazari 100 MW Peaking PP	Public	RE	F.oil	2012	2033	22	99
3	Lump HFO Public ~50 MW (Raojan 25 MW Peaking PP)	Public	RE	F.oil	2013	2033	21	25
4	Gazipur 52 MW PP	Public	RE	F.oil	2012	2032	21	51
5	Titas, Doudkandi 50 MW Peaking PP	Public	RE	F.oil	2011	2031	21	51
6	KHULNA (110 MW)	Public	ST	F.oil	1984	2016	33	50
7	Lump GT Public HSD ~20MW (BARISAL (40MW)	Public	GT	HSD	1984	2016	33	30
8	BHERAMARA (Kustia) (60 MW)	Public	GT	HSD	1976	2016	41	46
9	Khulna 150 MW PP (NWPGCL)	Public	GT	HSD	2013	2017	5	155
10	Faridpur 50 MW Peaking PP)	Public	RE	F.oil	2011	2031	21	52
11	Gopalgonj 100 MW Peaking PP)	Public	RE	F.oil	2011	2032	22	107
12	BAGHABARI 50 MW Peaking PP	Public	RE	F.oil	2011	2031	21	51
13	Lump HFO Public ~100 MW (BERA 70 MW Peaking PP	Public	RE	F.oil	2011	2032	22	70
14	RANGPUR (20 MW)	Public	GT	HSD	1988	2016	29	19
15	SAIDPUR (20 MW) (Dinajpur)	Public	GT	HSD	1987	2016	30	19
16	Santahar 50 MW Peaking PP	Public	RE	F.oil	2012	2032	21	49
17	Katakhali 50 MW Peaking PP	Public	RE	F.oil	2012	2032	21	49
18	KPCL BMPP 15 Years (Khulna) (Summit-United)	Private		F.oil	1998	2018	21	110
19	NEPC (110 MW) (Haripur BMPP)	Private		F.oil	1999	2019	21	110
20	Natore 52 MW IPP (Raj-Lanka)	Private		F.oil	2014	2029	16	52
21	Summit Meghnaghat Power Company Ltd. CCPP	Private		HSD	2015	2040	26	305
22	Gognagar 102 MW PP (Summit)	Private		F.oil	2014	2029	16	102
23	Baraka-Potenga 50 MW IPP	Private		F.oil	2014	2029	16	50
24	Potiya, Chittagong 100 MW Power Plant	Private		F.oil	2015	2030	16	108
25	Jangalia, Comilla (Lakdanvhi)	Private		F.oil	N/A	2030	-	52
26	Kathpotty, Munshigonj 53 MW PP (Sinha)	Private		F.oil	2015	2030	16	51
27	Lump Private Existing RE HFO ~50 (Shikal Baha RPP(Energ	Private		F.oil	2014	2018	5	40
28	Thakurgaon RPP (RZ Power)	Private		HSD	2015	2018	4	40
29	Khulna 55 MW QRPP (Aggreko))	Private		HSD	2010	2018	9	55
30	Lump HSD Rental ~50 MW (Pagla 50 MW QRPP (DPA)	Private		HSD	2010	2018	9	50
31	Bheramara 110 MW RPP (Quantum Power))	Private		HSD	2010	2018	9	105
32	Lump HSD Rental ~100 MW (Shiddirgonj 100 MW QRPP (	Private		HSD	2011	2019	9	98
33	Lump Private Existing RE HFO ~100 (Madangonj 102 MW	Private		F.oil	2011	2021	11	100
34	Khulna 115 MW QRPP (KPCL) (Summit-United)	Private		F.oil	2011	2021	11	115
35	Noapara 40 MW QRPP (Khan Jahan Ali)	Private		F.oil	2011	2029	19	40
36	Noapara 105 MW RPP (Quantum Power)	Private		F.oil	2011	2016	6	101
37	Meghnaghat 100 MW QRPP (IEL)	Private		F.oil	2011	2021	11	100
38	Siddirganj 100 MW QRPP (Dutch Bangla Power)	Private		F.oil	2011	2021	11	100
39	Amnura 50 MW QRPP (Sinha Power)	Private		F.oil	2012	2018	7	50
40	Keranigonj 100 MW QRPP (Power Pak)	Private		F.oil	2012	2017	6	100
41	Julda100 MW QRPP (Acron Infra Servicw)	Private		F.oil	2012	2018	7	100
42	Katakhali 50 MW QRPP (NPSL)	Private		F.oil	2012	2019	8	50
							Total MW	3,202

Source: JICA Survey Team

11.8.5 Hydropower

The list of existing hydropower plants is as follows and the total capacity is 230MW by only Kaptai Hydro Power Plant.

Table 11-15Existing hydropower capacity as of FY2015 [MW]

No.	Hydro Plant (Existing)	Type	COD	Retirement	Output (MW)
1	Kaptai Hydro Power Plant	Hydro	2000	9999	230

Source: JICA Survey Team

11.8.6 Power import

The list of existing power import is as follows and the total capacity is 500MW by only Bheramara-Bharampur HVDC (phase 1).

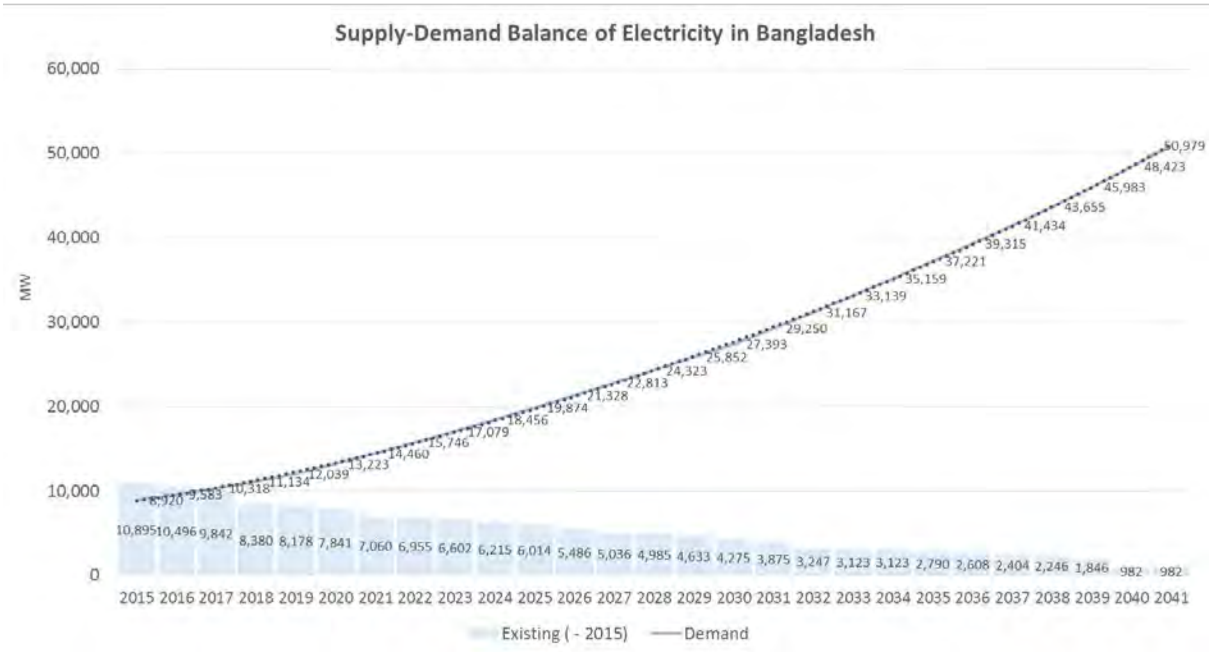
Table 11-16 Existing power import capacity as of FY2015 [MW]

No.	Power Import (Existing)	Type	COD	Retirement	Output (MW)
1	Bheramara-Bharampur HVDC Phase 1(from India)	HDVC	2013	9999	500

Source: JICA Survey Team

11.8.7 Retirement Plan

The lists of the existing power generation facilities above show their CODs, retirement years and operation periods. Analysis of these data has revealed that the average operation period for these power plants is approximately 20 years. It is difficult to improve the efficiency of the existing inefficient plants significantly because of the large cost required for such improvements. For these reasons, it has been concluded that the retirement plans prepared by the government are appropriate. The adoption of a strategy aiming at improving the efficiency of the entire power supply network by retiring the existing inefficient power plants gradually and replacing them with new, efficient facilities is considered essential for realizing the maximum use of the limited resources.



Source: JICA Survey Team

Figure 11-11 Esisting capacity considering retirement plan

11.9 Evaluation of the Plan Approved by the Government (Committed Plan)

Some of the facilities to be constructed are mentioned in the plan approved by the government (Committed Plan), confirmed by the Survey Team jointly with the persons involved in power development in the Bangladeshi Government, while the others are mentioned in a plan to be approved that is subject to changes (Candidate Plan).
The table below shows the capacities by fuel type of the power plants mentioned in the Committed Plan. Power plants with a total output capacity of approximately 14,000 MW are to be constructed in the next ten years.

Table 11-17 Comitted generation plan [MW]

Fuel type	Status	Capacity (MW)
Gas	committed	5,126
Coal	committed	6,543
Oil	committed	2,545
Total	committed	14,213

Source: JICA Survey Team

11.9.1 Gas-bsed power

The list of committed gas-fired power is as follows.

Table 11-18 Comitted plan of gas-fired generation [MW]

No.	Gas Plant (Committed)	Type		COD	Retirement	Output (MW)
1	Bhola 225 MW CCPP: SC GT Unit	BPDB	Gas	2016	2041	189
2	Siddirganj 335 MW CCPP: SC GT Unit	EGCB	Gas	2016	2041	328
3	Ashuganj (South) 450 MW CCPP	APSCL	Gas	2017	2042	370
4	Ashuganj (South) 450 MW CCPP	APSCL	Gas	2016	2041	361
5	Ghorasal 363 MW (7th Unit) CCPP	BPDB	Gas	2017	-	352
6	Shajibazar CCPP	-	Gas	2016	2041	322
7	Shikalbaha 225 MW CCPP	-	Gas	2017	-	218
8	Bibiana South CCPP BPDB	-	Gas	2018	-	372
9	Bibiana III CCPP BPDB	-	Gas	2019	-	388
10	Bheramara 414 MW CCPP	NWPGC	Gas	2018	2042	402
11	Fenchugonj 50 MW Power Plant	IPP/NRB	Gas	2019	2034	50
12	Sylhet 150 MW PP Conversion (Additional 75MW)	BPDB	Gas	2018	2042	221
13	Ghorasal 3rd Unit Repowering (Capacity Addition)	BPDB	Gas	2018	2042	776
14	Kusiara 163 MW CCPP	IPP	Gas	2018	-	163
15	Bagabari 100 MW PP Conversion	BPDB	Gas	2020	2042	102
16	Sirajganj 414 MW CCPP (4th unit)	-	Gas	2020	2043	414
17	Shahajibazar 100 MW	-	Gas	2018	2038	98
					Total MW	5,126

Source: JICA Survey Team

11.9.2 Coal-bsed power

The list of committed coal-fired power is as follows.

Table 11-19 Comitted plan of coal-fired generation [MW]

No.	Coal Plant (Committed)	Type				COD	Retirement	Output (MW)
1	Barapukuria 275MW (Unit 3)					2019	-	252
2	Matarbari#1,2	Public	CPGCBL	USC	Imp Coal	2023	-	1104
3	Rampal#1,2	Public	BIFPCL	SC	Imp Coal	2020	-	1214
4	Payra#1,2	Public	NWPGCL	SC	Imp Coal	2020	-	1214
5	Khulna	IPP	Orion Group	SC	Imp Coal	2020	-	630
6	Maowa	IPP	Orion Group	SC	Imp Coal	2020	-	522
7	Dhaka	IPP	Orion Group	SC	Imp Coal	2020	-	635
8	Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-1				Imp Coal	2020	-	612
9	Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-2				Imp Coal	2020	-	612
							Total MW	6,543

Source: JICA Survey Team

11.9.3 Oil-based power

The list of committed oil-fired power is as follows.

Table 11-20 Comitted plan of oil-fired generation [MW]

No.	Oil Plant (Committed)	Type	COD	Retirement	Output (MW)
1	Kodda, Gazipur 150 MW Power Plant	Oil	2016	2035	147
2	Chapai Nababganj 104 MW PP	Oil	2017	2032	102
3	Keranigonj 100 MW PP (Re from Khulna))	Oil	2019	2034	100
4	Bosila, Keranigonj 108 MW PP (CLC Power)	Oil	2017	2032	108
5	Jamalpur 100 MW Power Plant	Oil	2017	2032	95
6	Barisal 100 MW PP (Re. from Syedpur)	Oil	2016	2031	110
7	Lump HFO Private New ~50 MW (Madangonj 50 MW Pea	Oil	2016	2031	55
8	Manikgonj 55 MW PP	Oil	2016	2031	50
9	Kamalaghat 50 MW PP)	Oil	2017	2032	55
10	Nababgonj 55 MW PP	Oil	2016	2031	55
11	Satkhira 50 MW PP	Oil	2019	2034	50
12	Bhairab 50 MW PP	Oil	2019	2034	50
13	Upgradation of Khulna 150 MW to 225 MW	Oil	2017	2037	221
14	Khulna 200-300 MW CCPP	Oil	2019	2039	196
15	Patiya 100 Mw BOO FO power plant	Oil	2020	2035	100
16	Anwara 300 MW HFO plant	Oil	2022	2037	300
17	Julda 100 Mw BOO FO power plant	Oil	2020	2035	100
18	Sirajgonj 225 MW CCPP (2nd Unit)	Oil	2019	2039	216
19	Sirajgonj 225 MW CCPP (3rd Unit)	Oil	2020	2040	216
20	Bhola 220 MW CCPP Dual Fuel BOO power plant	Oil	2021	2041	220
				Total MW	2,545

Source: JICA Survey Team

11.9.4 Hydropower

The list of committed hydropower is as follows.

Table 11-21 Comitted plan of hydropower generation [MW]

No.	Hydro Plant (Committed)	Type	COD	Retirement	Output (MW)
1	New Kaptai Pumped Strage	Hydro	2030	9999	100

Source: JICA Survey Team

11.9.5 Power import

The list of committed power import is as follows.

Table 11-22 Comitted plan of power import [MW]

No.	Power Import (Committed)	Type	COD	Retirement	Output (MW)
1	Comilla - Tripura HVDC Phase 1-1 (100MW) (India)	PI	2016	9999	100

Source: JICA Survey Team

11.9.6 Nuclear power

The list of committed nuclear is as follows.

Table 11-23 Comitted plan of nuclear power [MW]

No.	Nuclear Plant (Committed)	Type	COD	Retirement	Output (MW)
1	Roopoor 1st Unit	Nuclear	2024	9999	1,116
2	Roopoor 2nd Unit	Nuclear	2025	9999	1,116

Source: JICA Survey Team

11.9.7 Validation of commissioning date

The current status of each thermal power development plan was confirmed based on the discussion with related companies, such as BPDB, BIFPCL, CPGCBL, NWPGCL, Orion Group, etc. The following tables shows the current status of thermal power plans for imported coal and LNG respectively.

(1) Coal-fired power generation

Matarbari #1 and 2, Matarbari/Maheshkhali #1, 2 and 3, Rampal #1 and 2, Payra #1 and 2, Maowa, Khulna and Chittagong projects are in progress. However, Rampal #1 and 2, Khulna and Maowa have some problems with environmental and financial issues. The location of Rampal #1 and 2 is near the Sundarbans, the largest Mangrove Forest in the world and a world heritage site as declared by UNESCO in 1997. Activists are concerned that the Rampal #1 and 2 projects, less than 10 miles from the protected Sundarbans mangrove forest, would lead to its environmental degradation from increased ship traffic, dredging and the pollution of air and water. The Khulna and Maowa projects also have financial issues with low tariffs for power supply and delays in EIA approval.

(2) Gas-fired power generation

a) Indian Reliance Power Limited

BPDB has signed an MOU with Indian Reliance Power Limited to install a 3,000MW regasified liquefied gas-based combined cycle power plant (Energy Bangla, on June 6, 2015).
Indian Reliance Power Limited has proposed two separate tariff structures between TK 7.99 and TK 8.22 per unit for implementing an LNG-based mega power project having the capacity to generate 3,000MW of electricity in three phases at Meghnaghat (Phase 1; 750MW), Chittagong (Phase 2; 1,500MW) and Maheshkhali (Phase 3; 750MW) (Energy Bangla, on September 14, 2015).

b) Adani Power limited

BPDB has signed an MOU with Adani Power Limited to install a 1,600MW ultra super critical coal-based power plant (Energy Bangla, on June 6, 2015).

c) Summit Group

Summit Group will invest at least $1 billion to install 1,310MW of electricity by 2020 (Energy Bangla, on June 28, 2015)

d) Shapoorji Pallonji Infrastructure Capital Company Ltd

Shapoorji Pallonji Infrastructure Capital Company Ltd proposed earlier to move its existing power project (225MW, dual-fuel power) at Udamsingnagar district under Uttarakhand Pradesh in India to Bhola (Energy Bangla, on August 19, 2015).

The current plans for the thermal power generation with imported coal and LNG are shown in the tables below. The Survey Team held sufficient discussion with the Government of Bangladesh and conducted a detailed study on the commissioning dates of individual power plants for the formulation of the power development plan. The team decided the dates on the basis of the outcomes of the discussion and study.

Table 11-24 Development status of gas-bsed power generation projects

Project	Capacity(MW)	Public	MOU	Government: F/S	Preliminary Development Project Proposal (PDPP) Financial source selection	Development Project Proposal (DPP), IEE, EIA)	Owner's Engineer Consultant selection	Tendering Process for EPC (including D/D)	–	Contract signed: PPA	Contract signed: –	Contract signed: Land lease agreement/land acquisition	Contract signed: Fuel supply agreement	Government: Completion of IEE/EIA	Financial closure for ECA	–	Construction	COD	GOB
Matarbari																			
Matarbari#1,2	1,200	Public(CPGCBL)	■	■	■	■	■	■	–		–			■		–			2023
Matarbari/Maheshkhali#1	600	Public(CPGCBL)							–		–					–			2026
Matarbari/Maheshkhali#2	600	Public(CPGCBL)							–		–					–			2027
Matarbari/Maheshkhali#3	600	Public(CPGCBL)							–		–					–			2027
Matarbari/Maheshkhali#4	600	Public(CPGCBL)							–		–					–			2032
Matarbari/Maheshkhali#5	600	Public(CPGCBL)							–		–					–			2033
Matarbari/Maheshkhali#6	600	Public(CPGCBL)							–		–					–			2034
Matarbari/Maheshkhali#7	600	Public(EGCB)							–		–					–			2036
Maheshkhali																			
Matarbari/Maheshkhali#8	1,000	Public(JV BPDB-Huadian)	■						–		–					–			2036
Matarbari/Maheshkhali#9	1,000	Public(BPDB:ADB)							–		–					–			2037
Matarbari/Maheshkhali#10	1,000	Public(JV BPDB-TNB)	■						–		–					–			2037
Matarbari/Maheshkhali#11	1,000	Public(BPDB)							–		–					–			2038
Matarbari/Maheshkhali#12	1,000	Public(BPDB)							–		–					–			2039
Matarbari/Maheshkhali#13	1,000	Public(JV BPDB-Kepco)							–		–					–			2040
Rampal																			
Rampal#1,2	1,214	Public(BIFPCL)	■	■	■	■	■	■	–	■	–			■		–			2020
Payra																			
Payra#1,2	1,214	Public(NWPGCL)	■						–		–					–			2020
Payra West#1	600	Public(NWPGCL)							–		–					–			2028
Payra West#2	600	Public(NWPGCL)							–		–					–			2031
Payra West#3	1,000	Public(NWPGCL)							–		–					–			2041
Payra West#4	1,000	Public(NWPGCL)							–		–					–			2041

Project	Capacity(MW)	Private	MOU	Government: F/S	–	D/D	–	Tendering Process for sponsor	LOI	Contract signed: PPA	Contract signed: Implementation Agreement (IA)	Contract signed: Land lease agreement/land acquisition	Contract signed: Fuel supply agreement	Investor side: Completion of IEE/EIA	Financial closure	Appointment of EPC Contractor	Construction	COD	GOB
Others																			
Khulna	630	IPP(Orion Group)	■	■	–	■	–	■	■	■	■	■		■					2020
Maowa	522	IPP(Orion Group)	■	■	–	■	–	■	■	■	■	■		■					2020
Dhaka	635	IPP(Orion Group)	■	■	–	■	–	■	■					■					2020
Chittagong	612	IPP(S.Alam Group)	■	■	–	■	–	■	■					■					2020
Chittagong	612	IPP(S.Alam Group)	■	■	–	■	–	■	■					■					2020

Source: JICA Survey Team /JICA Southern Chittagong MP Team

Table 11-25 Development status of gas-bsed power generation projects

Project	Capacity(MW)	Public	MOU	Government: F/S	Government: Preliminary Development Project Proposal (PDPP) Financial source selection	Government: Development Project Proposal (DPP), IEE, EIA)	Government: Owner's Engineer Consultant selection	Government: Tendering Process for EPC (including D/D)	Government: I	Contract signed: PPA	Contract signed: I	Contract signed: Land lease agreement/land acquisition	Contract signed: Fuel supply agreement	Government: Completion of IEE/EIA	Government: Financial closure for ECA	Government: I	Construction	COD	
Bhola 225 MW CCPP	189	Public(BPDB)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2016
Siddirganj 335 MW CCPP	328	Public(EGCB)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2016
Ashuganj (South) CCPP	370	Public(APSCL)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2016
Shajibazar CCPP	361	Public(BPDB)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2016
Ashuganj (North) CCPP	352	Public(APSCL)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2017
Bibiana South CCPP BPDB	322	Public(BPDB)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2018
Bheramara 414 MW CCPP	218	Public(NWPGC)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2018
Shikalbaha 225 MW CCPP	372	Public(BPDB)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2017
Bibiana III CCPP BPDB	388	Public(BPDB)	■	■	■	■	■	■	I	■	I	■	■	■	■	I	■		2019
Ghorasal 363 MW (7th Unit) CCPP	402	Public(BPDB)	■	■	■	■	■	■	I	■	I	■	■	■	■	I			2017
Sylhet 150 MW PP Conversion	221	Public(BPDB)	■	■	■	■	■	■	I		I					I			2018
Ghorasal 3rd & 4th Unit Repowering (Capacity Addition)	776	Public(BPDB)	■	■	■	■	■	■	I		I					I			2018
Bagabari 71MW PP Conversion	102	Public(BPDB)	■	■	■	■			I		I					I			2020
Shahajibazar 100 MW	414	Public(BPDB)	■	■	■	■			I		I					I			2018
Sirajganj 414 MW CCPP (4th unit)	98	Public(BPDB)	■	■	■	■			I		I					I			2020

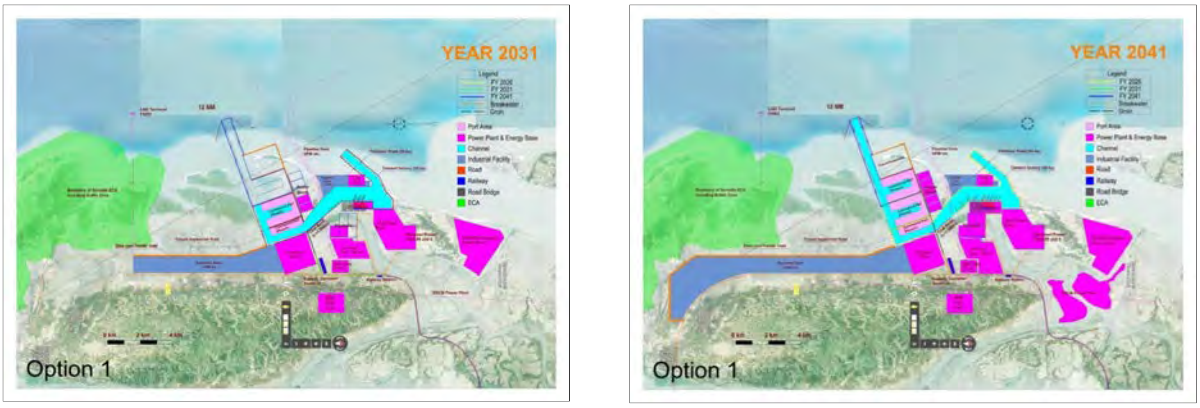
Project	Capacity(MW)	Private	MOU	Government: F/S	Government: I	Government: D/D	Government: Tendering Process for sponsor	Government: LOI	Contract signed: PPA	Contract signed: Implementation Agreement (IA)	Contract signed: Land lease agreement/land acquisition	Contract signed: Fuel supply agreement	Investor side: Completion of IEE/EIA	Investor side: Financial closure	Investor side: Appointment of EPC Contractor	Investor side: Construction	COD	GOB
Fenchugonj 50 MW Power Plant (NRB)	50	IPP/NRB	■	■	I	■	■											2019
Kushiara 163 MW CCPP	163	IPP	■	■	I	■	■	■	■	■								2018

Source: JICA Survey Team /JICA Southern Chittagong MP Team

11.10 Consistency with port infrastructure planning

11.10.1 Port infrastructure plan by JICA Southern Chittagong Master Plan

Guarantee of the long-term stability of the fuel supply is a very important factor in the formulation of a power development plan. The existence of a port infrastructure required for the importing of fuels including gas and coal during operation has to be a precondition for the decision on the CODs of new power plants, in particular.
Therefore, the infrastructure and port development plan formulated with the consent of the Government of Bangladesh in the Southern Chittagong MP Survey, implemented by JICA, was used as reference in this analysis and the CODs of the power supply facilities were set in a way consistent with the plan. The figures below show the infrastructure and port development plan (2031/2041) in the Southern Chittagong Region formulated in the Southern Chittagong MP Survey by JICA.

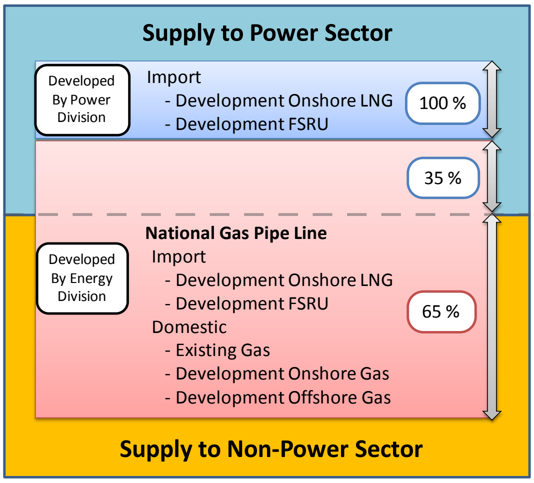


Source: JICA Southern Chittagong MP Team

Figure 11-12 Port infrastructure plan (2031/41) by JICA Southern Chittagong Master Plan

11.10.2 Allocation of natural gas supply

The following figure shows a scheme to develop natural gas in Bangladesh. The supply scheme is as follows. The gas facilities are divided into domestic gas facilities developed through the energy division, domestic on-shore and off-shore facilities to be developed in the future, on-shore LNG and off-shore FSRU facilities to be developed through the power division for imported gas.
Of the gas supplied through the energy division, 35% is supplied to the power sector and 65% to the non-power sector. The gas supplied through the power division is supplied 100% to the power sector.



Source: JICA Survey Team

Figure 11-13 Allocaion of natural gas

11.10.3 LNG terminal development scenario

The LNG development scenario will be adopted as per that which has been examined in the Southern Chittagong Master Plan Survey.

The LNG receiving terminals in the Matarbari area should be planned based on the following policies:

- There are no projects other than FSRU that are identified as “on-going”.
- It can be said that, except in the Matarbari area, it is difficult to find a suitable site for developing the multi-purpose port required for receiving a large-scale LNG carrier.
- It is economical to develop LNG receiving terminals in conjunction with the development of a multi-purpose port.

Development of onshore terminals should be planned in conjunction with the development plan for a port facility that can receive a large-scale LNG carrier.

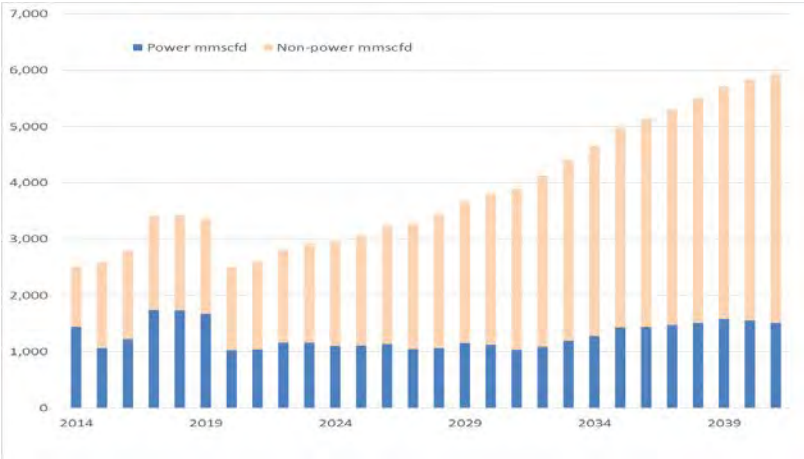
Onshore terminals generally require about four years for construction (not including land reclamation), and it is difficult to achieve early development considering the periods required for other activities such as FS, permits, design, tender, land reclamation, etc. Therefore, for FY2019 to FY2026, when the gas supply deficit emerges, FSRUs that require relatively short periods of time to begin operation (in addition to importing gas from India through a pipeline) should be introduced to correspond with the deficit. LNG receiving terminals should be developed in stages corresponding to demand increase. A standard capacity of 500 mmcfd should be adopted in each development stage.

Storage of LNG should be adequately planned considering the influence of bad weather, accidents, etc. The following table shows the proposed development scenario for LNG receiving terminals.

Table 11-26 Development scenario for LNG terminals

	Demand	Supply	Shortage	LNG (Gas) Import						Balance
	Total	Total		FSRU		Onshore Terminal		Pipeline from India	Total of Imported LNG	LNG (Gas) Import Surplus
				Energy Div		Energy Div	Power Div	NWPGCL		
Source			3 - 7						9 to 13	8 + 14
FY	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd
2015	**2,594**	**2,464**	**-130**						0	-130
2016	**2,793**	**2,653**	**-140**						0	-140
2017	**3,409**	**2,716**	**-693**						0	-693
2018	**3,422**	**2,662**	**-760**	500	0	0	0	0	500	-260
2019	**3,368**	**2,563**	**-805**	500	0	0	0	0	500	-305
2020	**2,497**	**2,547**	**50**	500	0	0	0	200	700	750
2021	**2,602**	**2,188**	**-414**	500	0	0	0	200	700	286
2022	**2,818**	**2,075**	**-744**	500	500	0	0	200	1,200	456
2023	**2,917**	**1,851**	**-1066**	500	500	0	0	200	1,200	134
2024	**2,958**	**1,747**	**-1211**	500	500	0	0	200	1,200	-11
2025	**3,081**	**1,741**	**-1340**	500	500	0	0	200	1,200	-140
2026	**3,236**	**1,766**	**-1470**	500	500	0	0	200	1,200	-270
2027	**3,279**	**1,805**	**-1474**	500	500	0	500	200	1,700	226
2028	**3,438**	**1,740**	**-1697**	500	500	0	500	200	1,700	3
2029	**3,677**	**1,696**	**-1981**	500	500	500	500	200	2,200	219
2030	**3,810**	**1,671**	**-2139**	500	500	500	500	200	2,200	61
2031	**3,903**	**1,653**	**-2250**	500	500	500	500	200	2,200	-50
2032	**4,132**	**1,642**	**-2490**	500	500	1,000	500	200	2,700	210
2033	**4,414**	**1,633**	**-2780**	500	500	1,000	500	200	2,700	-80
2034	**4,658**	**2,137**	**-2521**	500	500	1,000	500	200	2,700	179
2035	**4,981**	**2,104**	**-2877**	500	500	1,500	500	200	3,200	323
2036	**5,139**	**1,996**	**-3143**	500	500	1,500	500	200	3,200	57
2037	**5,312**	**1,996**	**-3316**	500	500	2,000	500	200	3,700	384
2038	**5,494**	**1,996**	**-3498**	500	500	2,000	500	200	3,700	202
2039	**5,721**	**1,997**	**-3724**	500	500	2,000	500	200	3,700	-24
2040	**5,837**	**1,999**	**-3838**	500	500	2,500	500	200	4,200	362
2041	**5,933**	**1,999**	**-3933**	500	500	2,500	500	200	4,200	267

Source: JICA Survey Team



Source: JICA Survey Team

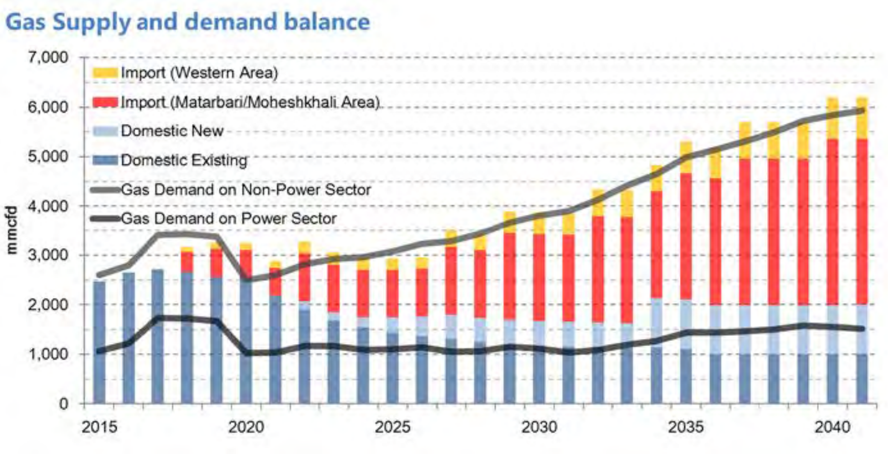
Figure 11-14 Gas Supply Scheme

From the above table, it is found that the amount of 4,000 mmcfd (2 x 500 mmcfd from the FSRU + 2,500 mmcfd from the Energy Div.'s onshore terminals + 500 mmcfd from the Power Div.'s onshore terminal) among the total demand of about 5,855 mmcfd in FY2041 should be supplied from the new LNG terminals and, if these terminals are constructed in the Matarbari area, a large portion of the total gas demand has to rely on one supply base. This situation is not preferable from the viewpoint of energy security. There may be operational problems in the existing gas supply network as well. Considering these points, it has been arbitrarily judged that the maximum supply capacity in the Matarbari area should be limited to about 50% of the total demand in FY2041 and thus, the last two onshore terminals (2 x 500 mmcfd capacity) in FY2037 and 2040 should be constructed at different locations.
Consequently, the new LNG terminals to be developed in the Matarbari area are as summarized below:

Table 11-27 New LNG Terminals to be developed in the Matarbari Area

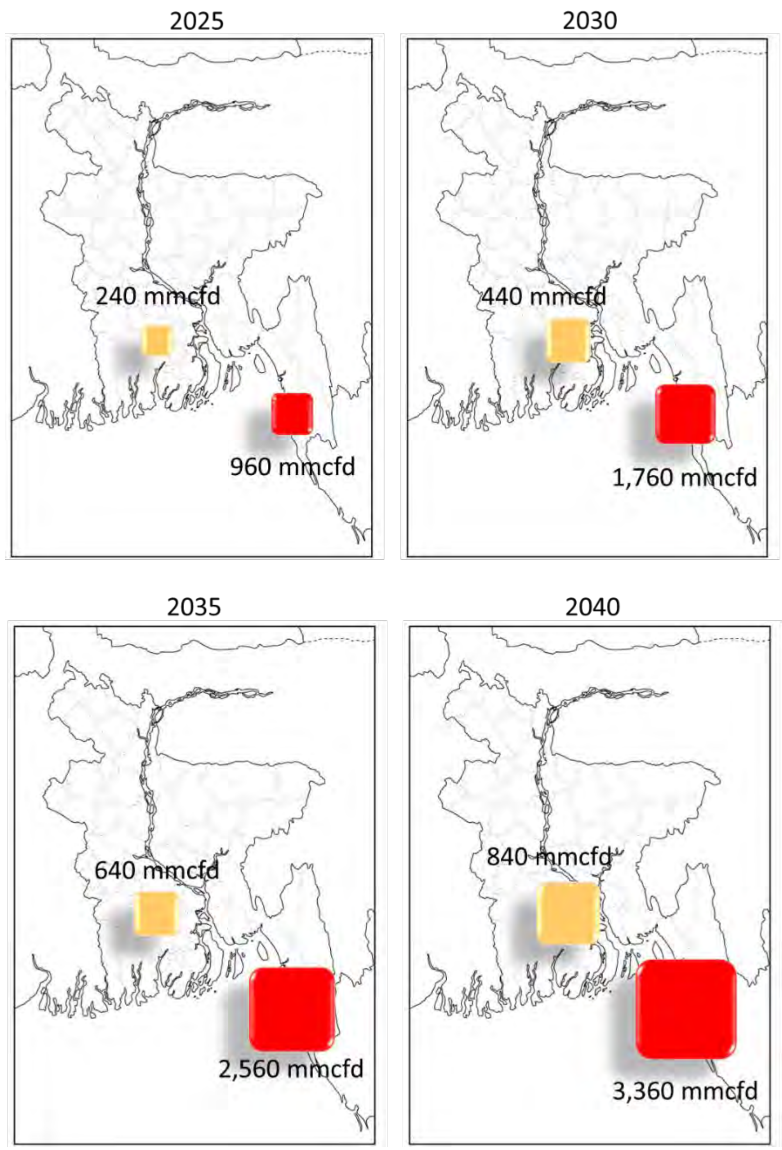
FY	Type of Terminal	Capacity (mmcfd)	Remarks
2018	FSRU	500	On-going project by Petrobangla
2022	FSRU	500	To be planned
2027	Onshore	500	To be planned
2029	Onshore	500	To be planned
2032	Onshore	500	To be planned
2035	Onshore	500	To be planned
Total Capacity		3,000	-

Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-15 Scenario to Develop Imported Gas in Each Region



Source: JICA Survey Team

Figure 11-16 Scenario to Develop Imported Gas in Each Region (Unit: mmctd)

11.10.4 Coal development scenario

(1) Existing coal development

Domestic coal production in Bangladesh is only from the Barapukuria coal mine (underground mine), which produces at present approximately 1 million tonnes annually and supplies Barapukuria power station, etc., and will produce only approximately 1.5 million tonnes annually for Barapukuria power station, etc. even after the implementation of the expansion plan. Although Phulbari coal mine has a huge reserve, its development was cancelled by the current government because many people needed to be resettled for the development. As the production of domestic gas and coal will not increase against the surge in power demand in future, imported coal and LNG will be necessary.

(2) New coal terminal development scenario

As for coal transportation from coal production countries, such as Australia, Indonesia and South Africa to Bangladesh, using larger vessels is a cost-effective transportation method. A Panamax vessel (80,000DWT) can access near Matarbari #1 and 2, and Matarbari/Maheshkhali #1, 2 and 8-13 project sites, if a multi-purpose port at Maheshkhali Island is constructed. On the other hand, the vessel cannot access near Maowa, Khulna, Chittagong, Rampal, Payra or Matarbari/Maheshkhali #3-7 project sites, because of the very shallow bay around these project sites. These projects may use onshore coal terminals or offshore coal trans-shipment stations to reduce fuel transportation costs.

As per the discussion with the power companies, that is, BIFPCL, CPGCBL, NWPGC, and Orion Group, etc., the following information was supplied.

a) Ramapal Project

Rampal projects will use an offshore coal trans-shipment station. An 8,000DWT-10,000DWT barge from the station to project sites has been considered. However, these projects will use CTT, in the case that the COD of CTT is earlier than the COD of the Rampal projects, and the tariff for the terminal is cheaper than the operation costs for the offshore coal trans-shipment station.

b) PayraProject

A deep sea port will be constructed at Payra, which also has a coal terminal.

c) Maowa and Khulna Project

Maowa and Khulna projects will use imported coal using a 5,000DWT barge via Chittagong port, whose maximum draft is 9.1m. A Panamax vessel cannot access Chittagong port because of the shallow waterway.

d) Matarbari North Project

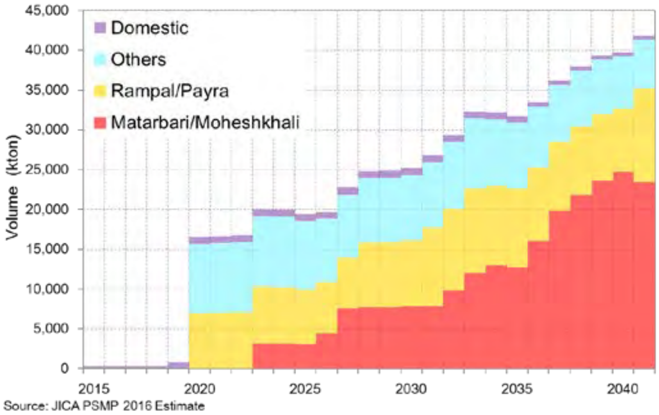
Matarbari North Projects will use CTT.

e) Brick manufacturers (Non-Power)

Brick manufacturers in the north of Dhaka use imported coal using 5,000DWT barges via Chittagong port. It is a possibility that the Rampal projects, Payra projects, Maowa, Khulna and Chittagong projects and brick manufacturers also use CTT, which a Panamax vessel can access, because of cheaper fuel transportation costs. The estimated annual trading volume of CTT depends on the development progress of the Payra deep sea port.

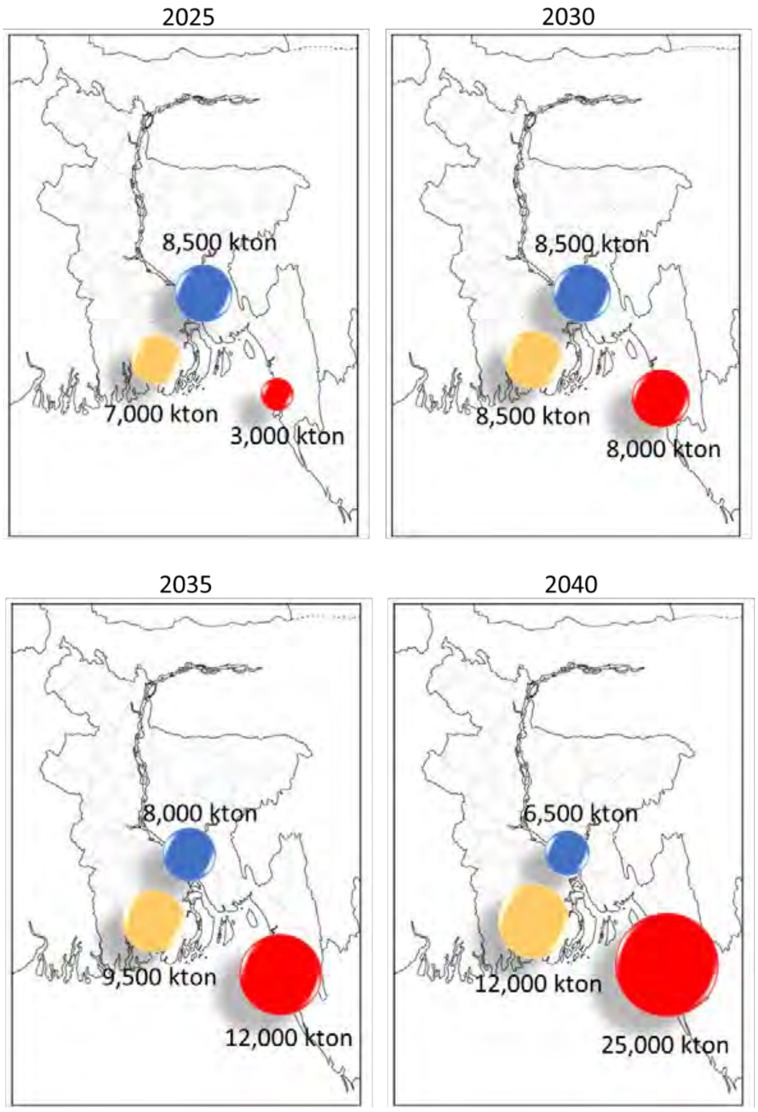
(3) Regional coal import scenario

The following figure shows the amount of coal supply by region. Imported coal is primarily used and coal is mainly imported to the Matarbari and Moheshkali regions (see Figure 11 18 (red)) as well as the Rampal and Payla regions (see Figure 11 18 (yellow)). Matarbari and Moheshkali expect to import 25,000 ktons of coal in 2040, while 11,000 ktons are supposed to be imported to Rampal and Payla. As shown in Figure 11 18, a total of 42,000 ktons of coal are estimated to be imported to Bangladesh in 2040.



Source: JICA Survey Team

Figure 11-17 Estimated Coal Demands for Power Supply (k tons)



Source: JICA Survey Team

Figure 11-18 Prospective imported coal amounts by 2041 (Unit: kTon)

11.11 Long and ultra-long term development plan (Candidate Plan)

A study on increasing the power sources by changing the ratios of the gas and coal power generation in accordance with the progress in the infrastructure and port development planned in JICA's Southern Chittagong MP Survey is to be conducted for the formulation of the candidate plan.

In this section, a scenario that sets the composition ratios of the gas and coal power generation in 2041 at 35% is to be used as the basic power development plan.

11.11.1 Gas based

The list of candidate gas-fired power plants is as follows.

Table 11-28 Candidate gas-fired power plants (Candidate)

No.	Gas Plant (Candidate)	Type	COD	Retirement	Output (MW)
	CC800				
1	Mohesikali	Gas	2032	-	800
2	Mohesikali	Gas	2033	-	800
3	Mohesikali	Gas	2034	-	800
4	Pyra	Gas	2034	-	800
5	Pyra	Gas	2035	-	800
6	Pyra	Gas	2035	-	800
7	Pyra	Gas	2035	-	800
8	Gas800 after 2035	Gas	2036	-	800
9	Gas800 after 2035	Gas	2037	-	800
10	Gas800 after 2035	Gas	2038	-	800
11	Gas800 after 2035	Gas	2039	-	800
12	Gas800 after 2035	Gas	2039	-	800
13	Gas800 after 2035	Gas	2040	-	800
14	Gas800 after 2035	Gas	2041	-	800
	CC500			-	
15	Mohesikali	Gas	2028	-	500
16	Mohesikali	Gas	2029	-	500
	CC250			-	
17	Anowara	Gas	2026	-	250
18	Anowara	Gas	2029	-	250
19	Anowara	Gas	2031	-	250
20	Pyra	Gas	2032	-	250
21	Pyra	Gas	2033	-	250
22	Pyra	Gas	2034	-	250
23	Pyra	Gas	2035	-	250
24	Gas250 after 2035	Gas	2036	-	250
25	Gas250 after 2035	Gas	2036	-	250
26	Gas250 after 2035	Gas	2037	-	250
27	Gas250 after 2035	Gas	2037	-	250
28	Gas250 after 2035	Gas	2038	-	250
29	Gas250 after 2035	Gas	2039	-	250
30	Gas250 after 2035	Gas	2041	-	250
	SGT100			-	
31	SGT100 -1	Gas	2027	-	100
32	SGT100 -2	Gas	2028	-	100
33	SGT100 -3	Gas	2028	-	100
34	SGT100 -4	Gas	2029	-	100
35	SGT100 -5	Gas	2029	-	100
36	SGT100 -6	Gas	2029	-	100
37	SGT100 -7	Gas	2029	-	100

Source: JICA Survey Team

11.11.2 Coal based

The list of candidate coal-fired power plants is as follows.

Table 11-29 Candidate coal-fired power plants (Candidate)

No.	Coal Plant (Candidate)	Type	COD	Retirement	Output (MW)
	CO600				
1	Matarbari/Maheshkhali #1	Imp. Coal	2026	-	600
2	Matarbari/Maheshkhali #2	Imp. Coal	2027	-	600
3	Matarbari/Maheshkhali #3	Imp. Coal	2027	-	600
4	payra West #1	Imp. Coal	2028	-	600
5	payra West #2	Imp. Coal	2031	-	600
6	Matarbari/Maheshkhali #4	Imp. Coal	2032	-	600
7	Matarbari/Maheshkhali #5	Imp. Coal	2033	-	600
8	Matarbari/Maheshkhali #6	Imp. Coal	2034	-	600
9	Matarbari/Maheshkhali #7	Imp. Coal	2036	-	600
	CO1000				
10	Matarbari/Maheshkhali #8	Imp. Coal	2036	-	1000
11	Matarbari/Maheshkhali #9	Imp. Coal	2037	-	1000
12	Matarbari/Maheshkhali #10	Imp. Coal	2037	-	1000
13	Matarbari/Maheshkhali #11	Imp. Coal	2038	-	1000
14	Matarbari/Maheshkhali #12	Imp. Coal	2039	-	1000
15	Matarbari/Maheshkhali #13	Imp. Coal	2040	-	1000
16	Payra West #3	Imp. Coal	2041	-	1000
17	payra West #4	Imp. Coal	2041	-	1000

Source: JICA Survey Team

11.11.3 Power Imports

The list of candidate power imports is as follows

Table 11-30 Candidate power import plans (Candidate)

No.	Power Import (Candidate)	Type	COD	Retirement	Output (MW)
1	Comilla - Tripura HVDC Phase 1-2 (100MW) (India)	P.I.	2020	-	100
2	Comilla - Tripura HVDC Phase 2 (300MW) (India)	P.I.	2021	-	300
3	Case 2 HVDC (Barapkuria S/S) Phase I-1 Bheramara - Baharampur Arunachal, India (East India)	P.I.	2028	-	500
4	Case 2 HVDC (Barapkuria S/S) Phase 1-2 Bheramara - Baharampur Arunachal, India (East India)	P.I.	2031	-	500
5	Case 2 HVDC (Barapkuria S/S) Phase II	P.I.	2036	-	500
6	Case 2 HVDC (Barapkuria S/S) Phase III	P.I.	2039	-	500
7	Case 3 HVDC (Barapkuria S/S) Phase I From India (Purnea - Barapukuria) (India)	P.I.	2021	-	500
8	Case 3 HVDC (Barapkuria S/S) Phase II Phase I From India (Purnea - Barapukuria) (India)	P.I.	2024	-	500
9	Case 3 HVDC (Barapkuria S/S) Phase III From Nepal (Purnea - Barapukuria) (Nepal)	P.I.	2027	-	500
10	Case 3 HVDC (Barapkuria S/S) Phase IV From Nepal (Purnea - Barapukuria) (Nepal)	P.I.	2029	-	500
11	Case 3 HVDC (Barapkuria S/S) Phase V From Nepal (Purnea - Barapukuria) (Nepal)	P.I.	2035	-	500
12	Case 3 HVDC (Barapkuria S/S) Phase VI From Nepal (Purnea - Barapukuria) (Nepal)	P.I.	2038	-	500
13	Bibiyana - Meghalaya (PSPP) (India)	P.I.	2030	-	1,000
14	Cox's Bazar - Myanmar	P.I.	2040	-	500
15	Rawta - Jamarpur HVDC PhaseI Bongaigaon/Rangia - Jamarpur (Bhutan)	P.I.	2032	-	500
16	Rawta - Jamarpur HVDC PhaseII Bongaigaon/Rangia - Jamarpur (Bhutan)	P.I.	2034	-	500

Source: JICA Survey Team

11.11.4 Nuclear power

The list of candidate nuclear power plants is as follows

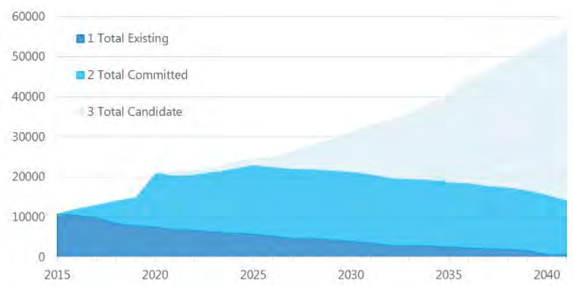
Table 11-31 Candidate nuclear power plants (Candidate)

No.	Nuclear Plant (Candidate)	Type	COD	Retirement	Output (MW)
1	Roopoor 3rd Unit	Nuclear	2030	-	1,200
2	Roopoor 4th Unit	Nuclear	2031	-	1,200
3	South West Nuc 5th Unit	Nuclear	2040	-	1,200
4	South West Nuc 6th Unit	Nuclear	2041	-	1,200

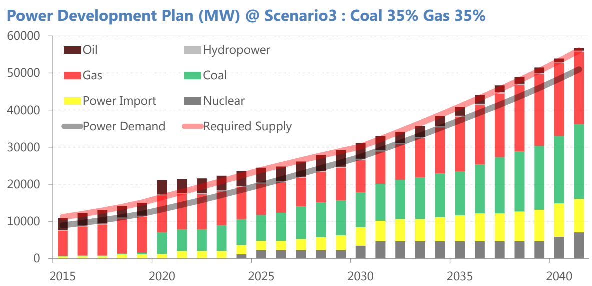
Source: JICA Survey Team

11.11.5 Summary of power development plan (Base case)

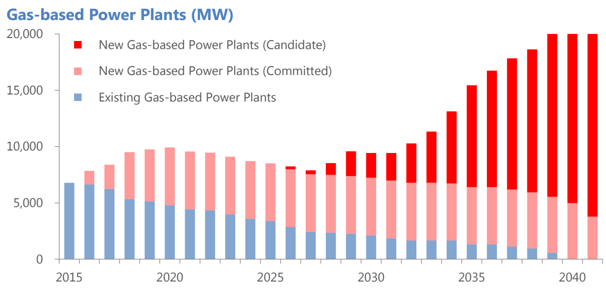
The figure below shows the power supply plan formulated by adding the capacity of the existing plants estimated with the retirement plan in the plan for the existing facilities taken into consideration (existing capacity), the capacity of the plants mentioned in the Committed Plan to be constructed by 2025, the capacity of the plants to be constructed later in the Candidate Plan that is subject to changes and the capacity required to ensure supply reliability during peak demand.



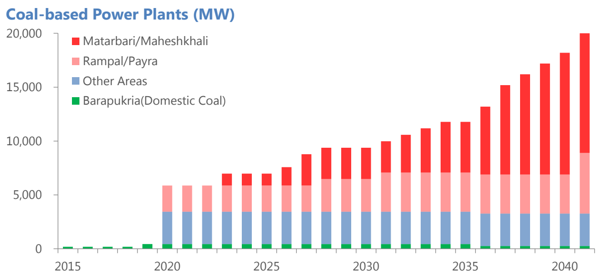
Power development plan (base case)



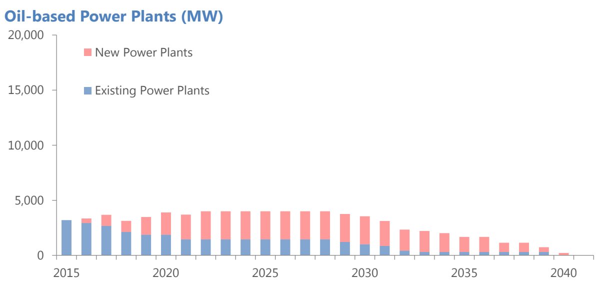
Power development plan of each power



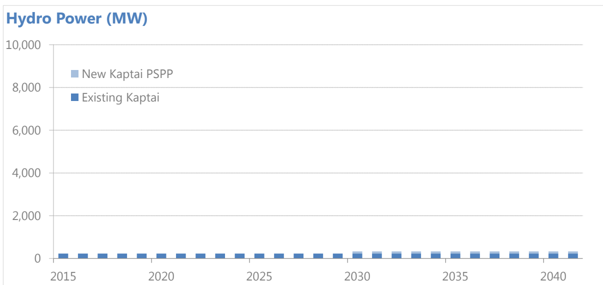
Gas



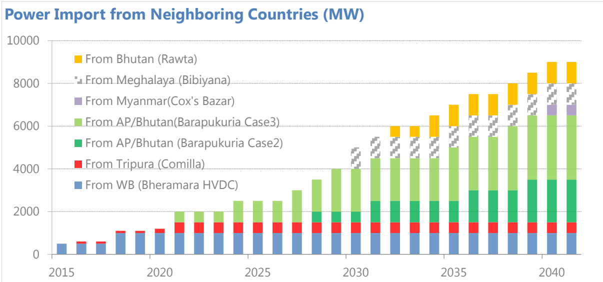
Coal



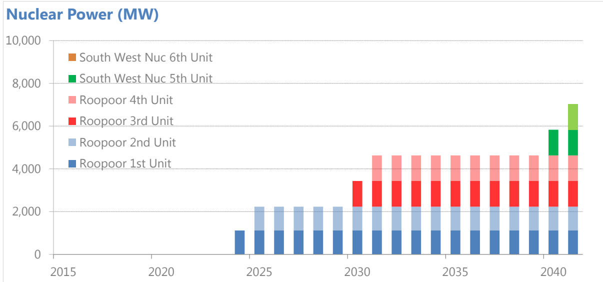
Oil



Hydro



Power Import



Nuclear

Source: JICA Survey Team

Figure 11-19 2015～2041 Power development plan（MW）

Table 11-32 List of power development plan

FY	Output (MW)	COD	Retirement	2015	2020	2025	2030	2035	2040	2041
1 Total Existing	Output (MW)			10,895	7,589	5,762	4,023	2,538	730	730
Coal				182	182	182	182	182	0	0
Barpapukuria 250MW (Unit 1&2)	182	2000	2036	182	182	182	182	182	0	0
Gas				6,781	4,802	3,390	2,106	1,321	0	0
Raojan (Chittagong) 2x210 MW	166	EX	2023	166	166	0	0	0	0	0
Raojan (Chittagong) 2x210 MW	166	EX	2023	166	166	0	0	0	0	0
SIKALBAHA (Chittagong) (60 MW)	39	EX	2016	39	0	0	0	0	0	0
Shikalbaha 150 MW PP	147	EX	2030	147	147	147	0	0	0	0
Ashuganj (B.Baria) 2x64 MW ST	89	EX	2017	89	0	0	0	0	0	0
Ashuganj (B.Baria) 3x150 MW ST	366	EX	2021	366	366	0	0	0	0	0
Ashuganj (B.Baria) 56 MW GT)	39	EX	2017	39	0	0	0	0	0	0
Ashugonj 50 MW Engine	44	EX	2031	44	44	44	44	0	0	0
Ashugonj 225 CCPP	218	EX	2040	218	218	218	218	218	0	0
Chandpur 150 MW CCPP	158	EX	2038	158	158	158	158	158	0	0
Ghorasal (Polash, Norshindi) 2x55 MW ST 1&2	78	EX	2019	78	0	0	0	0	0	0
Ghorasal (Polash, Norshindi) 210 MW ST 3,4,5&6	672	EX	2018	672	168	168	0	0	0	0
SIDDHIRGANJ (210 MW)	138	EX	2035	138	138	138	138	0	0	0
SIDDHIRGANJ 2x120 MW)	206	EX	2032	206	206	206	206	0	0	0
HARIPUR (96 MW) (Narayangonj)	59	EX	2017	59	0	0	0	0	0	0
Haripur 412 MW CCPP (EGCB)	400	EX	2039	400	400	400	400	400	0	0
TONGI (105 MW) (Dhaka)	103	EX	2025	103	103	0	0	0	0	0
Shahjibazar (Hobigonj) 2x35 MW GT 8&9	65	EX	2019	65	0	0	0	0	0	0
Lump GT Publick Gas ~30MW (SYLHET (20 MW)	19	EX	2018	19	0	0	0	0	0	0
SYLHET (150 MW) PP	139	EX	2018	139	0	0	0	0	0	0
Fenchuganj 97 & 104 MW CC BPDB	165	EX	2020	165	0	0	0	0	0	0
Lump GT Publick Gas ~100MW (Baghabari (Sirajgonj) 71 MW GT	69	EX	2020	69	0	0	0	0	0	0
Baghabari (Sirajgonj) 100 MW GT	98	EX	2025	98	98	0	0	0	0	0
Sirajgonj 210 MW CCPP (1st Unit)	204	EX	2037	204	204	204	204	204	0	0
RPCL (Mymenshing) (210 MW)	202	EX	2031	202	202	202	202	0	0	0
Haripur Power Ltd. (360 MW)	360	EX	2026	360	360	360	0	0	0	0
Meghnaghat power Ltd. (450 MW)	450	EX	2027	450	450	450	0	0	0	0
Ghorasal 108 MW IPP (Regent Power))	108	EX	2029	108	108	108	0	0	0	0
Ashugonj 195 MW Modular PP	195	EX	2035	195	195	195	195	0	0	0
Bibiana-II 341 MW CCPP (Summit)	341	EX	2040	341	341	341	341	341	0	0
Bogra 15 Years RPP (GBB)	22	EX	2023	22	22	0	0	0	0	0
Kumargoan, Sylhet RPP (Energyprima)	50	EX	2018	50	0	0	0	0	0	0
Shahjibazar 15 Yrs RPP (Shahjibazar Power)	86	EX	2024	86	86	0	0	0	0	0
Shahjibazar RPP (Energyprima)	50	EX	2017	50	0	0	0	0	0	0
Tangail SIPP (Doreen)	22	EX	2024	22	22	0	0	0	0	0
Feni SIPP (Doreen)	22	EX	2024	22	22	0	0	0	0	0
Lump Gas Rental ~50 MW (Kumkargoan, Sylhet 15 Years RPP (Des	10	EX	2024	10	10	0	0	0	0	0
Barobkundo SIPP (Regent Power)	22	EX	2024	22	22	0	0	0	0	0
Bhola 3 Years RPP (Venture)	33	EX	2017	33	0	0	0	0	0	0
Jangalia, Comilla SIPP (Summit))	33	EX	2024	33	33	0	0	0	0	0
Fenchuganj 15 Years RPP (Barakatullah)	51	EX	2024	51	51	0	0	0	0	0
Ashugong 55 MW RPP (Precision Energy))	55	EX	2018	55	0	0	0	0	0	0
Fenchugonj RPP (Energy Prima)	44	EX	2017	44	0	0	0	0	0	0
Ghorasal 45 MW QRPP (Aggreko)	45	EX	2018	45	0	0	0	0	0	0
Ghorasal 100 MW QRPP (Aggreko)	100	EX	2018	100	0	0	0	0	0	0
B. Baria 70 MW QRPP (Aggreco)	85	EX	2017	85	0	0	0	0	0	0
Lump Gas Rental ~100 MW (Ghorasal 78 MW QRPP (Max Power)	78	EX	2020	78	0	0	0	0	0	0
Ashugonj 80 MW QRPP (Aggreko)	95	EX	2016	95	0	0	0	0	0	0
Ashugonj 53 MW QRPP (United Power)	53	EX	2019	53	0	0	0	0	0	0
Shajahanullah Power Com. Ltd.	25	EX	2020	25	0	0	0	0	0	0
Summit Power(REB)	105	EX	2022	105	105	0	0	0	0	0
Bogra RPP (Energy Prima)	20	EX	2024	20	20	0	0	0	0	0
Lump SIPP Gas (Hobiganj SIPP (REB) (Confi-Energypac)	11	EX	2024	11	11	0	0	0	0	0
Ullapara SIPP (REB) (Summit)	11	EX	2024	11	11	0	0	0	0	0
Narsindi SIPP (REB) (Doreen)	22	EX	2024	22	22	0	0	0	0	0
Feni SIPP (REB) (Doreen)	11	EX	2024	11	11	0	0	0	0	0
Mouna, Gazipur SIPP (REB) (Summit)	33	EX	2024	33	33	0	0	0	0	0
Rupganj , Narayanganj SIPP (REB) (Summit)	33	EX	2024	33	33	0	0	0	0	0
Ashugonj 51 MW IPP (Midland)	51	EX	2028	51	51	51	0	0	0	0
Oil/HSD				922	305	305	305	305	0	0
Lump GT Public HSD ~20MW (BARISAL (40MW)	30	EX	2016	30	0	0	0	0	0	0
BHERAMARA (Kustia) (60 MW)	46	EX	2016	46	0	0	0	0	0	0
Khulna 150 MW PP (NWPGCL)	155	EX	2017	155	0	0	0	0	0	0
RANGPUR (20 MW)	19	EX	2016	19	0	0	0	0	0	0
SAIDPUR (20 MW) (Dinajpur)	19	EX	2016	19	0	0	0	0	0	0
Summit Meghnaghat Power Company Ltd. CCPP	305	EX	2040	305	305	305	305	305	0	0
Thakurgaon RPP (RZ Power)	40	EX	2018	40	0	0	0	0	0	0
Khulna 55 MW QRPP (Aggreko))	55	EX	2018	55	0	0	0	0	0	0
Lump HSD Rental ~50 MW (Pagla 50 MW QRPP (DPA)	50	EX	2018	50	0	0	0	0	0	0
Bheramara 110 MW RPP (Quantum Power))	105	EX	2018	105	0	0	0	0	0	0
Lump HSD Rental ~100 MW (Shiddirgonj 100 MW QRPP (Desh Ene	98	EX	2019	98	0	0	0	0	0	0
Oil/F.oil				2,281	1,570	1,155	700	0	0	0
Hathazari 100 MW Peaking PP	96	EX	2032	96	96	96	96	0	0	0
Sangu, Dohazari 100 MW Peaking PP	99	EX	2033	99	99	99	99	0	0	0
Lump HFO Public ~50 MW (Raojan 25 MW Peaking PP)	25	EX	2033	25	25	25	25	0	0	0
Gazipur 52 MW PP	51	EX	2032	51	51	51	51	0	0	0
Titas, Doudkandi 50 MW Peaking PP	51	EX	2031	51	51	51	51	0	0	0
KHULNA (110 MW)	50	EX	2016	50	0	0	0	0	0	0
Faridpur 50 MW Peaking PP)	52	EX	2031	52	52	52	52	0	0	0
Gopalgonj 100 MW Peaking PP)	107	EX	2032	107	107	107	107	0	0	0
BAGHABARI 50 MW Peaking PP	51	EX	2031	51	51	51	51	0	0	0
Lump HFO Public ~100 MW (BERA 70 MW Peaking PP	70	EX	2032	70	70	70	70	0	0	0
Santahar 50 MW Peaking PP	49	EX	2032	49	49	49	49	0	0	0
Katakhali 50 MW Peaking PP	49	EX	2032	49	49	49	49	0	0	0
KPCL BMPP 15 Years (Khulna) (Summit-United)	110	EX	2018	110	0	0	0	0	0	0
NEPC (110 MW) (Haripur BMPP)	110	EX	2019	110	0	0	0	0	0	0
Natore 52 MW IPP (Raj-Lanka)	52	EX	2029	52	52	52	0	0	0	0
Gognagar 102 MW PP (Summit)	102	EX	2029	102	102	102	0	0	0	0
Baraka-Potenga 50 MW IPP	50	EX	2029	50	50	50	0	0	0	0
Potiya, Chittagong 100 MW Power Plant	108	EX	2030	108	108	108	0	0	0	0
Jangalia, Comilla (Lakdanvhi)	52	EX	2030	52	52	52	0	0	0	0
Kathpotty, Munshigonj 53 MW PP (Sinha)	51	EX	2030	51	51	51	0	0	0	0
Lump Private Existing RE HFO ~50 (Shikal Baha RPP(Energis)	40	EX	2018	40	0	0	0	0	0	0
Lump Private Existing RE HFO ~100 (Madangonj 102 MW QRPP (Su	100	EX	2021	100	100	0	0	0	0	0
Khulna 115 MW QRPP (KPCL) (Summit-United)	115	EX	2021	115	115	0	0	0	0	0
Noapara 40 MW QRPP (Khan Jahan Ali)	40	EX	2029	40	40	40	0	0	0	0
Noapara 105 MW RPP (Quantum Power)	101	EX	2016	101	0	0	0	0	0	0
Meghnaghat 100 MW QRPP (IEL)	100	EX	2021	100	100	0	0	0	0	0
Siddirganj 100 MW QRPP (Dutch Bangla Power)	100	EX	2021	100	100	0	0	0	0	0
Amnura 50 MW QRPP (Sinha Power)	50	EX	2018	50	0	0	0	0	0	0
Keranigonj 100 MW QRPP (Power Pak)	100	EX	2017	100	0	0	0	0	0	0
Julda100 MW QRPP (Acron Infra Servicw)	100	EX	2018	100	0	0	0	0	0	0
Katakhali 50 MW QRPP (NPSL)	50	EX	2019	50	0	0	0	0	0	0
ImP				500	500	500	500	500	500	500
Bheramara-Bharampur HVDC Phase 1(from India)	500	2013	9999	500	500	500	500	500	500	500
Hyd				230	230	230	230	230	230	230
Kaptai Hydro Power Plant	230	2000	9999	230	230	230	230	230	230	230

FY	Output (MW)	COD	Retirement	2015	2020	2025	2030	2035	2040	2041
2 Total Comitted				0	13,441	17,297	17,397	16,170	14,925	13,504
Coal				0	5,691	6,795	6,795	6,795	6,795	6,795
Barapukuria 275MW (Unit 3)	252	2019	9999	0	252	252	252	252	252	252
Matarbari#1,2	1104	2023	9999	0	0	1,104	1,104	1,104	1,104	1,104
Rampal#1,2	1214	2020	9999	0	1,214	1,214	1,214	1,214	1,214	1,214
Payra#1,2	1214	2020	9999	0	1,214	1,214	1,214	1,214	1,214	1,214
Khulna	630	2020	9999	0	630	630	630	630	630	630
Maowa	522	2020	9999	0	522	522	522	522	522	522
Dhaka	635	2020	9999	0	635	635	635	635	635	635
Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-1	612	2020	9999	0	612	612	612	612	612	612
Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-2	612	2020	9999	0	612	612	612	612	612	612
Gas				0	5,126	5,126	5,126	5,076	4,978	3,777
Bhola 225 MW CCPP	189	2016	2041	0	189	189	189	189	189	0
Siddirganj 335 MW CCPP	328	2016	2041	0	328	328	328	328	328	0
Ashuganj (North) CCPP	370	2017	9999	0	370	370	370	370	370	370
Ashuganj (South) CCPP	361	2016	2041	0	361	361	361	361	361	0
Ghorasal 363 MW (7th Unit) CCPP	352	2017	9999	0	352	352	352	352	352	352
Shajibazar CCPP	322	2016	2041	0	322	322	322	322	322	0
Shikalbaha 225 MW CCPP	218	2017	9999	0	218	218	218	218	218	218
Bibiana South CCPP BPDB	372	2018	9999	0	372	372	372	372	372	372
Bibiana Ⅲ CCPP BPDB	388	2019	9999	0	388	388	388	388	388	388
Bheramara 414 MW CCPP	402	2018	9999	0	402	402	402	402	402	402
Fenchugonj 50 MW Power Plant (NRB)	50	2019	2034	0	50	50	50	0	0	0
Sylhet 150 MW PP Conversion	221	2018	9999	0	221	221	221	221	221	221
Ghorasal 3rd & 4th Unit Repowering (Capacity Addition)	776	2018	9999	0	776	776	776	776	776	776
Kushiara 163 MW CCPP	163	2018	9999	0	163	163	163	163	163	163
Bagabari 71MW PP Conversion	102	2020	2042	0	102	102	102	102	102	102
Sirajganj 414 MW CCPP (4th unit)	414	2020	9999	0	414	414	414	414	414	414
Shahajibazar 100 MW	98	2018	2038	0	98	98	98	98	0	0
Oil/HSD				0	995	1,215	1,215	1,068	220	0
Kodda, Gazipur 150 MW Power Plant	147	2016	2035	0	147	147	147	0	0	0
Upgradation of Khulna 150 MW to 225 MW	221	2017	2037	0	221	221	221	221	0	0
Khulna 200-300 MW CCPP	196	2019	2039	0	196	196	196	196	0	0
Sirajgonj 225 MW CCPP (2nd Unit)	216	2019	2039	0	216	216	216	216	0	0
Sirajgonj 225 MW CCPP (3rd Unit)	216	2020	2040	0	216	216	216	216	0	0
Bhola 220 MW CCPP Dual Fuel BOO power plant	220	2021	2041	0	0	220	220	220	220	0
Oil/F.oil				0	1,030	1,330	1,330	300	0	0
Chapai Nababganj 104 MW PP	102	2017	2032	0	102	102	102	0	0	0
Keranigonj 100 MW PP (Re from Khulna))	100	2019	2034	0	100	100	100	0	0	0
Bosila, Keranigonj 108 MW PP (CLC Power)	108	2017	2032	0	108	108	108	0	0	0
Jamalpur 100 MW Power Plant	95	2017	2032	0	95	95	95	0	0	0
Barisal 100 MW PP (Re. from Syedpur)	110	2016	2031	0	110	110	110	0	0	0
Lump HFO Private New ~50 MW (Madangonj 50 MW Peaking Plant (	55	2016	2031	0	55	55	55	0	0	0
Manikgonj 55 MW PP	50	2016	2031	0	50	50	50	0	0	0
Kamalaghat 50 MW PP)	55	2017	2032	0	55	55	55	0	0	0
Nababgonj 55 MW PP	55	2016	2031	0	55	55	55	0	0	0
Satkhira 50 MW PP	50	2019	2034	0	50	50	50	0	0	0
Bhairab 50 MW PP	50	2019	2034	0	50	50	50	0	0	0
Patiya 100 Mw BOO FO power plant	100	2020	2035	0	100	100	100	0	0	0
Anwara 300 MW HFO plant	300	2022	2037	0	0	300	300	300	0	0
Julda 100 Mw BOO FO power plant	100	2020	2035	0	100	100	100	0	0	0
ImP				0	600	600	600	600	600	600
Comilla - Tripura HVDC Phase 1-1 (100MW) (India)	100	2016	9999	0	100	100	100	100	100	100
Bheramara-Bharampur HVDC Phase 2 Bheramara - Baharampur (	500	2018	9999	0	500	500	500	500	500	500
Nuc				0	0	2,232	2,232	2,232	2,232	2,232
Roopoor 1st Unit	1,116	2024	9999	0	0	1,116	1,116	1,116	1,116	1,116
Roopoor 2nd Unit	1,116	2025	9999	0	0	1,116	1,116	1,116	1,116	1,116
Hyd				0	0	0	100	100	100	100
New Kaptai Pumped Strage	100	2030	9999	0	0	0	100	100	100	100

FY	Output (MW)	COD	Retirement	2015	2020	2025	2030	2035	2040	2041
3 Total Candidate				0	100	1,400	9,700	22,150	38,250	42,500
CO600				0	0	0	2400	4800	5400	5400
Matarbari/Maheshkhali #1	600	2026	9999	0	0	0	600	600	600	600
Matarbari/Maheshkhali #2	600	2027	9999	0	0	0	600	600	600	600
Matarbari/Maheshkhali #3	600	2027	9999	0	0	0	600	600	600	600
payra West #1	600	2028	9999	0	0	0	600	600	600	600
payra West #2	600	2031	9999	0	0	0	0	600	600	600
Matarbari/Maheshkhali #4	600	2032	9999	0	0	0	0	600	600	600
Matarbari/Maheshkhali #5	600	2033	9999	0	0	0	0	600	600	600
Matarbari/Maheshkhali #6	600	2034	9999	0	0	0	0	600	600	600
Matarbari/Maheshkhali #7	600	2036	9999	0	0	0	0	0	600	600
CO1000				0	0	0	0	0	6000	8000
Matarbari/Maheshkhali #8	1000	2036	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #9	1000	2037	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #10	1000	2037	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #11	1000	2038	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #12	1000	2039	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #13	1000	2040	9999	0	0	0	0	0	1,000	1,000
Payra West #3	1000	2041	9999	0	0	0	0	0	0	1,000
payra West #4	1000	2041	9999	0	0	0	0	0	0	1,000
CC800				0	0	0	0	5,600	10,400	11,200
Mohesikali	800	2032	9999	0	0	0	0	800	800	800
Mohesikali	800	2033	9999	0	0	0	0	800	800	800
Mohesikali	800	2034	9999	0	0	0	0	800	800	800
Pyra	800	2034	9999	0	0	0	0	800	800	800
Pyra	800	2035	9999	0	0	0	0	800	800	800
Pyra	800	2035	9999	0	0	0	0	800	800	800
Pyra	800	2035	9999	0	0	0	0	800	800	800
Gas800 after 2035	800	2036	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2037	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2038	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2039	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2039	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2040	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2041	9999	0	0	0	0	0	0	800
CC500				0	0	0	1,000	1,000	1,000	1,000
Mohesikali	500	2028	9999	0	0	0	500	500	500	500
Mohesikali	500	2029	9999	0	0	0	500	500	500	500
CC250				0	0	0	500	1,750	3,250	3,500
Anowara	250	2026	9999	0	0	0	250	250	250	250
Anowara	250	2029	9999	0	0	0	250	250	250	250
Anowara	250	2031	9999	0	0	0	0	250	250	250
Pyra	250	2032	9999	0	0	0	0	250	250	250
Pyra	250	2033	9999	0	0	0	0	250	250	250
Pyra	250	2034	9999	0	0	0	0	250	250	250
Pyra	250	2035	9999	0	0	0	0	250	250	250
Gas250 after 2035	250	2036	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2036	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2037	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2037	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2038	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2039	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2041	9999	0	0	0	0	0	0	250
SGT100				0	0	0	700	700	700	700
SGT100 -1	100	2027	9999	0	0	0	100	100	100	100
SGT100 -2	100	2028	9999	0	0	0	100	100	100	100
SGT100 -3	100	2028	9999	0	0	0	100	100	100	100
SGT100 -4	100	2029	9999	0	0	0	100	100	100	100
SGT100 -5	100	2029	9999	0	0	0	100	100	100	100
SGT100 -6	100	2029	9999	0	0	0	100	100	100	100
SGT100 -7	100	2029	9999	0	0	0	100	100	100	100
ImP				0	100	1,400	3,900	5,900	7,900	7,900
Comilla - Tripura HVDC Phase 1-2 (100MW) (India)	100	2020	9999	0	100	100	100	100	100	100
Comilla - Tripura HVDC Phase 2 (300MW) (India)	300	2021	9999	0	0	300	300	300	300	300
Case 2 HVDC (Barapkuria S/S) Phase I-1 Bheramara - Baharampur	500	2028	9999	0	0	0	500	500	500	500
Case 2 HVDC (Barapkuria S/S) Phase 1-2 Bheramara - Baharampu	500	2031	9999	0	0	0	0	500	500	500
Case 2 HVDC (Barapkuria S/S) Phase II	500	2036	9999	0	0	0	0	0	500	500
Case 2 HVDC (Barapkuria S/S) Phase III	500	2039	9999	0	0	0	0	0	500	500
Case 3 HVDC (Barapkuria S/S) Phase I From India (Purnea - Barap	500	2021	9999	0	0	500	500	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase II Phase I From India (Purne	500	2024	9999	0	0	500	500	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase III From Nepal (Purnea - Bar	500	2027	9999	0	0	0	500	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase IV From Nepal (Purnea - Ba	500	2029	9999	0	0	0	500	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase V From Nepal (Purnea - Bar	500	2035	9999	0	0	0	0	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase VI From Nepal (Purnea - Ba	500	2038	9999	0	0	0	0	0	500	500
Bibiyana - Meghalaya (PSPP) (India)	1,000	2030	9999	0	0	0	1,000	1,000	1,000	1,000
Cox's Bazar - Myanmar	500	2040	9999	0	0	0	0	0	500	500
Rawta - Jamarpur HVDC PhaseI Bongaigaon/Rangia - Jamarpur (Bh	500	2032	9999	0	0	0	0	500	500	500
Rawta - Jamarpur HVDC PhaseII Bongaigaon/Rangia - Jamarpur (Bh	500	2034	9999	0	0	0	0	500	500	500
Nuc				0	0	0	1,200	2,400	3,600	4,800
Roopoor 3rd Unit	1,200	2030	9999	0	0	0	1,200	1,200	1,200	1,200
Roopoor 4th Unit	1,200	2031	9999	0	0	0	0	1,200	1,200	1,200
South West Nuc 5th Unit	1,200	2040	9999	0	0	0	0	0	1,200	1,200
South West Nuc 6th Unit	1,200	2041	9999	0	0	0	0	0	0	1,200
Hyd				0	0	0	0	0	0	0

11.12 Preconditions for the estimation of the economic and environmental values

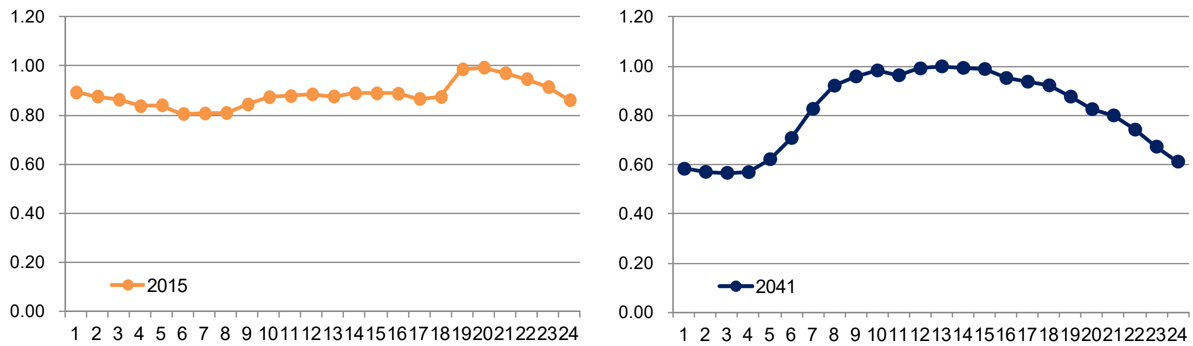
11.12.1 Daily load curve

(1) Estimating the daily load curve

The following estimates the daily load curve in Bangladesh during the 2015-2041 period. The performance records of the daily load curve in Bangladesh in 2015 are represented by a curve having a power demand peak in the evening, as illustrated below. In the meantime, by 2041, the economic growth rate in Bangladesh is estimated to reach the daily load curve of advanced countries, where the peak is found in the daytime and evening, if the growth of the electrification rate is taken into account.

In the fiscal 2015 daily load curve, consideration is given to the performance value for power consumption on a time-of-day basis in Bangladesh.

- From the fiscal 2015 power consumption (performance value) on a time-of-day basis in Bangladesh, the monthly Max/Average/Min data on a time-of-day basis will be created, where "Max" indicates the average value for highest three days for power consumption for each month, "Min" denotes the average value for lowest eight days for power consumption and "Average" represents the average value for the remaining days.
- According to the above-mentioned data, power consumption reaches the highest level in April. Thus, April is assumed as a "High" month. December is assumed as a "Low" month since power consumption reaches the lowest level in this month.
- The Max/Average/Min data will be standardized so that the Max value in April will be 1.0. This is assumed as the 2015 daily load curve for Bangladesh.



Source: JICA Survey Team

Figure 11-20 Daily load curve in Bangladesh (Performance record for 2015 on the left, and estimated value for 2041 on the right)

(2) Estimation method of load daily curve from 2015 to 2041

In the 2015-2041 daily load curve, there will be a gradual shift to the daily load curve of advanced countries by 2041.

i) The fiscal 2015 power consumption performance value on a time-of-day basis in Japan will be used as the data for advanced countries. Using the same procedure given in (1), Max/Average/Min data on a time-of-day basis for each month is created, and Max/Average/Min data is standardized so that the maximum value for August representing the maximum power consumption will be 1.0.

ii) "High" month in Bangladesh falls in April. Accordingly, the standardized Japan data for August created in (2)-i) will be applied to Bangladesh's April data for 2041. Similarly, "Low" month in Bangladesh falls in December. Accordingly, the standardized Japan data for May created in (2)-i) will be applied to Bangladesh's December data for 2041.

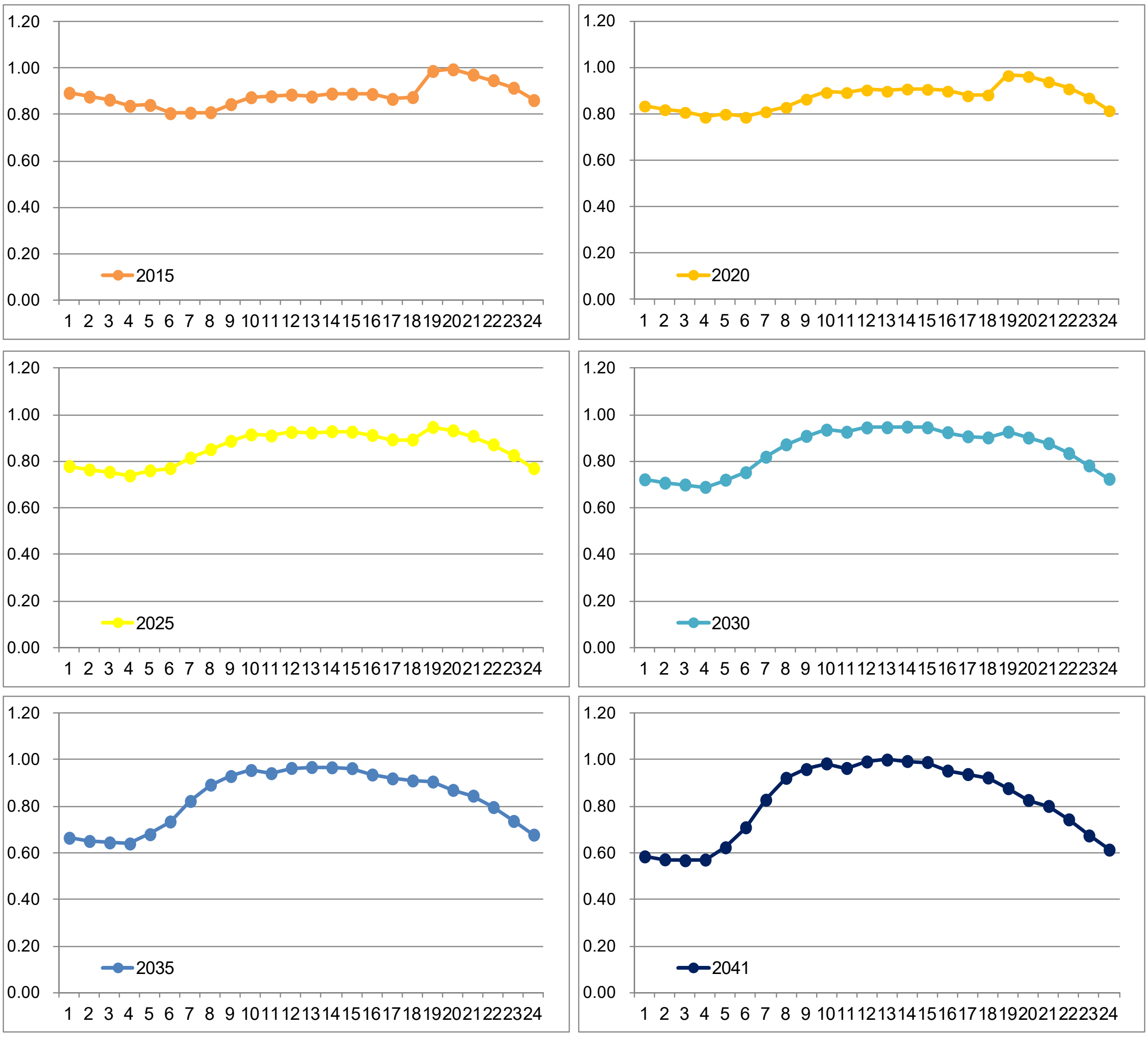
iii) For months other than December and May, there is a proportionate increase in power consumption from January to April, and a proportionate decrease in power consumption from June to November. This is assumed as an estimated daily load curve for 2041 in Bangladesh.

iv) From 2015 to 2040, there is assumed to be a proportionate increase or decrease in power consumption on a time-of-day basis. This is considered to be an estimated daily load curve for the 2015-2040 period in Bangladesh.

$$H_{i,t} = H_{i-1,t} + (H_{2041,t} - H_{2015,t}) / (2041\text{-}2015+1)$$

※ i: year, t: time of the day

The estimated result is illustrated below. Observing the transition of the daily load curve at intervals of five years from 2015, the evening peak curve as a 2015 performance value represents the yearly change in the daytime peak curve of advanced countries.



Source: JICA Survey Team

Figure 11-21 Estimated daily load curve for 2015-2041 period in Bangladesh

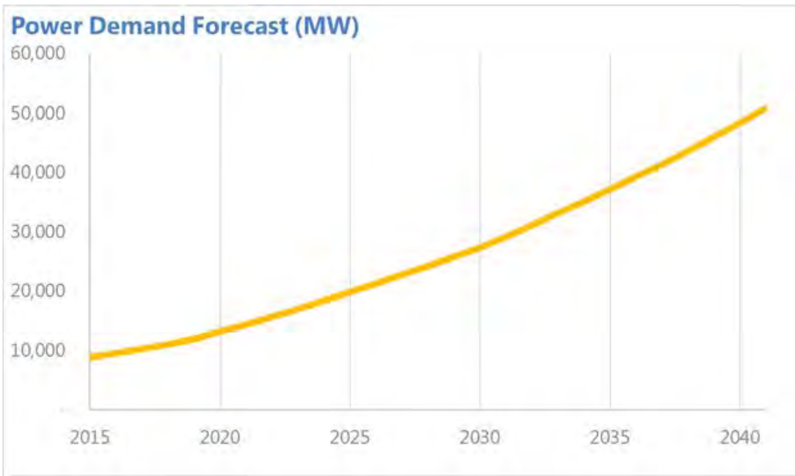
(3) Estimating the long-term power demand considering the future change in daily load curve

To estimate the long-term power demand considering the future change in daily load curve, the daily load curve up to 2041 estimated in (2) is superimposed on the maximum power demand with consideration given to the potential demand up to 2041 estimated in (1). The maximum power demand up to 2041 is estimated in another chapter. The value is shown in the Table and Figure.

Table 11-33 Maximum power demand from 2015 to 2041 (Unit: MW)

Power Demand	2015	2021	2026	2031	2036	2041
MW	8,921	14,460	21,328	29,250	39,315	50,979

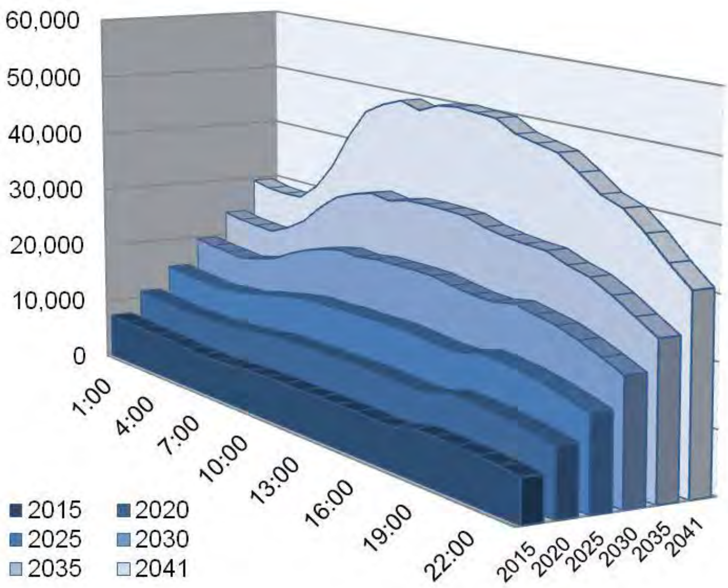
Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-22 Maximum power demand from 2015 to 2041 (Unit: MW)

The results of the estimation are illustrated below. The transition of the power demand at intervals of five years from 2015 suggests that there is a rise in power demand during the 2015-2041 period, and a change from the evening peak daily power demand to the daytime peak daily power demand in conformity with the changes in daily load curve.



Source: JICA Survey Team

Figure 11-23 Transition of power demand in 2015-2041 in Bangladesh (Unit: MW)

11.12.2 Supply Reliability

(1) Power supply reliability

Power supply reliability of electric power systems is generally evaluated based on the LOLE (loss of load expectation) value, which represents the number of hours (expected value) of power supply failure events out of 8760 annual operating hours.

i) Demand shape

The demand shape will decide the probability of the approximate level rising to the recorded maximum demand. The more frequently the demand approximately reaches the maximum demand, the higher the probability of power supply failures will be.

ii) Errors in the demand forecast

Errors in the demand forecast are divided into two types—short-term errors in daily operational forecasts and long-term errors in annual development forecasts.
A short-term error is a deviation in actual daily demand from the demand that is forecasted for the daily operation planning of the following day. An example is the unpredicted demand change caused by a weather forecasting error. Since short-term deviations cannot be covered by the sudden development of extra supply capacity, reserve capacity must be prepared for such deviations.
On the other hand, errors resulting from a long-term (e.g. 10-year term) demand forecast can be absorbed to a certain extent in the rolling development plans prepared each year. Thus, the supply reserve margin does not have to cover all of the long-term deviation. However, the annual rolling plan cannot alter power facility development plans with a long lead-time, a fact that necessitates a certain level of reserve margin to cover for the long-term deviation.

iii) Forced outage rate

Power outages are divided into two types—forced outages from accidents or other reasons and planned outages for regular inspections. Of the two, forced outages resulting, for example, from sudden accidents are a particularly important factor in determining the supply reliability. Thus, planned outages will not be considered normally.
Here, the outage rate is defined as the ratio of the number of outage hours to the total number of operating hours.

iv) Unit capacity and system scale

If the power system contains generators of large unit capacities, the probability of suddenly losing a large-scale supply capability will increase. The loss of a large supply capability not only causes a severe transitional impact on the system but also makes it quite difficult to recover the lost capability, and thus, increases the probability of power supply failure.

v) Water inflow fluctuations and reliance on hydropower (ratio against the whole capacity)

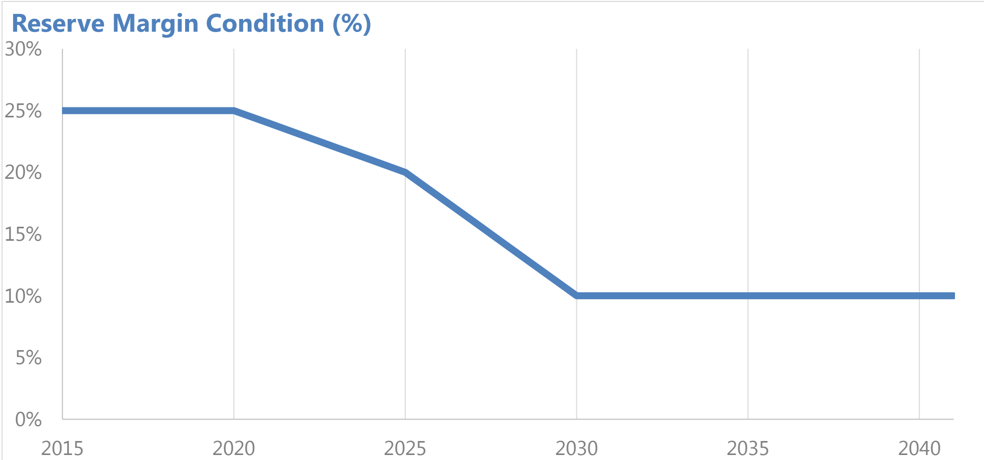
If hydropower makes up a large portion of the whole supply capacity, the influence on power supply capacity that comes from the fluctuations in annual precipitation, and the resulting river flow, is large. In Bangladesh, the capacity of hydropower is very small so these effects can be ignored.

vi) Connection with Other Systems

Connecting two power supply systems has the advantage of improving the reliability of the power supply in both systems because the connection enables mutual power interchange between them. It is considered possible to utilize this advantage fully if the international connection between Bangladesh and neighboring countries is extended in future. However, this advantage, which is an uncertain factor at present, is not considered in the formulation of the power development plan from a conservative viewpoint.

(2) Relationship between Reliability of Supply and Required Capacity

An analysis was conducted on the relationship between the reliability of power supply and the required capacity based on the power demand forecast (Base Case) and PDP. The relationship between the reserve margin and LOLE changes from year to year. If the value of LOLE is set at the standard value for developing countries of 1.0 to 1.5%, the reserve margin theoretically appropriate for the current state is approximately 25%. If international linkage and nuclear power generation are to be introduced *ca*. 2025, the reliability of the power supply shall have to be improved, as mentioned in detail in the chapter on power quality. A margin of between 8% and 15% will be required in order to achieve the target of LOLE = 0.3%, which is acknowledged to be a very challenging target. Therefore, it was assumed that the reserve margin shall be reduced from 25% in 2020 to the target of 10% by 2030 and shall be maintained at this level thereafter.



Source: JICA Survey Team

Figure 11-24 Reserve Margin

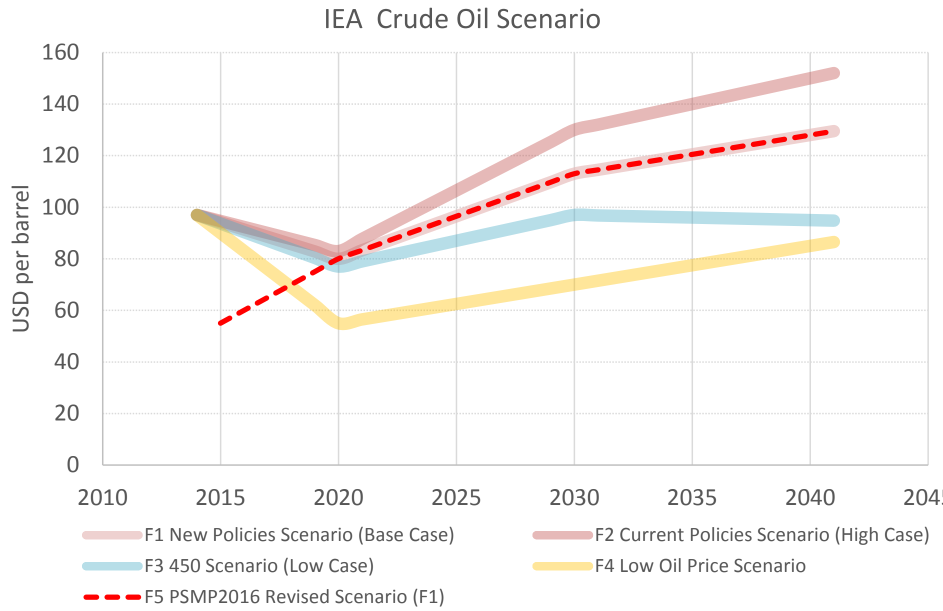
11.12.3 Fuel Price Scenarios

(1) IEA crude oil scenario

The differences between the prices of fuels in Bangladesh, including the price of domestically produced gas in particular, and the prices in the international market are large and fuel in Bangladesh is provided at prices significantly lower than those in the international market. As the future economic growth will inevitably make it impossible to satisfy the power demand with domestically produced resources, the proportion of imported fuel in the fuel supply is expected to increase rapidly and the prices of fuel are expected to increase to close to those in the international market.

In the discussion with the Government of Bangladesh and the IEA, the international organization on energy, it was decided to use the IEA Scenario for the price of crude oil that projected the price on the basis of a very long-term projection of the supply/demand balance in this analysis.

However, there is a difference between the market price of crude oil in the IEA scenario and the actual price in the market in Bangladesh at present. Therefore, an original scenario for this analysis (F5) has been formulated as the basic scenario for the price of crude oil. In this scenario, the reference price is set at the average price of crude oil in the domestic market in 2015 and the price is projected to follow the New Policies Scenario of the IEA (F1) from 2020 onward.



Source: JICA Survey Team

Figure 11-25 IEACrude Oil Scenario

(2) Long-term scenarios of the prices of fuel other than crude oil
The conversion factors shown in the table blow were used for the formulation of long-term scenarios of the prices of fuel other than crude oil based on the price of crude oil.

Table 11-34 Ratio of crude oil price

Items	Ratio to crude oil price/Ratio
Fuel oil price as % of Crude	0.80
Low Sulfur Diesel as % of crude	1.20
High Sulfur Diesel as % of crude	1.15
Natural gas price as % of fuel oil price	0.75
Domestic coal as % of imported coal	80%

Source: JICA Survey Team

Table 11-35 Long-term scenarios of the fuel prices

Fuel	Unit	2015	2020	2025	2030	2035	2040	2041
Crude Oil Price (IEA)	$/BBL	55.0	80.0	96.5	113.0	120.5	128.0	129.5
LNG@Bangladesh	$/MMBTU	9.2	13.3	16.0	16.0	16.0	16.0	16.0
Domestic Gas	$/GJ	6.3	9.1	11.0	12.9	13.8	14.6	14.8
Furnace Oil	$/GJ	8.4	12.2	14.7	17.2	18.3	19.5	19.7
High Sulfur Diesel	$/GJ	12.0	17.5	21.1	24.7	26.4	28.0	28.3
Import Coal	$/GJ	2.4	3.0	3.6	4.2	4.8	5.5	5.6
Domestic coal	$/GJ	1.9	2.4	2.9	3.4	3.9	4.4	4.5
LNG@Bangladesh	Cents/Mcal	3.6	5.3	6.3	6.3	6.3	6.3	6.3
Domestic Gas	Cents/Mcal	2.6	3.8	4.6	5.4	5.8	6.1	6.2
Heavy Fuel Oil	Cents/Mcal	3.5	5.1	6.1	7.2	7.7	8.1	8.2

Fuel	Unit	2015	2020	2025	2030	2035	2040	2041
High Sulfur Diesel	Cents/Mcal	5.0	7.3	8.8	10.3	11.0	11.7	11.8
Imported Coal	Cents/Mcal	1.0	1.3	1.5	1.8	2.0	2.3	2.3
Domestic coal	Cents/Mcal	0.8	1.0	1.2	1.4	1.6	1.8	1.9

Source: JICA Survey Team

A fuel unit price scenario was estimated for each type of fuel for the analysis of the economic value of the power development plan. The fuel market in Bangladesh is characterized by stable supply of fuel, that of the domestically produced natural gas in particular, at prices that are significantly lower than in the international market. However, because the economic growth was expected to make the significant increase in the demand for the primary energy sources and the reliance on the imported primary energy sources inevitable, it was decided to use the price scenario based on the very-long-term projection of the supply/demand balance of IEA.

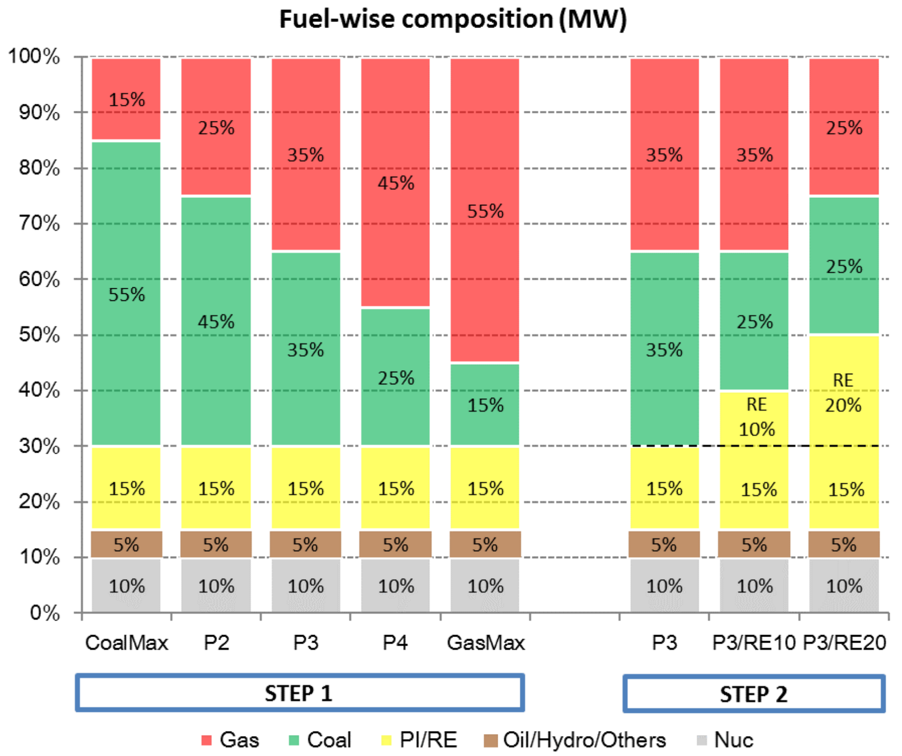
A revised fuel price scenario (F5) was formulated in order to reflect the current prices of fuel in the domestic market in the forecast for the period between 2015 and 2020. In this scenario formulated in consultation with IEA, the average fuel price in the domestic market in the period was forecast with the actual price in 2015 used as the baseline and the forecast price in 2020 of the New Policies Scenario (F1) of IEA as the goal.

The scenarios for the changes in the prices of various types of fuel were formulated in the discussion with the Government of Bangladesh and the IEA based on the IEA's crude oil scenario and the price conversion table (Table 11-34). Table 11-35 shows the fuel price scenarios used in this analysis.

11.13 Examination of economic and environmental value via power development planning simulation

The scenarios with the fixed and variable factors set as shown in the figure below were used in the simulation of the supply/demand operation. The scenario of "the basic power development plan (with the variable factors of the compositions of gas and coal set at 35%)" discussed earlier in this chapter was used as the Basic Scenario (P3).

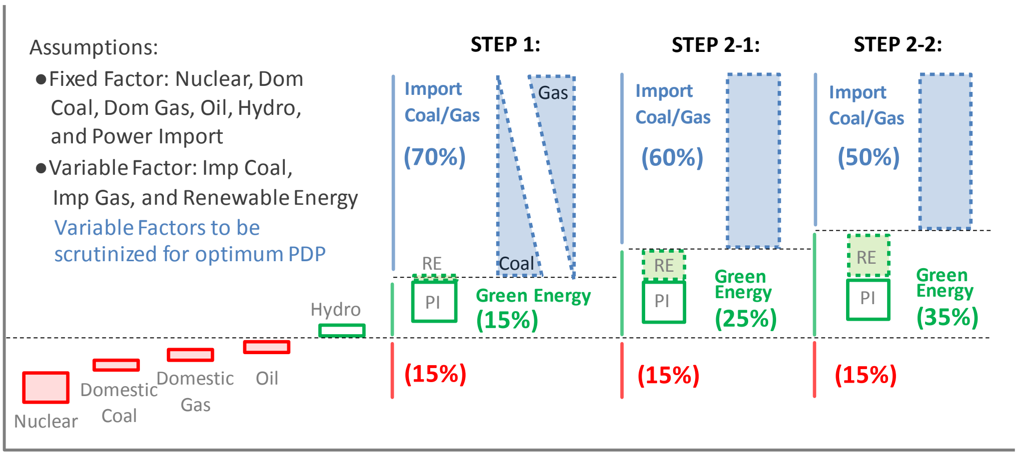
The capacities of the nuclear power plants, international connections, hydroelectric power plants, existing coal, gas and petroleum power plants and new coal, gas and petroleum power plants the construction of which was in progress were considered as fixed conditions. The five composition ratio scenarios, P1 – P5 in Fig. 11-27, with different compositions of coal and gas power generation in 2041 as variable conditions were studied in order to find the optimum power source composition, on the assumption that the coal and gas power generation accounts for 70% of the total power generation, which is considered appropriate for the formulation of a power development plan. The power source composition ratios of other power sources including petroleum were fixed in each of the five scenarios in the study. The power source composition ratios of each type of fuel between 2015 and 2041 are shown in the following table.



Source: JICA Survey Team

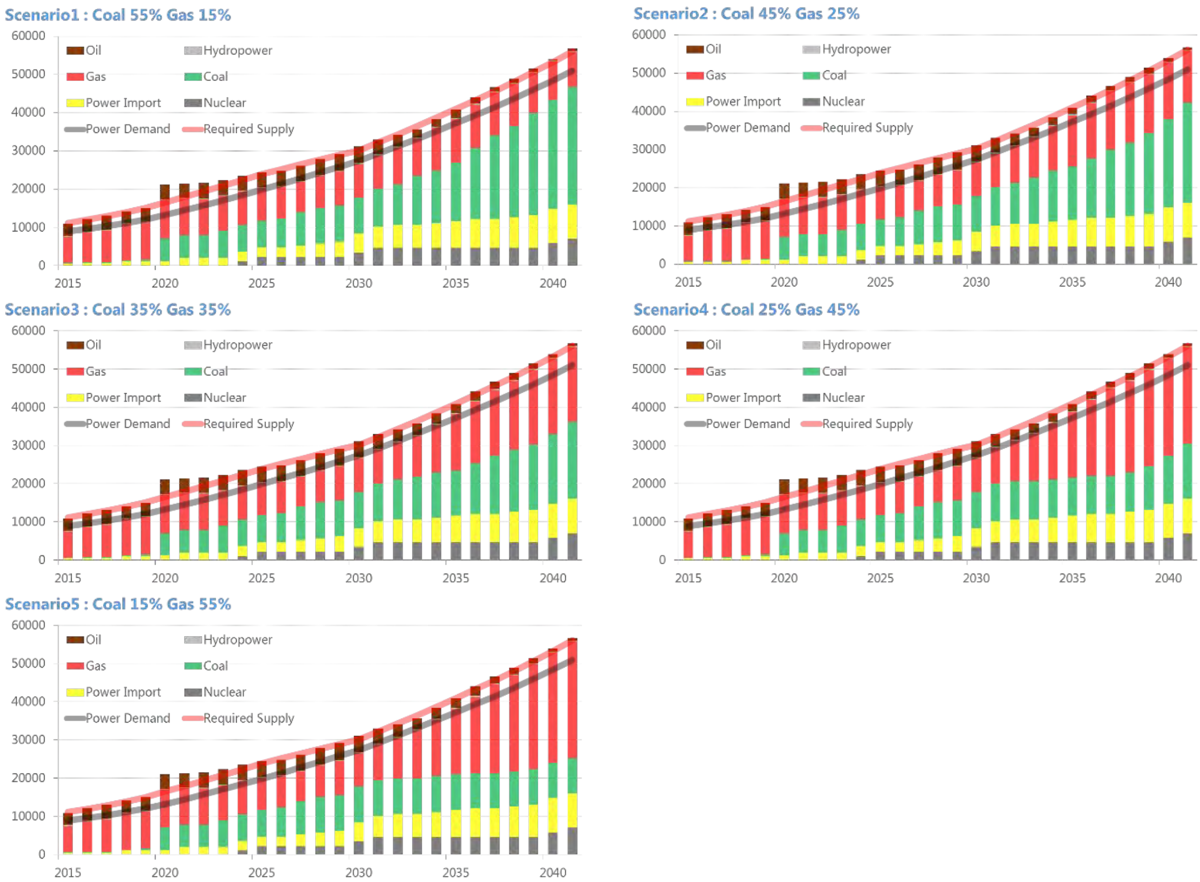
Figure 11-26 Fuel-wise composition of power development plan

After determining the optimum share of gas and coal in the energy mix, for Step 2, changing the share of fuels other than thermal power and nuclear power in the energy mix should be considered.



Source: JICA Survey Team

Figure 11-27 Methodology for demand and supply simulation



Source: JICA Survey Team

Figure 11-28 Fuel-wise composition of power development plan（MW）

11.14 Economic value

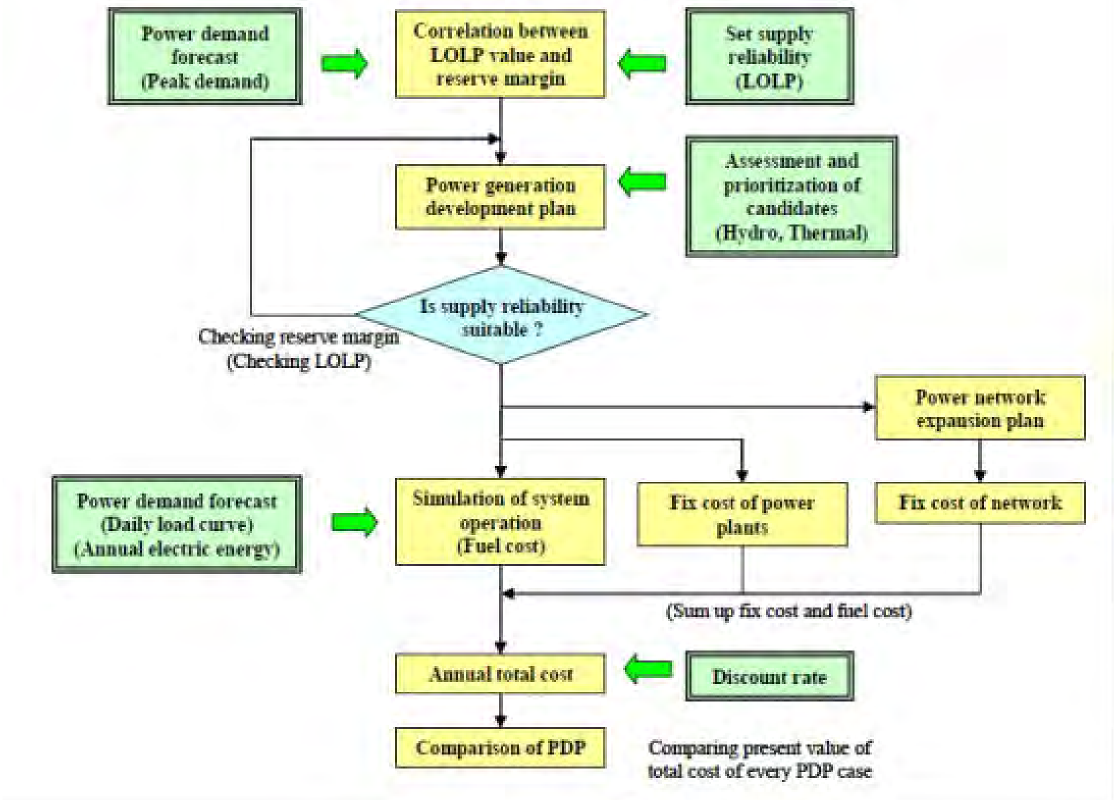
11.14.1 Economic value index

In long-term, Bangladesh will not owe much its economy on domestic energy mining industry nor plant manufacture industry. This means that lower power supply cost will bring lower burden to Bangladeshi economy as whole.
Thus, this study simply employed power generation cost (cost per unit electricity generated) to evaluate economic value of each power development scenario. Power generation cost consists of fixed price and fuel price. Fuel price projection in 2014 is shown in the previous clouse.

11.14.2 Concept of simulation for demand and supply planning

The estimation with the least cost method was used in the quantitative evaluation of the optimum power development plan. A good balance of the economic, environmental and energy security values based on the primary energy supply/demand balance, PDP, power system analysis and power system operation was taken into account in the evaluation. The results of the evaluation were reflected in PDP. PDPAT II and WASP IV were used as the tools for the simulation of supply/demand operation in the formulation of PDP, which was implemented in accordance with the flowchart shown in the figure below.

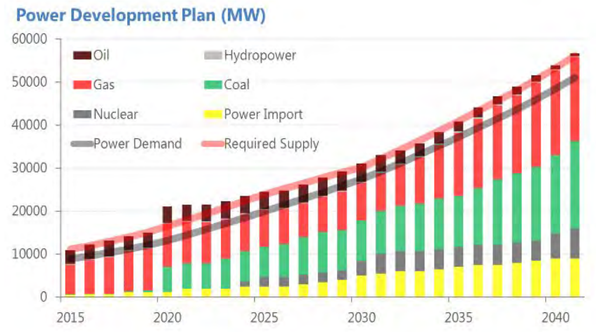
The annual fuel cost for a certain year was estimated by finding the most cost-effective operation of the given power generation facilities to satisfy a given demand of the year concerned in the simulation of the supply/demand operation. At the same time, a comparison of the fuel cost was conducted, the annual expenses were estimated as a total of the fixed cost, fuel cost and inter-connected cost, the least cost operation, the most cost-effective operation of the total power system, was identified in the simulation and the economic value of the power development plan was evaluated. The optimum development plan was selected by comparing the estimated annual expenses with those of other development plans.



Source: JICA Survey Team

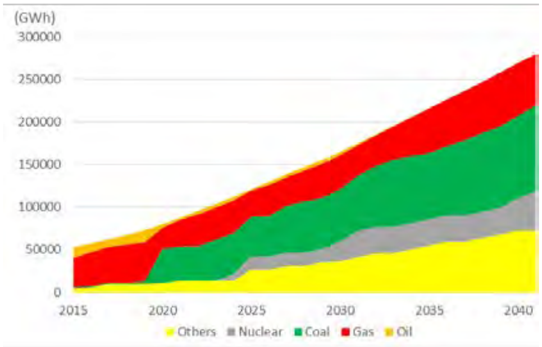
Figure 11-29 simulation of the supply/demand operation

The conditions mentioned above were used for the estimation of the consumption, unit power generation cost and CO2 emission by type of fuel in each scenario and the results of the estimation were used for the evaluation of the economic value of each scenario. The figure below shows the projection of the total power generation (GWh) in F5-P3 Scenario with its breakdown by fuel type.



Source: JICA Survey Team

Figure 11-30 Power development plan(MW)



Source: JICA Survey Team

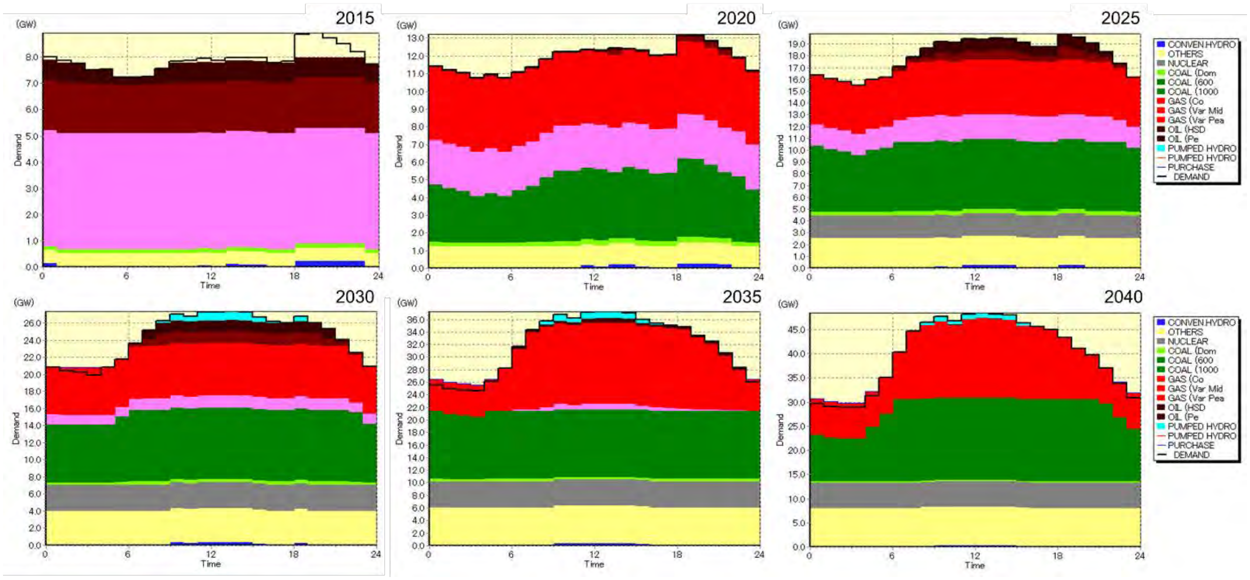
Figure 11-31 Total power generation (GWh)

11.14.3 Optimum operation pattern

The figure below shows the change in the optimum operation pattern estimated in the simulation of the supply/demand operation. At present, the base load and part of the intermediate load are supplied by power plants using the inexpensive domestically-produced fuel and part of the intermediate load and the peak load are supplied by the petroleum power plants. The base power source is expected to shift from gas to the international connection and coal gradually from 2020 onward with the commencement of operation of the large-scale coal power plants planned by the government.

The power demand in Bangladesh peaks in the evening as is seen in many developing countries where the demand for lighting accounts for a large proportion. Rolling blackouts have been used in the peak hours in the summer when the demand exceeds the supply capacity. As mentioned in detail in the previous section, the peak hours of power demand are expected to shift from the evening to the daytime between 2030 and 2035 as the economic growth is expected to increase power consumption from industrial and commercial activities.

When the international pumped storage power generation commences in 2030, the petroleum power generation that has been used as the source of the power supply in the peak hours will be replaced by the pumped storage power generation. Therefore, the role of the pumped storage power generation in the exit strategy for the use of petroleum in power generation is extremely important. The optimum operation pattern is expected to be realized in the period between 2035 and 2040 with partial replacement of the expensive gas power generation by low-cost coal power generation, which has been the main power source for the base load, as the source of the intermediate load.

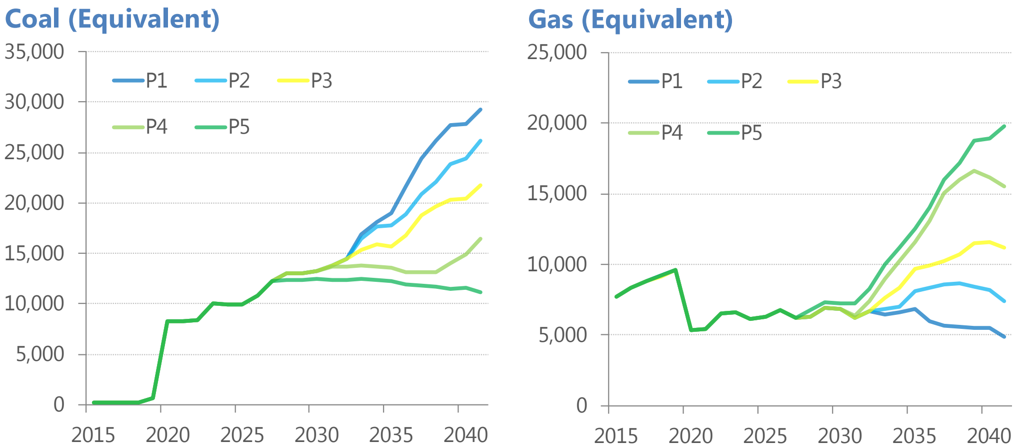


Source: JICA Survey Team

Figure 11-32 Transition of daily load curve

11.14.4 Transition of fuel consumption

The figure below shows the fuel consumption in different scenarios. The coal consumption is the highest in Scenario P1 and the lowest in Scenario P5. Conversely, the gas consumption is the highest in Scenario P5 and the lowest in Scenario P1.

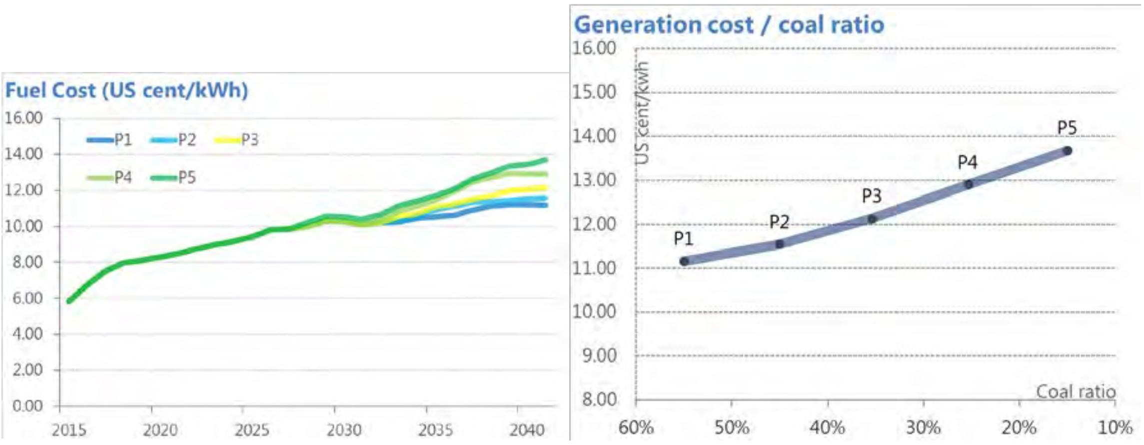


Source: JICA Survey Team

Figure 11-33 Scenario-wise gas and coal consumption (Unit / kTon of oil equivalent)

11.14.5 Transition of generation cost

The following figure shows the trends of five scenarios for generation cost. As the use of coal spreads in stages, the fuel expense will be slashed, helping curve increases in power generation costs. Thus, the power generation cost is estimated at 9 to 12 US cents/kWh for 2040. In addition, comparison of the power generation cost between the five scenarios for energy source ratio (P1 to P5) shows that the power generation cost becomes higher as the ratio of coal to all the energy sources becomes smaller.



Source: JICA Survey Team

Figure 11-34 Power generation cost under each scenario and Ratio of coal

11.15 Environmental Value

11.15.1 CO2 emission value

Environmental value of CO2 emissions has been examined by adopting the following equation. Each value is indicated in the following table based on the IPCC report.

CO2 emission [kg-CO2/Mcal]
= carboncontent per calorific value [t-CO2/TJ] / calorific consumption per calorific value [kcal/MJ]

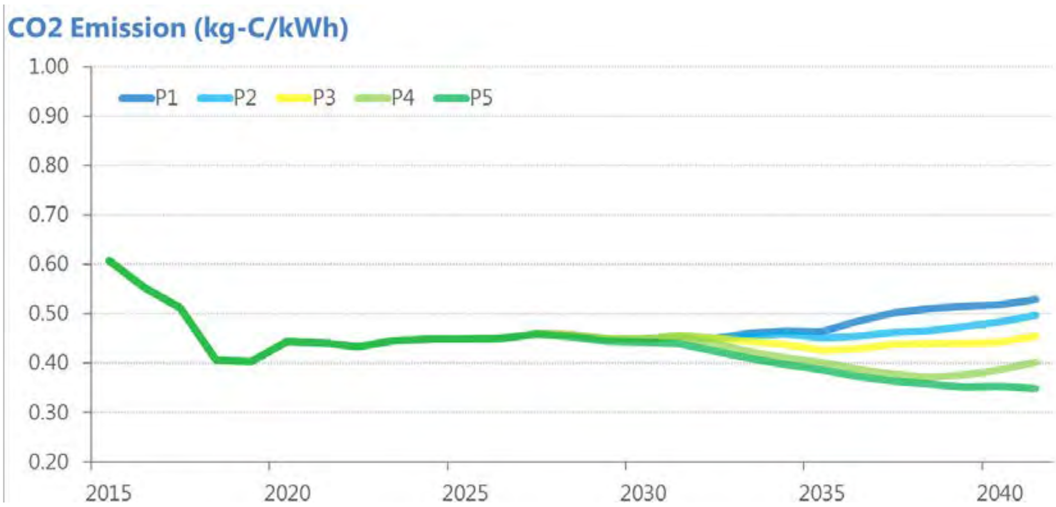
Table 11-36 Fuel-wise CO2 emission value

Item	CO2 emission (kg-CO2/Mcal)
COAL (Domestic)	0.39615
COAL (Import)	0.40229
HSD	0.30095
OIL	0.30709
GAS	0.23492

Source: JICA Survey Team based on IPCC report

11.15.2 Transition of CO2 emission

CO2 emissions in different scenarios are shown in the figure below. The CO2 emissions in 2041 are the highest (0.82 CO2 kg-C/kWh) in Scenario P1, with a high share of coal in the energy mix, and the lowest (0.55 CO2 kg-C/kWh) in Scenario P5, with a low share of coal in the energy mix.



Source: JICA Survey Team

Figure 11-35 Scenario-wise CO2 Emissions

11.15.3 Quantitative evaluation of environment value

As discussed in Chapter 5, which analyzes the environmental policy, climate change is one of the most critical issues among the environmental impacts of power supply. Bangladesh also submitted INDC to UNFCCC in 2015 and projected greenhouse gas emission reductions in the power sector by 2030.
Thus, the environmental value of each power development scenario should be evaluated focusing on CO2 emissions. This study employed CO2 cost per unit of electricity generated to evaluate the environmental value of each power development scenario. CO2 cost is calculated by multiplying CO2 emissions and CO2 price. In this study, 125 USD/tCO2 is used for the CO2 price, referring to the assumption in the 450 scenario of IEA World Energy Outlook 2015.

Table 11-37 CO2 emiaaion value by IEA World Enwegy Outlook 2015

	Region	Sectors	2020	2030	2040
450 Scenario	United States and Canada	Power and industry	20	100	140
	European Union	Power, industry and aviation	22	100	140
	Japan	Power and industry	20	100	140
	Korea	Power and industry	22	100	140
	Australia and New Zealand	Power and industry	20	100	140
	China, Russia, Brazil and South Africa	Power and industry	10	75	125

(USD2014 per ton)
Source: IEA World Energy Outlook 2015

11.16 Energy Security Evaluation

Energy security covers many concepts and there are no common approaches to evaluate it unlike previous two values. Here we presented the overview of energy security evaluation and reviewed past studies and then explained the methodology we employed.

11.16.1 Quantitative evaluation

Risk assessment is a theory of decision-making that was established in the field of engineering study. Risks consist of two factors, i.e. the probability of risk realization and the impact of the consequence.
It needs to be noted that studying on the risks concerning energy security covers a broad range of issues. According to International Energy Agency (IEA), energy security is defined as "the uninterrupted availability of energy sources at an affordable price".
An example of energy supply interruption was the case that European countries were faced with in 2006. At that time the natural gas supply from Russia was reduced because of soured relationship between Russia and Ukraine. In addition to the political incidents like that, economical incident and accidental event can bring about a problem of energy supply shortage. We also experienced a turbulent change in energy price recently when oil price rose to 150 USD per barrel in 2007 due to the turbulence in the Middle East, which then dropped to 40 USD per barrel after the Global Financial Crisis. Such high volatility is considered to be caused by the influx of speculative money in the energy market.
On a longer-term basis, the effect of continuous growth of energy demand and the depletion of fossil fuel needs to be taken into account. Uncertainty about the international policy on climate change can be also considered a kind of risk. The measurement for energy security may also change depending on the targeted period.
Furthermore, in discussing the availability of energy resources, it needs to be clarified who is the beneficiary as the precondition of the discussion. Energy availability can be discussed either as the availability at nation-level or as the availability for end-consumers. When we discuss the availability for the end-consumers, the channels of energy supply to them such as the conditions of domestic energy markets and energy supply network also need to be considered. Sometimes the accessibility to energy supply is regarded as one of the performance indicators of energy security.
Table 11-38 is one example to classify the risks concerning energy security from the aspect of different types of impact. Any kinds of risk related to energy security can be evaluated using risk assessment theory if they can be plotted with the axes of probability and impact.
A realistic approach to quantify the risks is the empirical approach. For example, it is empirically understood that, if we diversify the sources of energy supply, the possibility that all of them are suspended at once can be reduced. So the degree of diversification of energy sources can be an empirical index to measure energy security. In fact, most of the trials to quantify energy security were made based on the empirical approaches like that. Specific examples are discussed in the following section.

Table 11-38 An Example of Classifying Risks of Energy Security

Impact to what	Price (hike, volatility) Quantity (shortage)
Impact of when	Short-term Long-term
Impact to whom	Nation (consumers are also affected in the end) Consumers (risks in the course of energy distribution)

Source: JICA Survey Team

11.16.2 Past Studies on the Quantitative Evaluation of Energy Security

A standard methodology to evaluate the degree of diversification is to use "Herfindahl-Hirschman Index" (HHI). HHI was originally established to measure the status of market competition, and is formulated as the sum of the square of each business entity's market share. When this index is applied to energy supply, this can be used as a measure to evaluate the diversification of energy supply. That is, the smaller the index is, the more diversified the status of energy supply is.

Table 11-39 is the list of past studies to address the quantitative evaluation of energy security. HHI is applied in some of these studies such as IEA (2007), METI (2010) and IMF (2011), to evaluate the degree of diversification of energy suppler countries and/or primary energy sources. These studies concluded that HHI is too simple as a tool to express energy security, so they modified HHI by adding weights to parameters. For example, country risks of energy supplier countries are employed to weigh the suppliers' market share. Hence the index becomes smaller when the energy sources for a country rely on the supplier countries with lower country risk. This weighted HHI is utilized as an index to measure the risks for national-level energy supply on a short-term basis.
However, these studies did not provide clear explanation how the weight is determined quantitatively. Another drawback is that the proximity among supplier countries is not taken into account. That is, if a country relies on the energy import from two adjacent countries, this situation is considered to be riskier than importing from two distant countries.

The study of METI (2015) tried to address these issues. This METI study adopted a portfolio theory to evaluate the diversification of supplier countries and primary energy sources. The theory originally derives from the field of finance for deciding the portfolio of assets to gain expected return while minimizing risk. If this is applied to energy supply, return from each asset corresponds to energy import from a supplier country. Actually, weighted HHI can be interpreted as one specific situation of composite risks under the portfolio theory.

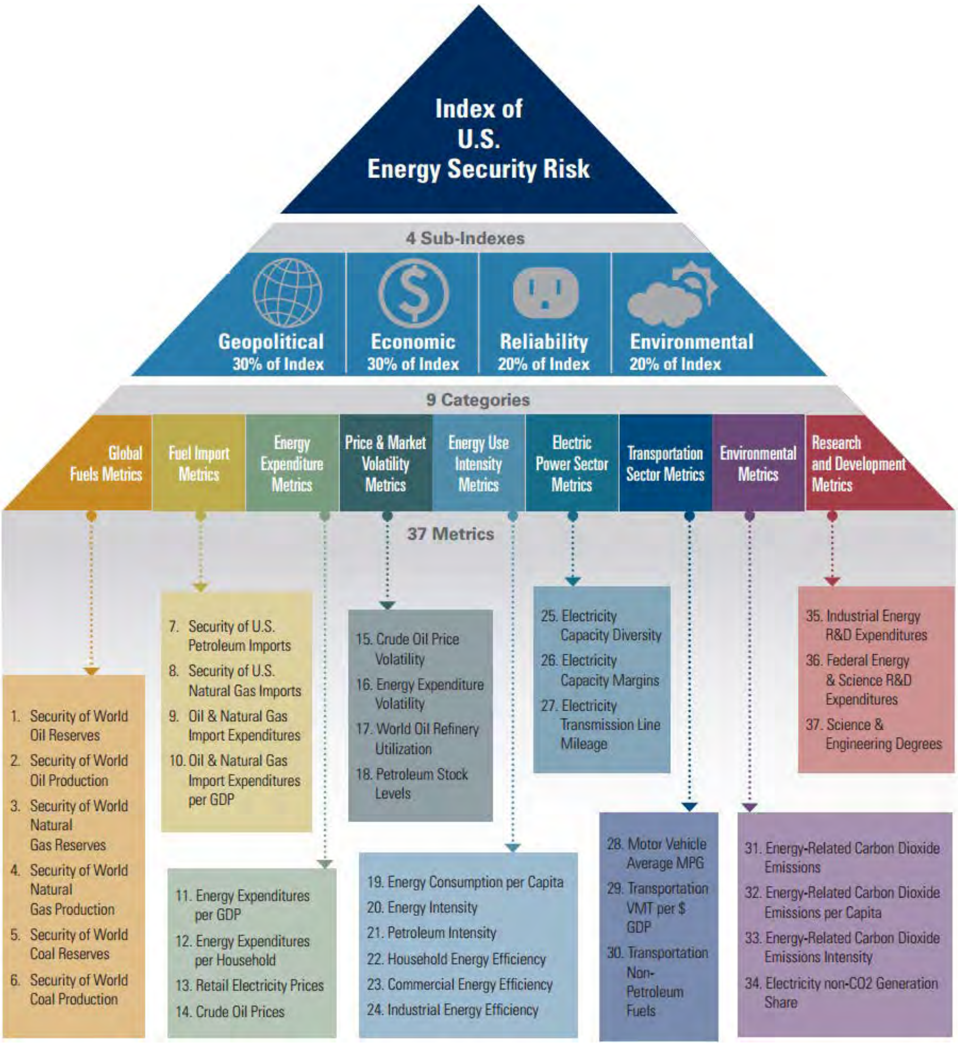
American Chamber of Commerce (ACC) takes a different approach to express various aspects of energy security. They employed no less than 37 indices that are considered to be related to energy security. Making use of empirically formulated weights, these indices are integrated into a single index called Index of U.S. Energy Security Index (see Figure 11-36). ACC also provides evaluations of the energy security of other countries (though Bangladesh is not covered), which is called International Energy Security Risk Index, where 29 indices are used. A previous study of METI (2010) also devised several indices for evaluating the entire supply chain of energy, besides the evaluation using HHI (see Figure 11-37).

A study of IEA (2011) ranked countries using a performance indicator combining various statistic data such as energy import ratio, number of energy-import ports and oil storage, on a highly empirical basis. A remarkable point of this study is that it distinguishes between risk and resilience in evaluating energy security (see Figure 11-38). Evaluating not only the extent of remaining risks but also the intensity of resilience can contribute to the effective evaluation of energy security.

Table 11-39 Past Studies on Quantitative Evaluation of Energy Security

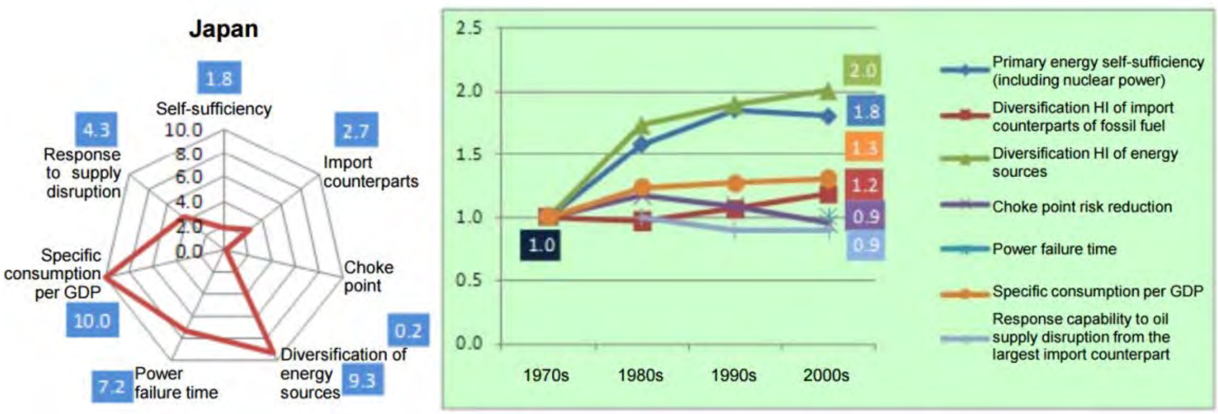
Literature	Approach
IEA "Energy Security and Climate Policy" , 2007	An index of market concentration is formulated considering the diversification of supply sources. The adopted index, which is a sort of weighted Herfindahl-Hirschman Index. Here the extent of concentration of each energy source is defined as the square sum of each supplier country's share in the energy supply, weighted by the country risk. Then the weighted average of each energy source's index is formulated considering the share of each energy source in the total primary energy supply.
METI (Japan), "2010 Annual Report on Energy (Energy white paper 2010)", 2010	Here energy security is defined as being able to secure energy in the "quantity" necessary for people's live, economic and social activities, and national defense etc. at affordable "price". National energy security is evaluated using 8 indices across energy supply chain, including primary energy self-sufficiency, diversification of countries from which energy is imported, diversification of energy source and reduction of dependency on choke points. Herfindahl-Hirschman Index is employed to evaluate the diversification.
IMF working paper, "Measuring Energy Security :Trends in the Diversification of Oil and Natural Gas Supplies ", 2011	Diversification of primary energy supplier is evaluated using the squared sum of the shares of energy suppliers, which are weighted with country risk of each supplier, proxy to each supplier, and the share of energy import of evaluated country (smaller import share means more flexibility in supply).
METI (Japan), "Toward the Stable Assurance of Fuel Resources ~ Energy Risk Index (Security Index) ~", 2015	The stability of energy supply is evaluated by focusing on the supply chain from supplier countries to Japan. Suppliers' country risk, sea-lane risk, and the effect of diversification of suppliers and sources are considered in an integrated way.
American Chamber of Commerce (ACC), "Index of US Energy Security Risk", annually updated	US's national energy security is evaluated using 37 different indices including geopolitical factor (ex. production of fossil fuel, import of US), economic factor (ex. energy price, energy consumption per GDP), reliability factor (ex. Electricity reserve rate), environmental factor (CO2 emission, R&D investment to renewable energy) etc.
IEA "Measuring Short-term Energy Security" , 2011	Energy security on each energy source is evaluated, taking into account the "risk"-related data and the "resilience"-related data. Countries are experientially ranked using these statistics data. The extent of energy source mix is not considered.

Source: JICA Survey Team



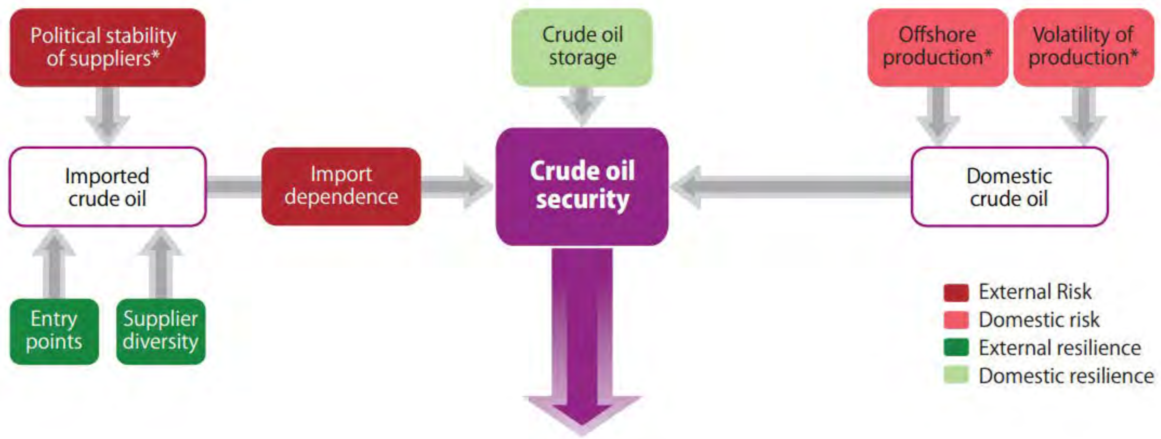
Source) American Chamber of Commerce (ACC), "Index of US Energy Security Risk 2014", 2014

Figure 11-36 Diagram of Indices that Form ACC's "Index of US Energy Security Risk"



Source: METI (Japan), "2010 Annual Report on Energy (Energy white paper 2010)", 2010

Figure 11-37 METI's Evaluation on the Status of Energy Security in Japan



Source: IEA "Measuring Short-term Energy Security", 2011

Figure 11-38 IEA's Schematic Diagram for Analyzing the Energy Security of Crude Oil

11.16.3 Key Issues in Considering the Energy Security in Bangladesh

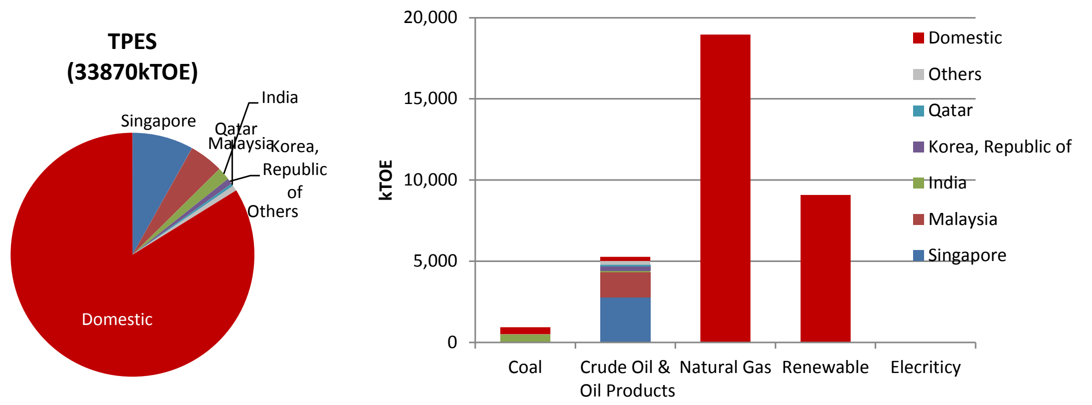
Because there is no agreed or standardize approach to evaluate energy security, this study recommends that a methodology of quantitative evaluation of energy security in Bangladesh should be devised by considering the characteristics of Bangladesh's energy supply and demand besides referring to the aforementioned approaches.
There are several studies on energy security in Bangladesh as shown in Table 11-40. These studies focus on relatively nation-side long-term energy supply. They commonly mention the importance stable expansion of energy supply capacity to achieve the economic growth target.

Figure 11-39 illustrates current energy supplier to Bangladesh. In 2013, around 80% of Bangladeshi energy was supplied by itself. India supplies coal by land. Southeast Asian countries supply oil products by sea, much of which is originally from Middle East. In the future, increase of energy import of Bangladesh is inevitable along with economic development. Which energy sources and from which countries Bangladesh can import are the key concerns in Bangladesh.
To evaluate energy security in this 3E evaluation, we focused on risk of sudden shortage in energy supply quantity, which would directly damage Bangladesh economic activities. The difference ratio of coal and gas among power development scenarios brings different dependence on supplier countries and delivery routes, and thus different shortage risks. This energy shortage risk can be quantified in monetary value as potential loss value of economic production.
There are of course other approaches to evaluate energy security. Energy price stability and predictability are other important aspects for energy security. We considered such aspects regrading price in "Economic viability" among 3E. Feasibility of these scenarios can be another aspect to ensure long-term energy security. We judged that these scenarios have similar feasibility and need equally intense policies, so considering this aspect will not be information for making a decision.

Table 11-40 Past Studies on Energy Security in Bangladesh

Literature	Approach
Unnayan Onneshan, "Energy Security: Trends and Challenges - Bangladesh Economic Update", 2014	It discusses current energy security situation using related data like below: • Power ➢ Availability (Consumption per capita, electricity access, load shedding) ➢ Reliability (Ownership, use of fuel) ➢ Affordability (Tariff and subsidy, system loss, cost) • Other energy ➢ Reserve, production, import ➢ Price, import cost
T. Ishtiaque (Bangladesh University) et al., "Energy Sector Development and Energy Security in Bangladesh", 2013	Energy sector development to 2050 is discussed. It points out that long-term energy policy is crucial to sustainable development of Bangladesh. As for energy security, it mentions the importance of cooperation with other countries to ensure energy supply, especially hydropower from Bhutan and Nepal.
ANM Obaidullah, Energy Security & Climate Change: Challenge for Bangladesh, Energy & Power	Uninterrupted energy supply is essential for stable economic growth in Bangladesh. It focuses on primary energy mix to ensure such energy supply. It consists coal is the most stable commodity in Bangladesh in spite of high CO2 emission. LNG, nuclear and renewables are other prospective commodities.

Source: JICA Survey Team



Source: JICA Survey Team

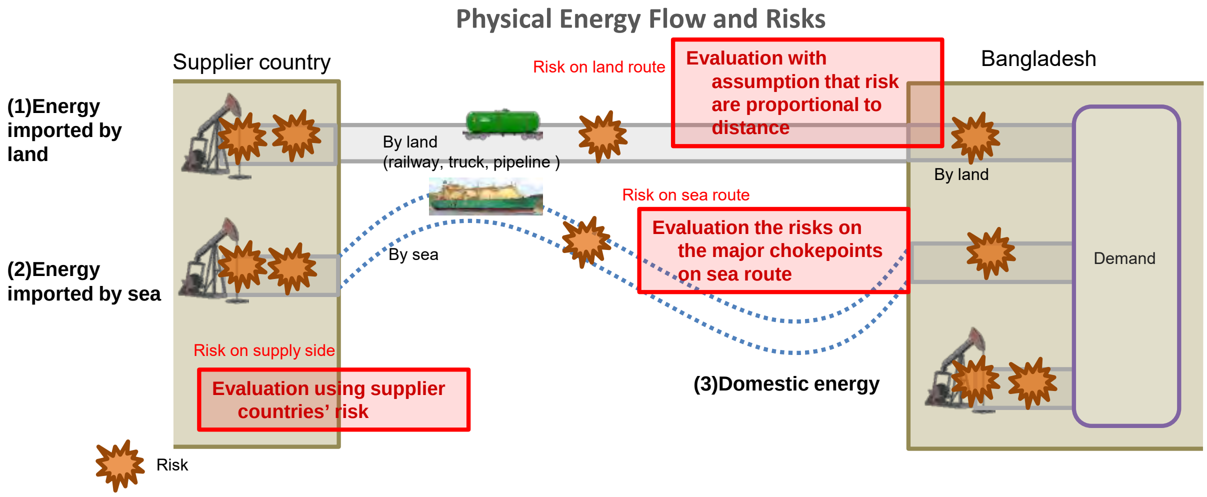
Figure 11-39 Current energy suppliers to Bangladesh in 2013

11.16.4 Methodologies of Evaluaion

As discussed above, we focused on risk of sudden shortage in energy supply to evaluate energy security. Proposed index is calculated using the formula below.

Energy Security Index [USD / kWh]
= GDP [USD] x Possible non-delivery rate [%] / Primary Energy Supply [toe] / Generation Efficiency [kWh/toe]

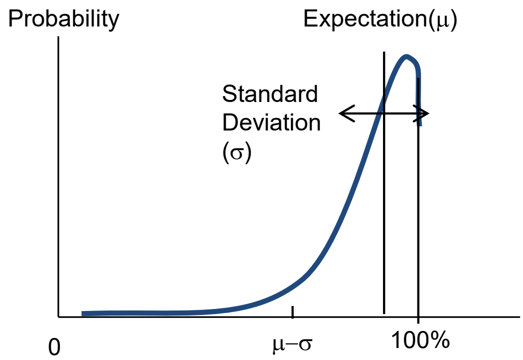
To calculate "possible non-delivery rate", we modeled physical energy delivery routes to Bangladesh and assumed the blockage probability of each point on the routes.
The following figure illustrates the model concept. Among many kinds of risk on the energy delivery routes, we focused on three risks: export suspension risk, blockage risk on land route, and blockage risk on sea route. We ignored the risks to deliver domestic energy.



Source: JICA Survey Team

Figure 11-40 Physical Energy Delivery Routes and Risks

With the model, energy delivery rate to Bangladesh can be expressed in the form of probability density function as shown in Figure 11-41, considering many different combinations of risk realization. This curve itself reflects the risk situation of the physical energy delivery of the country. Using the parameter of the expectation (μ) and the standard deviation (σ) of this distribution curve, we can calculate a value of (μ− σ) which shows minimum delivery rate with 84% confident interval mathematically. In the other word, 1− (μ− σ) shows maximum non-delivery rate. This number is that we call "Possible non-delivery rate" here.



Source: JICA Survey Team

Figure 11-41 An Example of Probability Density of Energy Delivery

In order to calculate these values, this study defined a portfolio of energy sources (share of domestic production and import as well as the source country of import) and the blockage probability of transport routes for each scenario.

Based on the analysis of natural gas, LNG, coal and oil supply in the previous chapters, and also referring to the current status of other Asian countries' fossil fuel import, the maximum volume of supply from domestic production, the volume of export from abroad, and the source countries are assumed, as summarized in Table 11-41.

As for natural gas, this study assumed that, even when LNG import is suspended, at maximum 10,000 ktoe of domestic gas production per year (about 1,300 mmcfd) can be appropriated for power generation, which is almost equivalent to the current level of natural gas supply for power generation on the grid and for captive power' own consumption in total, and that the gas supply exceeding this needs to be imported from Qatar for estimating the blockage risk of import. For the scenarios where the annual gas consumption for power generation in 2041 is less than 10,000 ktoe per year, gas supply will be managed anyhow by providing domestic gas for power generation with priority even when LNG import is suspended.

As for coal, this study assumed that the maximum consumption of domestic coal for power generation is 600 ktoe per year (the maximum possible coal consumption of power stations that can use domestic coal only) and that remaining coal supply needs to be the import from abroad, which is the mix of 70% from Indonesia (low-grade coal) and 30% from Australia (high-grade coal) for estimating the blockage risk of import.

Whereas it is relatively easy for a gas-fired power station that usually uses imported LNG to switch to domestic natural gas as far as it's connected to a domestic gas pipeline, it is far difficult for a coal-fired power station, which is designed to use imported coal, to switch to domestic coal in a short period because of the difference in combustion characteristics among fuels and the difficulty with securing fuel transport etc. Therefore, this study does not consider the expanded use of domestic coal in the case of blockage of coal import. In general, the blockage risk of coal import is considered to be lower than that of LNG import because of the diversity of source countries, but the difference in flexibility in fuel switching between them leads to an implication that too much dependence on coal use in Bangladesh may become riskier than the balanced energy mix of coal and gas.

Regarding crude oil and oil products for power generation, this study assumed that all will be the import from the Middle East, for instance 50% each from UAE and Saudi Arabia.

Though there may be a possibility that a route of importing natural gas and coal via surface transport from India may be established, this study considers that its probability is negligibly low at this moment, thus this assumption was disregarded.

Table 11-41 Assumption of Supplier Countries and Volume of Fossil Fuel Supply for Power Generation (as of 2041)

Fuel supply	Natural gas	Coal	Crude oil and oil products
Domestic production	Max. 10,000 ktoe	Max. 600 ktoe	—
Import (maritime transport)	Qatar: all of the remaining	Out of the remaining: Indonesia: 70% Australia: 30%	UAE:50% Saudi Arabia: 50%
Imported (surface transport)	—	—	—

Source: JICA Survey Team

Though accurate quantization of routes' blockage probabilities is hardly possible, this study provisionally set parameters of risks as shown in Table 11-42 for quantitative evaluation of 3E.

In setting the export suspension risk, this study referred to the country risk classification of OECD and assumed the probability of blockage in accordance with the grades of risk classification.

Blockage probability of maritime transport was calculated as the product of the number of major chokepoints on the route and the constant factors. Blockage risk of import from the Middle East was set higher considering the transport via the Strait of Hormuz. Surface transport from India was not considered in this study, but just for reference, blockage probability was also calculated as the product of the travelling distance and the constant factors.

Table 11-42 Assumption of Export Suspension Risk

Fuel;	Supplier	Classification by OECD	Assumed export suspension risk	Assumed transport blockage risk
Coal	India	3	5%	0.5%
	Indonesia	3	5%	2%
	Australia	(High Income OECD Country not reviewed or classified)	0.1%	2%
Oil	UAE	2	1%	4%
	Saudi Arabia	2	1%	4%
Natural Gas	India	3	5%	1.5%
	Qatar	3	5%	4%

Note) Classifying countries into 7 grades (from 1(best) to 7(worst))
Source) OECD Country Risk Classification

11.17 3E Evaluation

Power supply is closely related with economic activities and environmental issues. For a certain pattern of energy supply to be sustainable, it has to satisfy the conditions called “3E,” consisting of the economic value, environmental value and energy security value. The Basic Energy Plan of Japan states that the energy policy of Japan shall satisfy the “3E” conditions.
A quantitative evaluation of the 3E values in 2041 of each of the power development scenarios proposed in the previous section conducted for the selection of the most recommendable scenario is described in this chapter.

11.17.1 Selection of the Optimum Scenario of Energy Mix Based on 3E Evaluation

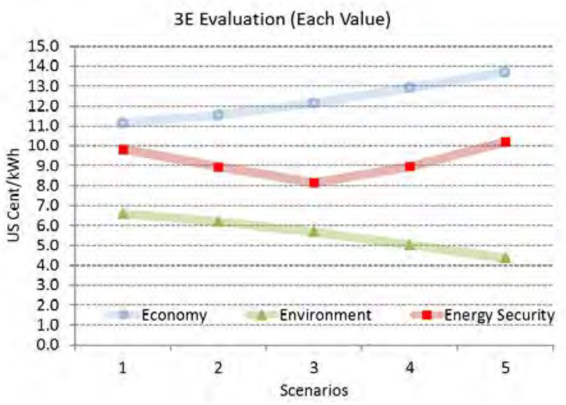
Based on the aforementioned methodologies, five scenarios of power development were evaluated using 3E indicators, as shown in the following table. All indicators are expressed in monetary values and they indicate better performance when the number is small. The sum of these three indicators is the total score for the 3E evaluation.
The economic indicator becomes favorable when the share of coal generation in the total power supply is high. Conversely, the environmental indicator becomes favorable when the share of coal in the total power supply is low. The energy security indicator becomes optimized when the shares of coal and natural gas are balanced.

Table 11-43 Results of 3E Evaluation for Each Power Development Scenario

[US cent/kWh]

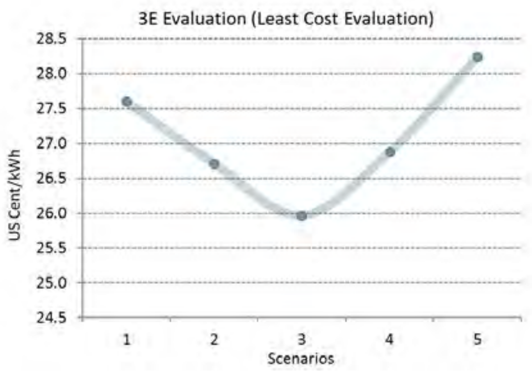
Scenario	Shares in generation capacity (in MW)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]
1	Gas 15%, coal 55%	11.2	6.6	9.8	27.6
2	Gas 25%, coal 45%	11.6	6.2	8.9	26.7
3	Gas 35%, coal 35%	12.1	5.7	8.2	26.0
4	Gas 45%, coal 25%	12.9	5.0	9.0	26.9
5	Gas 55%, coal 15%	13.7	4.4	10.2	28.2

Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-42 3E value (each value)

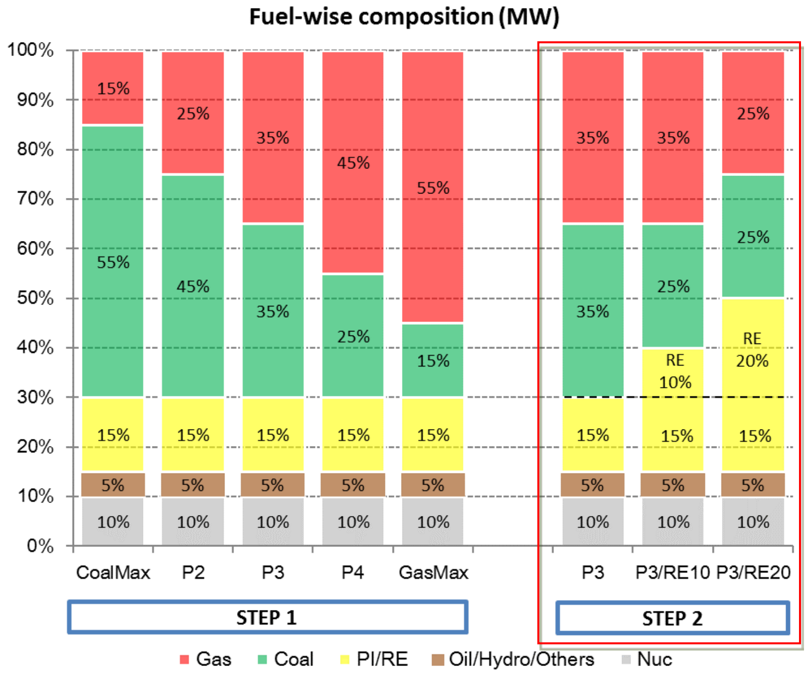


Source: JICA Survey Team

Figure 11-43 3E value (total value)

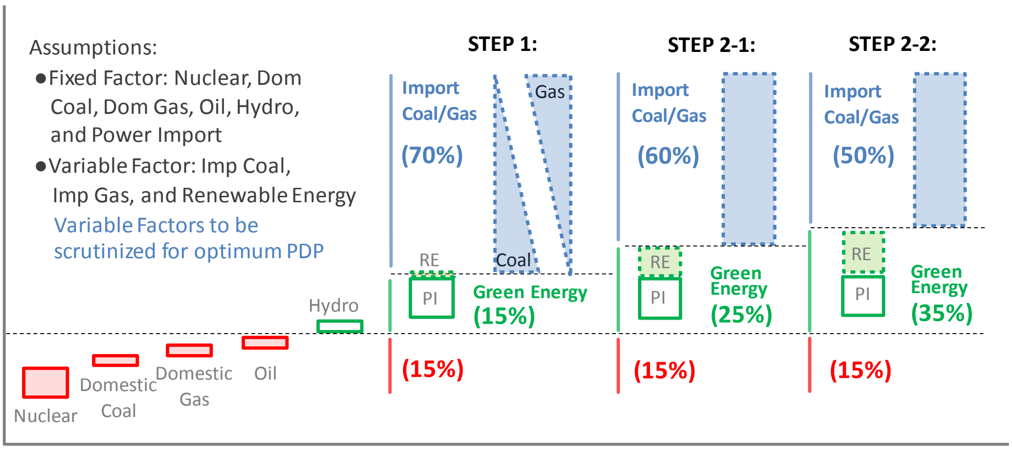
11.17.2 Challenging for renewable energy expansion

As mentioned above, the possibility of increasing the use of renewable energy was studied by changing the composition ratios of power sources other than the thermal and nuclear power generation in Step 2 after the optimum composition ratios of the gas and coal power generation had been decided. The scenarios in which the ratio of renewable energy was increased by 10% (RE10 Scenario) and 20% (RE20 Scenario) were used in this study. The composition ratios of gas and coal in each scenario are shown in the following fugure.



Source: JICA Survey Team

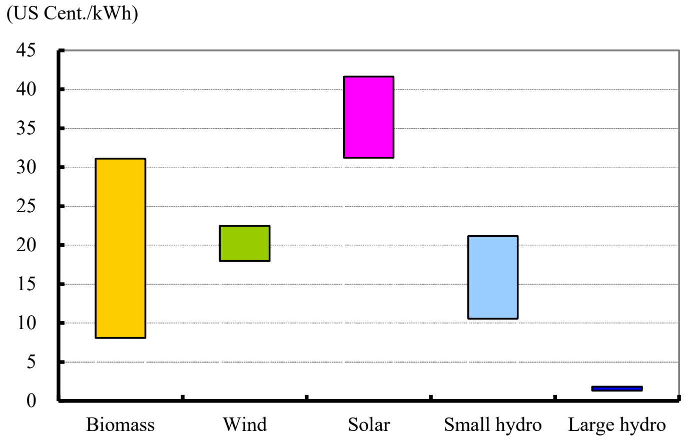
Figure 11-44 Simulation pattern



Source: JICA Survey Team

Figure 11-45 Power Source Composition in FY 2041 (as shown above)

(1) Matters to be Considered regarding the Introduction of Renewable Energy
The output of renewable energy power plants such as photovoltaic (PV) and wind power plants is significantly affected by weather conditions. Thus, unstable, actual supplies from these plants are much smaller than their installed capacities. In fact, the maximum supply is estimated at approximately 30% of the expected plant capacity. Therefore, installed capacity of approximately three times' the required supplies will be required if 10% and 20% of the total power supply is to be generated by renewable energy power plants as assumed in RE 10 Scenario and RE 20 Scenario, respectively.
The capacity factor of renewable energy power plants was assumed as 30%, and the construction of renewable power plants of the total installed capacity of three times' the power required to be supplied by those plants to achieve RE 10 and RE 20 Scenarios in the plan was assumed in this analysis in order to consider the conditions mentioned above. The table below shows the standard specifications of the renewable energy used in the estimation.



Source: JICA Survey Team

Figure 11-46 Renewable energy typical generation cost

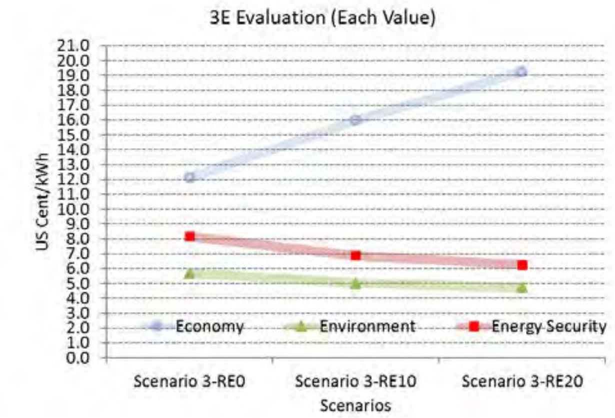
(2) 3E evaluation including the possibility of the use of renewable energy
Figs. 11-47 and -48 show the 3E values of the scenarios estimated with the "3E" Evaluation Indicator Estimation Method mentioned above. The introduction of power generation with renewable energy in RE Scenarios 10 and 20 will lead to a significant increase in the unit power generation cost because of the increase in the cost for its introduction.

Table 11-44 3E evaluation of each scenario with renewable energy

[US cent/kWh]

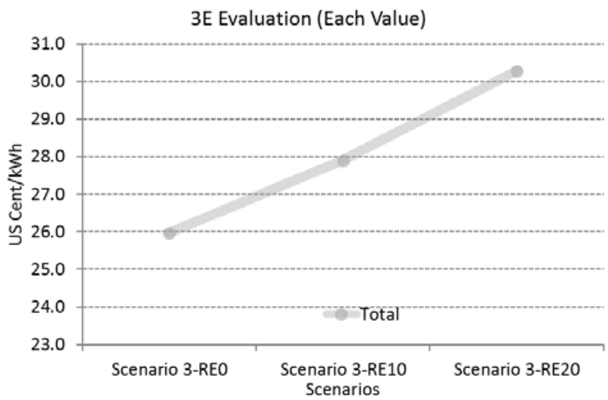
Scenario	Shares in generation capacity (in MW)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]
3-Base	Gas 35%, coal 35%	12.1	5.7	8.2	26.0
3-RE10	Gas 35%, coal 25%	16.0	5.0	6.9	27.9
3-RE20	Gas 25%, coal 25%	19.2	4.7	6.2	30.2

Source: JICA Survey Team



Source: JICA Survey Team

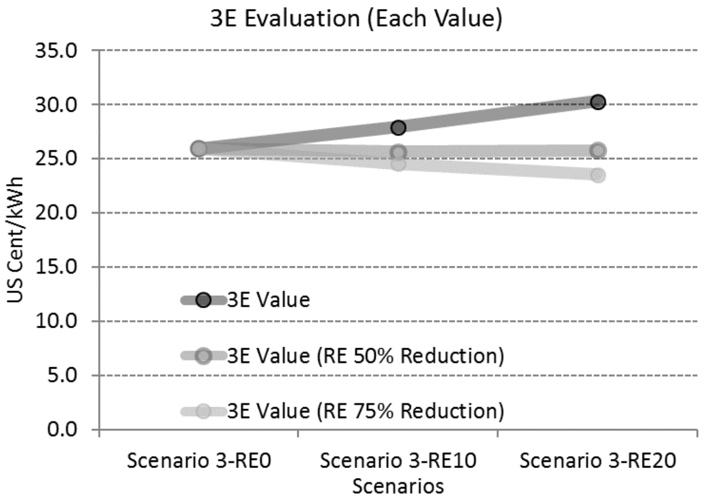
Figure 11-47 3E value (each value)



Source: JICA Survey Team

Figure 11-48 3E value (total value)

(3) Sensitivity Analysis on the Cost of Introducing Power Generation with Renewable Energy
Because the power generation cost is an economic indicator that has a great impact on the 3E evaluation, a sensitivity analysis was conducted with different costs for the introduction of renewable energy power generation. Fig. 12-48 shows the result of the comparison of cases in which the introduction cost is assumed to have been reduced by 50% and 75% with the case of introduction at the current price.
The 3E evaluation values of the scenarios with the introduction of renewable energy power generation are lower than those of the scenario without the introduction when the cost of the introduction has been reduced by at least 50%. Therefore, it is advisable to decide the proportion of the power supply generated with renewable energy in the total supply with the reduction in the cost of the introduction to be realized by technical innovation taken into account.



Source: JICA Survey Team

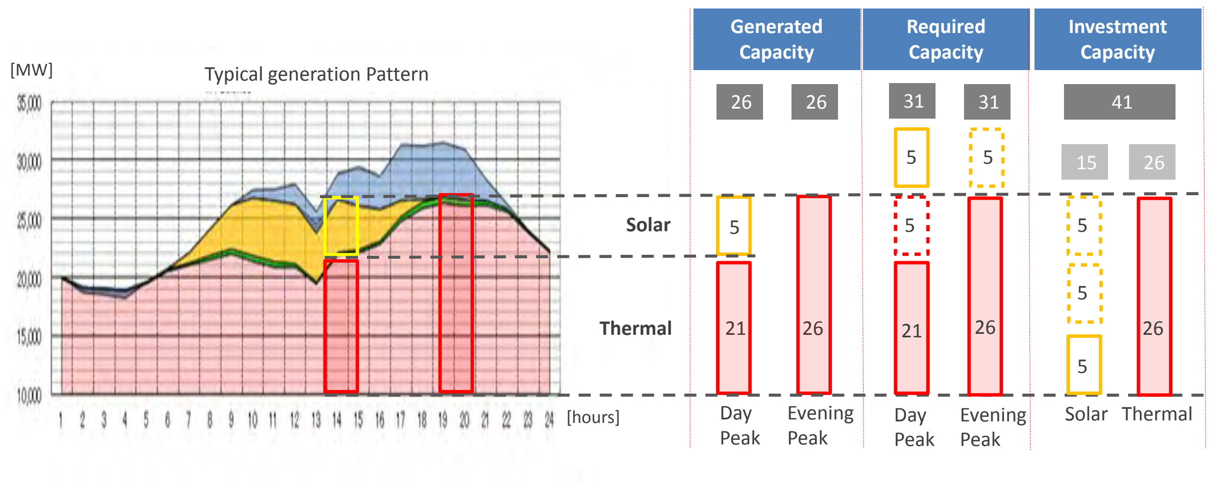
Figure 11-49 3E value (total value)

(4) Challenge and issued of expansion of renewable energy
An illustration of the patterns of operation of thermal and PV power plants on a fine day in the peak-demand period in the summer is shown in the figure below. The figure shows that the output of the PV power generation begins to increase gradually at around 7 a.m. until it reaches the maximum output of 5,000 MW at around 10:00. This maximum output is maintained until around 14:00. The output of the thermal power plants operated with an installed capacity of 26,000 MW is reduced in tandem with the increase in the output of the PV power generation system between 7 a.m. and 10 a.m. and the output is

maintained at 21,000 MW in the peak hours between 10:00 and 14:00. After 14:00, the output of the PV power generation gradually decreases until it reaches zero in the evening, while the output of the thermal power plants is increased. When the output of the thermal plants has returned to 26,000 MW, preparations for the evening peak shall be made.

During the daytime peak hours, 5,000 MW of the thermal generation capacity remains unused because of the use of PV power plants with an installed capacity of 5,000 MW. Therefore, a total installed capacity of 31,000 MW, consisting of 26,000 MW of thermal power generation and 5,000 MW of PV power generation, is required to satisfy both the daytime and evening peak demands. In addition, it is very difficult to forecast the output of a PV power plant accurately because it changes depending on weather conditions. The kW equivalent of the output of renewable energy power plants was estimated with the (expected) contribution of power generation with renewable energy to a peak demand empirically set at approximately 30%. If 5 MW of the net power supply is to be realized from power generation with renewable energy, investment in the development of renewable energy power plants with a total capacity of approximately 15 MW will be required, as 5 MW ÷ 0.3 (expected proportion of the contribution) ≃ 15 MW. Therefore, it should be fully noted that, when the target output of power generation with renewable energy is set on the MW base, facilities with a total capacity of three times' the target output will be required to supply the target output stably throughout the year.

As mentioned in the description of the demand forecast, the peak demand that is currently found in the evening is expected to shift to the daytime sometime between 2030 and 2035 as a result of the economic development in Bangladesh. The optimum power source composition in a PDP is generally formulated against the annual peak demand. Although it is not impossible to use the power generated by PV power plants (from renewable energy) and stored in storage batteries for the evening peak hours if the cost and the operational difficulty of such a system can be ignored, it is advisable to introduce this system after economic development has moved the peak demand to the daytime, with the unpredictability of the output of power generation with renewable energy taken into account. Therefore, it is recommended that investment be made in the development of ordinary power sources to make the supply meet the demand at the moment.



Source: JICA Survey Team

Figure 11-50 Operation pattern in case of renewable energy installation

11.18 General strategy for finding the optimum energy mix

11.18.1 Outline

(1) Short term (up to 2020)

- Capacity building for MP revision
  - ✓ Collaboration between organizations for power and energy master plan
  - ✓ Periodic rolling revisions for milestone mater plan
  - ✓ Comprehensive statistical work function
  - ✓ Introduction of KPI management
- Improvement in the investment climate
  - ✓ Improvement of PPA
  - ✓ Reinforcing tax exemption for FDI
  - ✓ Prompt procedure
  - ✓ Financial credit approval by international organization
- Eliminating rolling blackouts
- Reform of O&M of power plants and revision of electricity charges

(2) Short- to medium-term (up to 2025)

- Breaking away from the dependence on costly petroleum and rental power generation
- Promotion of PPP investment in power generation projects
- Reform of O&M of power plants and revision of electricity rates

(3) Medium- to very long-term (up to 2041)

- Establishment of reliable large-scale base power sources
  Promotion of PPP investment in power generation projects
  Reform of O&M of power plants and revision of electricity rates
  Realization of the best mix of power sources with high 3E values

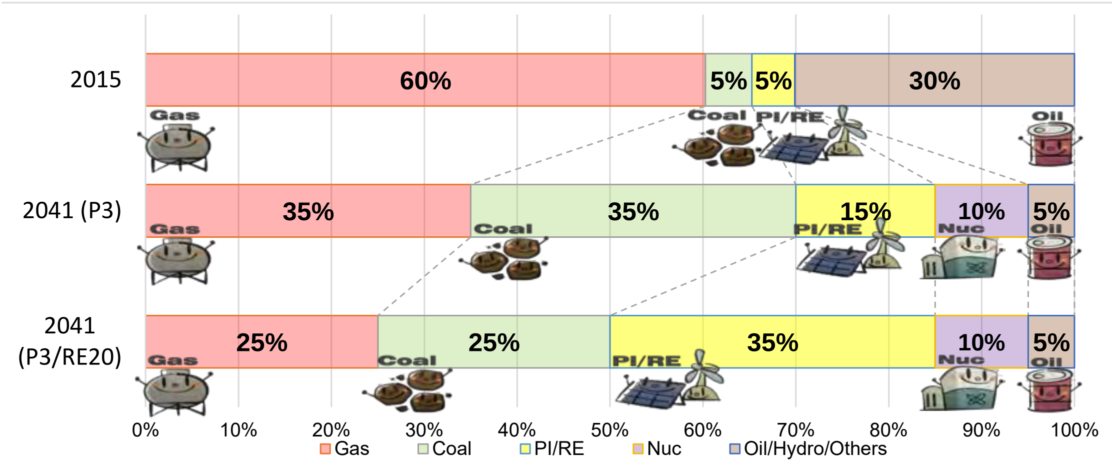
Table 11-45Road map of power development plan

Category PSMP2016	Target	Action Plan	Sort Term FY2016～2020	Mid-Long Term FY2021～2025/ 2026-2035	Super Long Term FY2036～2041
Power Development Plan	Optimized Energy Mix	**1. Energy mix: minimize 3E-Value(Economy/Environment/Energy Security)**			Energy Mix-Min 3E
		2. Capacity building for MP revision	Well-organized planning climate		
		-Collaboration between organizations for power and energy master plan			
		-Periodical rolling revision for milestoned-MP			
		-Strengthen comprehensive statistical work function			
		-Introduction of KPI management			
		3. Improvement in the investment climate	Well-organized investment climate		
		-PPA improvement			
		-FDI improvement			
		-Prompt procedure of invenstment application			
		-Introduction of financial credit approval by international organization			
		4. No load shedding		Power for all	
		5. Exiting from high cost rental power			
		6. Securing low cost power supply for baseload			
		7. Integrated energy infrastructure (Port facility for fuel terminal)			
		8. Securing low cost power supply for baseload			
		9. Integrated energy infrastructure (Port facility for fuel terminal)			

Source: JICA Survey Team

11.18.2 Acchieve to best energy mix

In order to maximize the 3E value (the total of the economic, environmental and energy security values) of the power source composition of the energy mix, a portfolio consisting of well-balanced proportions of gas, coal and other power sources shall be realized. This shall be done by halving the proportion of gas power generation to depart from the current heavy reliance on gas, and with the systematic expansion of relatively inexpensive large-scale coal power generation and international connection with the neighboring countries as an exit strategy from the reliance on expensive oil-based rental power.
In addition, the investment cost for the use of renewable energy, which is larger than that for the use of conventional energy sources, is expected to reduce in future with technological advancements and the extension of its use in society. When this condition has been met, a shift to the active use of renewable energy and a reduction in the consumption of fossil fuel shall have to be realized, following the global trend, with the aim of increasing the use of zero-emission power sources.



Source: JICA Survey Team

Figure 11-51 Best mix including expansion of renewable enegy

11.18.3 Recommendations on the implementation & monitoring of the master plan

(1) Capacity building for master plan revision

(a) Collaboration and cooperation between organizations involved in the formulation of mp

In Bangladesh, the Power Division under the Ministry of Power, Energy and Mineral Resources (MoPEMR) is responsible for developing power development plan, and the practical works are done by the Bangladesh Power Development Board (BPDB). In the meanwhile, the Energy and Mineral Resource Division under MoPEMR is responsible for the energy supply plan other than electricity and the practical works are done by Petrobangla, Bangladesh Petroleum Corporation (BPC) and so on.
This study observed that, because of the separated administration between electricity and other energy sources, there is no organizational structure that supervises the overall energy supply and demand in Bangladesh comprehensively. As the domestic production of natural gas in Bangladesh is expected to deplete whereas the energy demand will continue to increase rapidly, the country will need to depend more on imported energy sources.
Considering this situation, the importance of developing an energy supply plan from a comprehensive viewpoint is expected to gain importance for determining how to appropriate the limited domestic energy production among various sectors and which energy sources to import for supplying to which sector and how much.
In developing the aforementioned power development plan and energy supply plan, a systematic relation among stakeholders is needed so that the responsibility of various data necessary for making future projection such as the actual operational data and facility development plan is identified and that these data are administrated in unity. Current status is that, as observed by the JICA Study Team, relations among the organizations responsible for administrating these data are not sufficiently established.
These power development plan and energy supply plan need to be updated regularly by reflecting the conditional changes. Therefore, establishing an institutional framework is necessary to develop and implement both plans comprehensively by involving all the relevant stakeholders for these plans to share information.

(b) Periodical rolling revision of the milestone plan

Although a PSMP has been formulated every five years as a milestone plan, its periodical revision based on a rolling plan has not been conducted appropriately. In principle, a power supply plan in a power development plan is formulated on the basis of demand projection and appropriate standards for ensuring the reliability of supply. However, as the proportions of the projects mentioned in power development plans that have reached the operation stage have been small, a list of prospective projects for investment tends to be included in a power development plan as it is. In principle, a power development plan has to be revised in accordance with power demand and the supply reliability standards as the planning and preparation for projects progress. It is also necessary to revise the power development plan and the energy supply plan formulated in this survey periodically, at least once a year, with changes in the situation including the state of the economy, supply/demand balance of energy sources including domestically-produced natural gas and power supply/demand balance taken into consideration.

(c) Strengthening of integrated statistical processing functions

BPDB has a record of electricity sales to its customers and those wholesaling to other distributing companies. The total sum of them is the total volume of electricity sold by BPDB, but is not identical with the total volume of electricity that is sold by distribution companies including BPDB and used by end consumers. For analyzing the trend of electricity consumption in Bangladesh more specifically, grasping the electricity sales of all distribution companies to end-consumers with sectorial breakdown, such as residential, commercial, industrial etc., is more important. Power Division and/or BPDB is suggested to take an initiative to develop a database of nationwide electricity consumption uniformly as a routine.

The JICA Study Team also observed that there is no government agency responsible for grasping how each sector (residential, commercial, industrial, transport etc.) utilizes energy as the combination of various sources of energy supply such as electricity, natural gas, LPG, oil products, non-commercial fuel (bio fuel) etc. When the JICA Study Team interviewed with various organizations, there were some opinions that, in order to mitigate the increase of natural gas demand, new supply of natural gas to residential sector and transport sector should be restricted and these sectors should be induced to use LPG instead. However, if this idea is actually implemented without long-term perspective of energy supply and demand, it may result in the rapid increase of LPG procurement that is apt to be costlier than LNG, and the burden of nationwide energy cost may become heavier. In order to realize the long-term optimization of nationwide energy balances, GoB needs to strengthen the function to consider and coordinate the national energy policy comprehensively.
Although it should be the Government of Bangladesh that decides which organization is to be responsible for performing these integrated statistic processing functions, the Survey Team recommends the establishment of Integrated Statistics Bureau in MoPEMR for the centralized management of all the data from the organizations under the jurisdiction of the Power Division and the Energy Division with the need to revise the power and energy master plan periodically taken into consideration.

(d) Introduction of Key Performance Indicators

Furthermore, GoB is suggested to set appropriate KPIs (key performance indicators) in the process of planning and to set quantitative target based on this, in order to indicate clearly the directions of energy policy of Bangladesh. Above all, as the country’s energy demand is expected to increase rapidly, target setting for rationalizing energy supply and demand (energy efficiency) is indispensable. In addition, strengthening the capacity to analyze the effect of conditional changes on these KPIs and, if necessary, to adjust the targets and plans flexibly to reflect the changes is also required.
Examples of KPIs that serve for target-setting for the power and energy sectors are as follows.

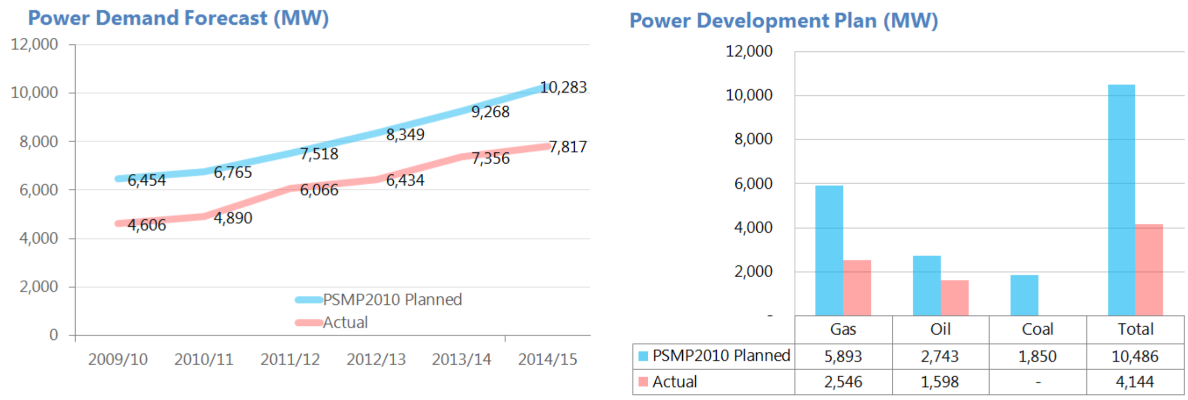
- Energy efficiency: energy intensity per GDP (toe/million BDT), GDP elasticity of energy consumption etc.;
- Economy: cost per unit of energy supply (BDT/kWh) etc.;
- Environmental consideration: emission factor of greenhouse gas etc.;
- Stable supply of energy: energy security index (dependence on energy import, diversification of energy sources), average frequency and duration of power interruption (SAIFI, SAIDI) etc.;
- Optimized supply of energy: balance of aforementioned 3E (integrated indicator), composition of energy source mix etc.;

Currently the main stakeholder agencies in Bangladesh do not have sufficient organizational and staff capacity to deal with these new challenges and international support for improving the capacity of planning, policy implementation and monitoring/evaluation is also needed. Japan has also provided various kinds of assistance such as the dispatch of policy advisors, training programmes and capacity development support programmes. These kinds of assistance will still be needed for Bangladesh.

(2) Measures to Facilitate Improvement of Investment Climate

(a) Outline

As a rapid economic growth is expected in Bangladesh, a power development plan has been formulated to reinforce power generation facilities to meet the increasing power demand. However, as the construction of power generation facilities has not been progressing as planned in reality, as mentioned in detail in the chapter of the power development plan, the demand has been suppressed due to the limited supply and, therefore, the difference between the actual demand and the demand projection including potential demand has been large. This fact may have undeniably had negative impact on the economic growth in Bangladesh.
It is obvious that the milestones in a power development plan, however theoretically the plan may have been formulated, will be just empty theories in the current state in which various factors impede the construction of power source facilities.
Therefore, a discussion conducted on the way to create a climate that makes investment in power development attractive with opinions of investors taken into account is described in the following.



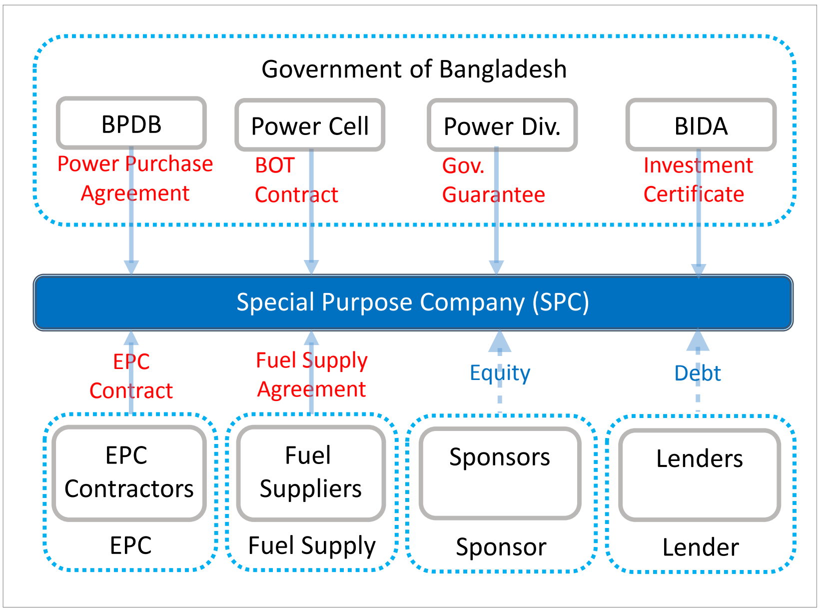
	Gas	Oil	Coal	Total
PSMP2010 Planned	5,893	2,743	1,850	10,486
Actual	2,546	1,598	-	4,144

Source : JICA Study Team

Figure 11-52 PSMP2010 Review (Demand and Power development plan)

(b) Project implementation structure

In addition to conventional loan projects implemented with public financing from international organizations, projects with PPP investment that utilize the technological capacity and capital of the private sector more than the loan projects are considered a promising means of power development in Bangladesh. The figure below shows a possible project implementation structure assumed for the implementation of IPP projects in Bangladesh.



Source: JICA Survey Team

Figure 11-53 Organaization of IPP

The sponsor of a project consisting of a contractor and an investor usually minimizes the project risk by establishing a special purpose company (SPC) and concluding contracts with various organizations to be involved in it through the SPC. The major project risks are summarized in the following.

- ■ Risks directly concerned with the Government
- ✓ Risks associated with power sales agreements and payment of electricity charges
- ✓ Foreign exchange and remittance risks
- ✓ Country and political risks
- ■ Risks to be controlled mainly by contractors
- ✓ Risks of delay and cost overrun
- ✓ Risks in fuel procurement
- ✓ O&M risks (including risks in the construction of power transmission, transforming and distribution facilities)

(c) Risks directly concerned with the Government

In Bangladesh, an SPC and BPDP conclude a power purchase agreement (PPA) and the SPC becomes the only off-taker of the power under the PPA. Because this agreement provides long-term security, in principle, investors consider it an important agreement that promises profitability of their investment in the project life. Investors prefer a large proportion of the payment for electric power to be made in foreign currencies, while the investee prefers a large proportion of it to be made in the local currency, as they collect electricity charges from users in the local currency. This proportion of the payment in foreign currency has significant influence on investors' decision on investment. If there is a restriction on foreign exchange applicable to a case in which a SPC exchanges the profit from a project after deducting the local costs that it has saved in the local currency in a foreign currency and remits it to the country of the investor, such a restriction will also be an obstacle to the investment.
Power Division applies for the licenses and permits for the establishment of SPCs and construction of facilities with a consent of Power Cell and applies for a government guarantee with a consent of the Ministry of Finance. All the permission and licensing for investment in foreign currencies used to be controlled by the Board of Investment, Bangladesh, (BOI). However, it is currently controlled by Bangladesh Investment Development Authority, which was established recently as a one-stop center for foreign investors. The government's efforts in reorganizing itself in accordance with the needs of

investors such as the case mentioned above should be highly appreciated. A contractor for the implementation of a project with foreign investment is required to be established as a joint venture (JV) of a foreign investor and a local partner, and a foreign investor is not allowed to participate in such a project as its sole investor in many countries, including Bangladesh, in order to facilitate the development of domestic and local industries.

Successful project implementation naturally requires strict compliance with agreed rules and provisions of the agreement, which requires minimization of the country and political risks as the major precondition. These are the risk factors in the agreement directly concerned with the Government.

(d) Risks to be controlled mainly by contractors

The risk of delay and cost overrun is a risk to be hedged by contractors. The conclusion of an EPC agreement between a SPC and an EPC contractor is a means to hedge such risk. The risk in fuel procurement, which may emerge in different forms in different projects, is considered a risk to be controlled by contractors. The O&M risk is also considered a risk to be controlled by contractors.

There is a risk that power may not be transmitted as planned when the power source facilities have been constructed and put in use as planned, if a project for constructing transmission lines and substations is delayed by various factors. If such a project is not in the scope of the investment in the power source development of an investor, it is considered extremely difficult for the investor to control the project concerned. Therefore, a mechanism that places the responsibility for the consequence of the delay of the project to its contractor has to be established.

(e) Recommendations for improvemen

- PPA

A PPA will stipulate the standards of tariffs that sufficiently accommodate various risks associated with foreign exchange and international remittance. The privileges to receive electricity tariffs in US dollars and transfer the revenue in dollars received from the sale of electricity overseas without restriction will be granted to investors.

- Tax exemption for FDI

The tax exemption to be granted will include exemption from the customs duties on all the imported materials and equipment required for the plant construction, exemption from the corporate and personal income taxes for a certain period of time and exemption from the import tax on vehicles and heavy and specialized equipment to be used by contractors.

- Streamlining of procedures

It is not sufficient just to establish better rules. It is also necessary to reduce the time required for the issuance of licenses and permits.

- Credit enhancement to local enterprises by international organizations

A tripartite relationship of the political system, bureaucracy and private sector led by a local large-scale company has been formed in many of the successfully implemented IPP projects in Bangladesh. A foreign investor must form a JV with a local investor if the foreign investor intends to implement such a project because there is a law that does not allow purchase of land solely with a foreign currency in Bangladesh. Therefore, such a project will be implemented as a long-term joint investment project with a local company to ensure steady cash flow into the project and the financial credibility of such a local company may have significant influence on the decision of a foreign investor. For example, an international organization will enhance credit limit of a local company as a guarantor of its credit in order to improve its credibility in the local industry sector in a scheme to implement large-scale IPP project as a “model PPP project.” In practice, a mechanism that guarantees the payment of fees by guarantor in the case of breech of a provision in a PPA and fully covers damage to a developer will be established.

Chapter 12 Hydropower

12.1 Outline of Hydropower Potential Study

12.1.1 Background

Bangladesh's climate is categorized as a subtropical zone monsoonal climate, and its characteristic is abundant rainfall. In the winter, from October to March, it is warm and dried by the Northeast monsoon. In summer, from March to June, it is hot and humid, and particularly from June to October, squalls and monsoons hit the country. Average annual rainfall is recorded as 1500 to 1800 mm in Western areas, 2000 mm in the area surrounding Dhaka, and more than 5000 mm in the Assam hilly terrain area in the Northeast. In the Chittagong hilly terrain area in the Southeast, annual rainfall is recorded as 2500 to 4000 mm on average. As such, Bangladesh has relatively high rainfall and abundant water resources, particularly in the Northeast and Southeast of the country.

On the other hand, as for the topography of Bangladesh, most of the national land is spread over the delta area, along the Bay of Bengal on the Indian subcontinent. There are lots of swamps and jungles. Most of the areas are lowland lower than 9 m above sea level. Even in the hilliest area of Chittagong, elevation of the area is from 300 m to 600 m. The highest point of Bangladesh is known as Mount Keokradong, at 1230 m above sea level. In this regard, Bangladesh has relatively limited hydropower potential even though it has abundant water resources.

Karnafuli Hydropower Plant, using the water of Kaptai Lake, is the only hydropower plant in Bangladesh, with a total installed capacity of 230 MW. Its No.1 and 2 units (2 units of 40 MW) and No.3 unit (50MW) were installed with assistance from the United States, and operation started in 1962 and 1982 respectively. No. 4 and 5 units were installed with assistance from Japan, and operation started in 1987. Further, No. 6 and 7 units were planned as Japanese Yen Loan Projects in order to strengthen the power supply for peak demand. However, since an Environmental Impact Assessment was not carried out and local consensus was not attained, a Japanese ODA loan was not provided for the project. The problem was caused by conflicts between indigenous people and immigrant Bengali people who were living around Kaptai Lake. Compensation issues during the construction of Kaptai Dam were also one of the causes. Even now, entry to the area is restricted because of order problems.

Despite of such a situation, the Government of Bangladesh expects hydropower development for reduction of CO2 emissions and power system stability as well. The JICA Survey Team carried out a hydropower potential study for Pumped Storage Power Plant (PSPP) and Small Scale Hydropower Plant (SSHP).

12.1.2 Objective of the study

The objective of the Study is to identify hydropower potential sites for the future development. Pumped Storage Power Plant (PSPP) and Ordinary Hydropower Plant (Ordinary HP) or Small Scale Hydropower Plant (SSHP) are targeted in this Study.

12.1.3 Study flow

The study flow for identification of potential sites for PSPP and SSHP is shown in Figure 12-1.

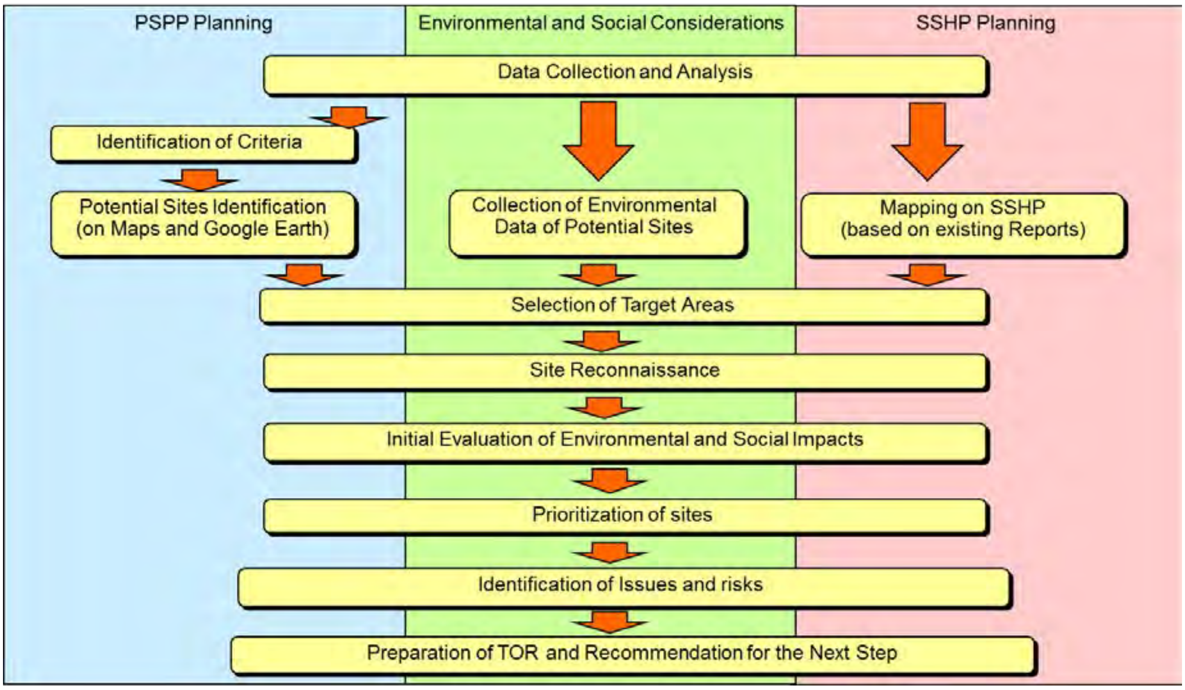
12.1.4 Limitation in the study

On the course of the study, the JICA Survey Team encountered the following difficulties:

- Limitation of maps available, and
- Limitation of access to the potential site areas due to security reasons.

Since topographic maps available for Chittagong hilly areas are only 1/50,000 scale maps with 100m counter lines, those maps could not be used for planning purpose and even for conceptual design of hydropower projects. Therefore, the JICA Survey Team identified and planned potential sites based on google earth with limited accuracy.

The JICA Survey Team also encountered the difficulty to access to the remote locations in Chittagong hilly areas due to security reasons. During the site reconnaissance, the Survey Team hired security guards. The Survey Team was, however, able to stay in the hilly areas for limited time only during day time, and to visit only the locations accessible by cars. And also, talking directly to local people was also restricted.



Source: JICA Survey Team

Figure 12-1 Flowchart of Hydropower Potential Study

12.2 Current Situation of Hydropower Development in Bangladesh

12.2.1 Outline of Karnafuli Hydropower Plant

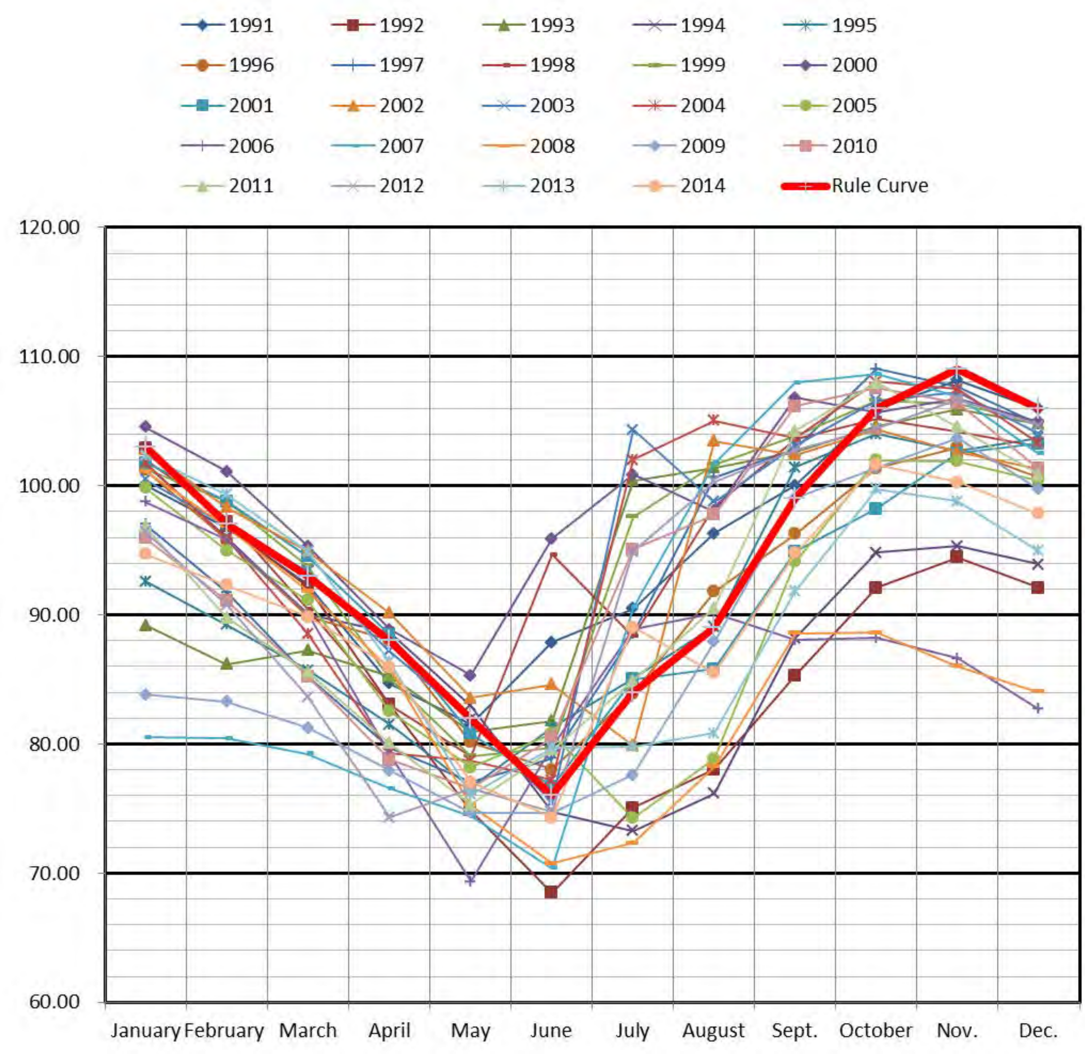
Kaptai Dam is on the Karnafuli River at Kaptai, 65 km (40 mile) upstream of Chittagong in Rangamati District, Bangladesh. It is an earth-fill embankment dam with a reservoir (known as Kaptai Lake) water storage capacity of 6,477 million m3 (5,251,000 acre·ft). The primary purpose of the dam and the reservoir was to generate hydroelectric power. Its construction was completed in 1962. The generators of the 230 MW (310,000 hp) Karnafuli Hydroelectric Power Station were commissioned between 1962 and 1988. It is the only hydropower plant in Bangladesh.

A brief reconnaissance occurred in 1906 when the Karnafuli Hydropower Plant was first contemplated. The second study was carried out in 1923. In 1946, E. A. Moore recommended the proposed project at Barkal about 65 km upstream of the present dam site at Kaptai. In 1950, the Marz Rendal Vatten Consulting Engineers suggested a site at Chilardak, about 45 km upstream of Kaptai. In 1951, the government engineers proposed Chitmoram, 11 km downstream of the present site. Under the guidance of then chief engineer (Irrigation) Khwaja Azimuddin, the construction site was finally chosen at the present site in 1951.

Utah International Inc. was selected as the construction contractor. The construction of the dam was started in 1957. When the first phase of the construction was completed in 1962, the dam, spillway, penstock and two units of 40 MW Kaplan turbines and generators were built in the power station. In August 1982, the third unit of 50 MW was commissioned. In October 1988, the fourth and fifth units of 50 MW turbines and generators were installed, and then the total generation capacity became 230 MW.

The Kaptai dam is an earth-fill type dam with 45.7m (150 ft) high, 670 m (2,200 ft) long, and it has a spillway with 16-radial gates whose each width is 11.5m on the left side. The construction of the dam submerged 655 km2 (253 sq mile) area that included 220 km2 (85 sq mile) of cultivable land, 40 percent of the cultivable land in the area. It also forced resettlement of 18,000 families and 100,000 tribal people of which 70% were Chakma. The dam flooded the original Rangamati town and other structures.

As per rule curve the water level of the reservoir is supposed to be 33.2m (109 ft) MSL of the highest water level in November and 23.2m (76 ft) MSL of the lowest level in June as shown in Figure 12-2. In reality actual reservoir operation was different from the rule curve due to difference in rainfall year to year.



Source: JICA Survey Team

Figure 12-2 Karnafuli Hydro Station Reservoir Operation Rule Curve and its Records

12.2.2 Hydropower potential and hydropower development plan in Bangladesh

There are only two studies on hydropower potential and/or hydropower development plan in Bangladesh at this moment. The first hydropower potential study in Bangladesh was carried out by National Rural Electric Cooperative Association (NRECA) under the assistance of US-AID in 1981. It covered small scale hydropower potential sites in the whole country except Chittagong Hilly areas. The second study on hydropower potential was carried out by Ministry of Power, Energy and Mineral Resources (MPEMR) in 2014 targeting Ordinary HP potential sites particularly in Chittagong Hilly areas.

Outline of the studies conducted in the past are briefly described below.

(1) Small hydropower potential sites in Bangladesh (except Chittagong Hilly areas)

Under the assistance of US-AID, National Rural Electric Cooperative Association (NRECA) carried out small hydropower potential study in 1981, and 20 sites were listed as shown in Table 12-1 and Figure 12-3.

Most of the potential sites are to utilize dams and/or canals for irrigation, and those capacities are relatively small from several ten to 200kW, which are a range of micro hydropower projects. Only some potential sites with capacity of several MW are also included in the list. In the study, Chittagong hilly areas where there is high possibility of high hydropower potential due to relatively large undulation are not included.

Table 12-1 SSHP Potential Sites List in the Country (excluding Chittagong Hilly Area)

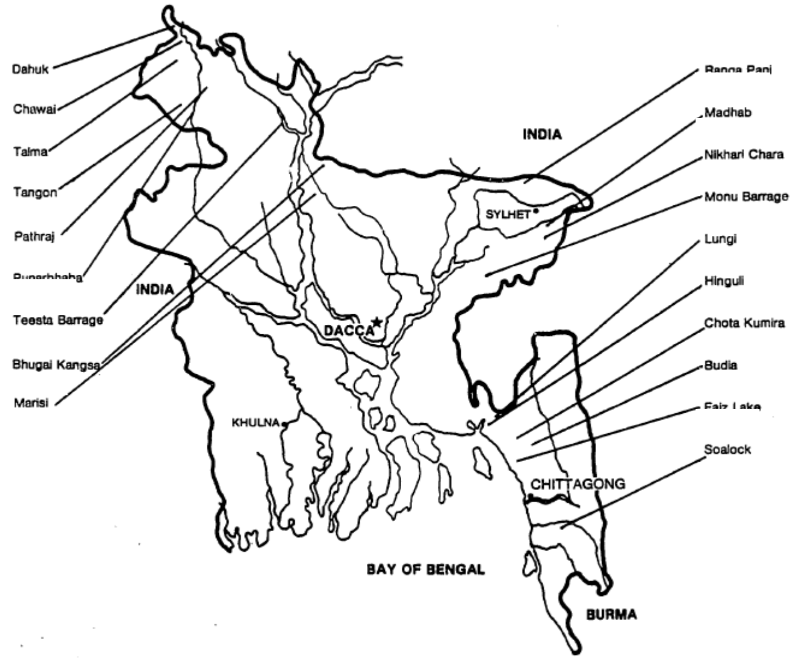
Sites	Discharge (cfs)	Head (feet)	Available Operation Months (months)	Installed Capacity (kW)	Annual Generation (1000kWh)	Type
Chota Kumira	11	40	12	30	250	New Storgae Dam
Hinguli	12	15	12	12	100	New Storgae Dam
Soalock	70	35	12	170	1400	New Storgae Dam
Longi	15	10	12	10	90	New Storgae Dam
Dudia	6	25	12	10	90	New Storgae Dam
Nikhari Chara	17	40	12	50	400	New Dam
Monu Barrage	200	12	7	160	800	Existing Dam
Marisi	120	18	12	80	600	Storage Dam
Bhgai-Kangsa	280	18	12	190	1400	Storage Dam
Dahuk	140	12	12	75	500	Storage Dam
Chawai	200	12	12	100	700	Storage Dam
Talma	140	12	12	75	500	Storage Dam
Patraj	200	12	12	100	100	Storage Dam
Tangon	200	12	12	100	700	Storage Dam
Teesta Canal Mile23	7300	10	12	5000	36000	Canal Head
Rangpur Canal Mile7	2500	10	12	1700	12000	Canal Head
Rangpur Canal Mile19	1800	10	12	1250	9000	Canal Head
Rangpur Canal Mile33	1100	10	12	750	5000	Canal Head
Bogra Canal Mile7	4000	10	12	2700	20000	Canal Head
Teesta Barrage	2000	7	7	1200	5000	Dam

Source: Bangladesh An assessment of small hydropower potential, NRECA, November 1981

(2) Ordinary HP potential sites in Chittagong Hilly Area

Ministry of Power, Energy and Mineral Resources (MPEMR) requested Streams Tech, Inc. (STI), which is an American firm, to carry out a hydropower potential study on the three river basins (Sangu River, Matamuhuri River and Bakkhali River) in Chittagong Hilly Area in order to find potential sites for hydropower development next to Kaptai hydropower plant.

As results of the potential study, 18 sites in total were found; 10 sites in the Sangu River, 5 sites in the Matamuhuri River, and three sites in the Bakkhali River as shown in Table 12-2 and Figure 12-4. Installed capacities of those potential sites would be varied from 0.1 MW to 201.7 MW.



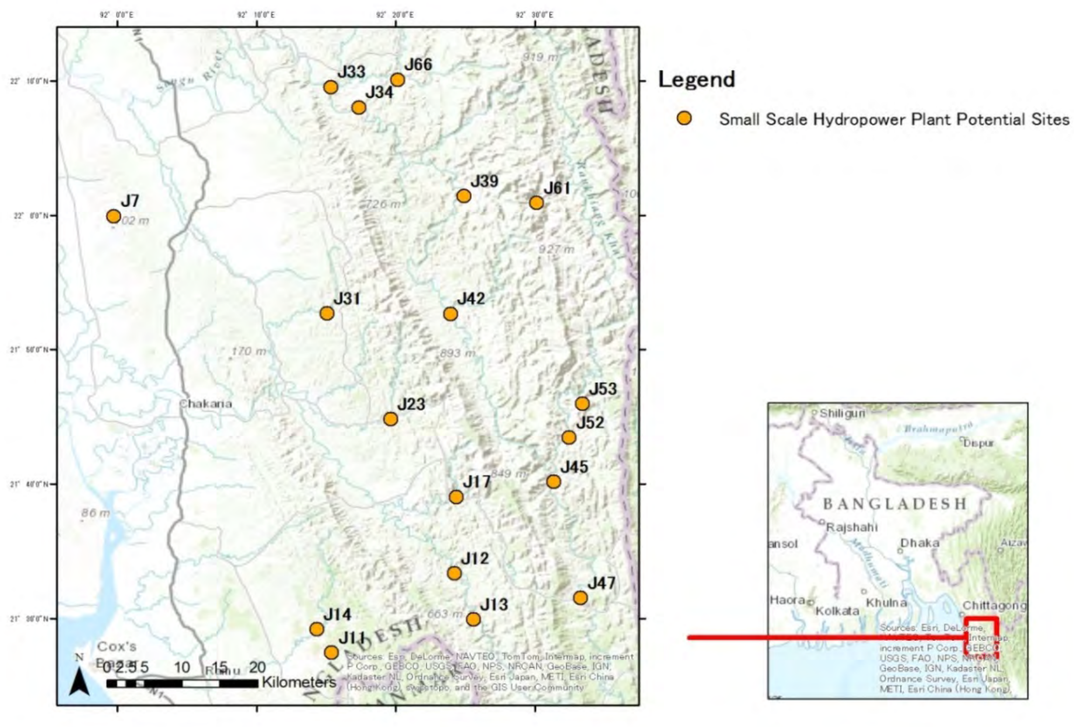
Source: Bangladesh An assessment of small hydropower potential, NRECA, November 1981

Figure 12-3 Location Map of SSHP Potential Sites in the Country

Table 12-2 Ordinary HP Potential Sites List in Chittagong Hilly Area

River	Location	Head	Flow (m^3/s)	Power (MW)	Max. Energy (MWh/year)	Percent of Time
Sangu	J33	12	268	23.5	37,648	18.3
Sangu	J34	20	217	31.8	50,877	18.3
Sangu	J39	70	200	102.7	144,000	16.0
Sangu	J42	60	156	68.6	96,676	16.1
Sangu	J45	20	101	14.8	21,035	16.2
Sangu	J47	40	47	13.9	16,126	13.3
Sangu	J52	20	30	4.4	5,733	15.0
Sangu	J53	30	25	5.5	7,106	14.7
Sangu	J61	40	9	2.6	3,296	14.6
Sangu	J66	20	31	4.6	6,426	16.0
Matamuhuri	J12	20	55	8.0	7,406	10.6
Matamuhuri	J13	15	41	4.5	4,430	11.3
Matamuhuri	J17	50	21	7.5	8,295	12.7
Matamuhuri	J23	50	16	5.9	6,535	12.7
Matamuhuri	J31	10	10	0.7	842	12.9
Bakkhali	J11	10	14	1.0	1,388	16.1
Bakkhali	J14	10	16	1.1	1,547	15.5
Banshkhali	J7	12	1	0.1	95	13.1

Source: Study on Prospective Hydropelectricity Generation in Southeast Bangladesh



Source: Study on Prospective Hydropelectricity Generation in Southeast Bangladesh

Figure 12-4 Location Map of Ordinary HP Potential Sites in Chittagong Hilly Area

(3) Hydropower projects under other donors' assistance

The JICA Survey Team conducted interview with MPEMR, Power Division, BPDP as well as donor agencies such as WB, ADB, US-Aid, to ask if they have any projects related to hydropower projects in Bangladesh. According to the their answers, there is no project conducted in the past and planned for the future even technical assistance related to hydropower development other than the two studies mentioned above.

12.3 Environmental Law and Regulations

Environmental laws and regulations related to hydropower development are as follows:

12.3.1 Environment Conservation Act

Bangladesh Environment Conservation Act (1995) covers environmental protection, pollution control, conservation area, environmental clearance, industrial discharge standards, environmental standards, solid waste discharge standards, and environmental guidelines. Bangladesh Environment Conservation Rules (1997) stipulate the following items including procedures of issuance of Environment Clearance Certificate (ECC).

- Declaration of ecologically critical area
- Vehicles emitting smoke injurious to health and otherwise harmful
- Application relating to pollution or degradation of environment
- Notice for collection of sample
- Procedure for issuing ECC
- Procedure for hearing of appeal
- Determination of environmental standards

- Information of special incident

12.3.2 Environmental Impact Assessment Regulations and Guidelines

Procedures of Environmental Impact Assessment (EIA) are stipulated in Bangladesh Environment Conservation Rules (1997), and EIA Guidelines for Industries (1997) are also provided by Department of Environment (DoE).

There are no rules and regulations which instruct Strategic Environmental Assessment for this study in such Master Plan stage in Bangladesh.

Procedures of EIA in Feasibility Study stage are provided in Bangladesh Environment Conservation Rules (1997). The rules classify project types in four (Green, Amber-A, Amber-B, Red) and different procedures for each category. A power plant project is categorized in Red which requires Initial Environmental Examination (IEE) followed by comprehensive EIA. The locations for the power plant are restricted under the following conditions:

- Industrial units shall not be located in any residential area
- Industrial units shall preferably be located in areas declared as industrial zones or in areas where there is concentration of industries or in vacant areas.
- Industrial units likely to produce sound, smoke, odor beyond permissible limit shall not be acceptable in commercial areas.

The projects catagorized in Red have to obtain both Site Clearance Certificate (SCC) and ECC based on the Bangladesh Environment Conservation Rules (1997). The SCC and ECC are normally applied at the same time. But they can be applied separately if the project such as manufacturing facility adds the pollution control facilities later. In case of the power plant, SCC and ECC should be applied at the same time and those procedures are described as follows:

1) Project proponent prepares IEE and Terms of Reference of EIA (TOR/EIA) and submits them to DoE.
2) DoE reviews the IEE and TOR/EIA and issues approval or rejection.
3) When Project Proponent gets approval of IEE and TOR/EIA, Project proponent can conduct EIA study and prepares EIA report.
4) Project proponent submits EIA application to DoE.
5) DoE reviews the application documents
6) When the EIA is approved, the project proponent applies ECC and SCC to DoE.
7) DoE grants ECC and SCC to the project proponent within thirty working days, or the application shall be rejected mentioning appropriate reasons.
8) The project proponent can start construction with ECC and SCC.

EIA Guidelines for Industries (1997) mentions that the public participation is important during EIA preparation and information disclosure and exchanging views with many stakeholders in various ways are required for effective public participations. Some sample methods for public participations introduced in the EIA Guidelines (1997) are:

- Radio and Television
- Newspaper
- Advertisement
- Lobbying activity
- Workshop
- Public explanatory meeting
- Public discussion meeting

- Civil advisory committee

12.3.3 Relevant ministries and agencies to Environmental Conservation

Ministry of Environment and Forest (MoEF) takes the main role for Environmental policies and regulations. Responding to the growing Environmental concern MoEF was established in 1989 substituting Ministry of Forest. MoEF has been a permanent member of the Executive Council of National Economic Commission. The Council is the main decision maker of the economic policy and responsible for approval of all the public investment projects. As a member of the Council MoEF supervises the activities of the following organizations:

- Department of Environment (DoE)
- Department of Forest (DoF)
- Forest Industries Development Corporation (FIDC)

In order to expand the scope of environmental management and strength the performance, the government stipulates the environment pollution control ordinance in 1977. Based on the ordinance Environmental Pollution Control Board was proposed for deciding policies and planning approaches. The Environmental Pollution Control Board was renamed to Department of Environmental Pollution Control (DEPC) in 1982 and six sub-departments are established in Dhaka, Chittagong, Khulna, Barisal, Sylhet, and Rajshahi. DEPC was changed to DoE and settled under the MoEF jurisdiction by Presidential order.

12.3.4 Laws and regulations on Land acquisition and Resettlement

Laws and regulations relevant to land acquisition and resettlement are the Land Acquisition Act (1894), The Acquisition and Requisition of the Immovable Property (Amendment) Act (1994), and The Acquisition and Requisition of Immovable Property Ordinance (1982) were revised in 2004. The main procedures are as follows:

1) Project owner applies for expropriation of land and immovable property to Deputy Commissioner
2) Deputy Commissioner gives public notice of the application and starts site survey
3) Deputy Commissioner gives public notice of the decision of the expropriation
4) Deputy Commissioner decides the compensation cost and pays compensation
5) Implement the expropriation

Preparation of the Resettlement Action Plan by the project proponent is not mandated but land owners have a right to take objections.

12.4 Selection of Hydropower Potential Sites for this Study

12.4.1 Identification of Pumped Storage Power Plant (PSPP) Sites

(1) Criteria for finding PSPP potential sites

In consideration of technical, economic, environmental and social aspects, criteria for finding PSPP potential sites were determined as shown in Table 12-3. However, in consideration of the limited data available, the criteria were used just for reference in order to identify potential sites as many as possible.

For comparison of the potential sites, those installed capacities were set as 500MW in consideration of scale of the potential sites.

Table 12-3 Criteria for Finding PSPP Potential Sites

Item		Consideration Point	Criteria	
Technical	Generation plan	· Peak duration time · Installed capacity	· 7hrs · About 500 MW	○ ○
Technical	Limit of manufacturing of power facility	· Design head · K Value (Hpmax / Hgmin) · Max. utilizing water depth of pond	· Less than 750m of maximum head · Less than the limit (1.25-1.4) · Less than 30m (40m in case of full facing pond type)	○ ○ ○
Technical	Location / Layout	· Catchment area of Lower reservoir · Crest length of Lower Dam · Dam height · Length of water way · Length / Head (L/H) · Overburden of underground power cavern	· More than 50km^2 · Less than 500m · Less than 200m · Less than 10km · Less than 10 · Less than 500m	○ ○ ○ ○ ○ ○
Technical	Geological conditions	· Active fault (Quaternary fault) · Fault and fractured zone · Landslide area · Permeability of peripheral rock of upper reservoir	· Elongation from active faults >10km · Avoid large-scaled fault and fractured zone · Avoid large-scaled landslide area · Avoid lime stone / Quaternary volcanic rock	● ● ● ●
Topographical conditions		· Demand center / pumping energy source · Existing and planned power network · Accessibility	· Near demand center / pumping energy source · Near bulk power network (Substation) · Good accessibility to the site	○ ○ ●
Environmental	Natural	· Protected Area (e.g. Natural Parks) · Endangered species	· Avoid important Protected Areas (Natural Parks, Nature Parks, and Ramsar Sites) · Avoid the critical habitats of important fauna and flora	○ ●
Environmental	Social	· Mining right · Historical and Cultural heritage · Houses to be resettled	· Avoid the area of mining concession · Avoid being submerged · Less than 50	● ● ●

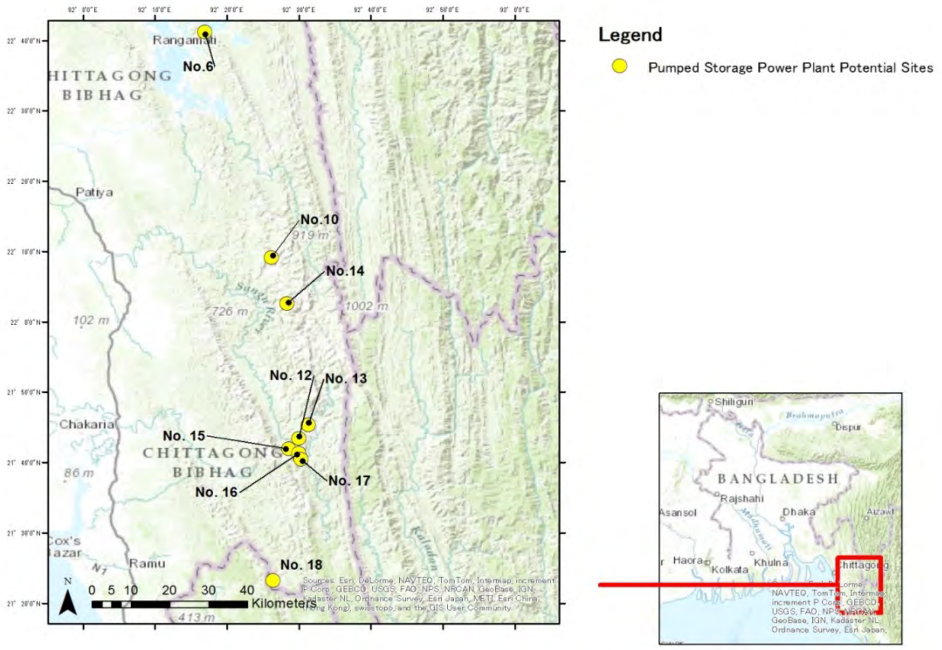
○ : considered in primary project finding ● : necessary to confirm the situation by site survey

Source: JICA Survey Team

(2) Finding of PSPP potential sites

In consideration of the criteria for finding of PSPP potential sites mentioned above, the JICA Survey Team carried out the finding PSPP potential sites with the Google Earth. In total, nine potential sites were found as shown in Figure 12-5.

No. 6 site is only potential site, which utilizes Kaptai Lake as a lower reservoir. The remaining eight sites found are located in the Sangu River basin, which require new construction of both upper reservoir and lower reservoir.

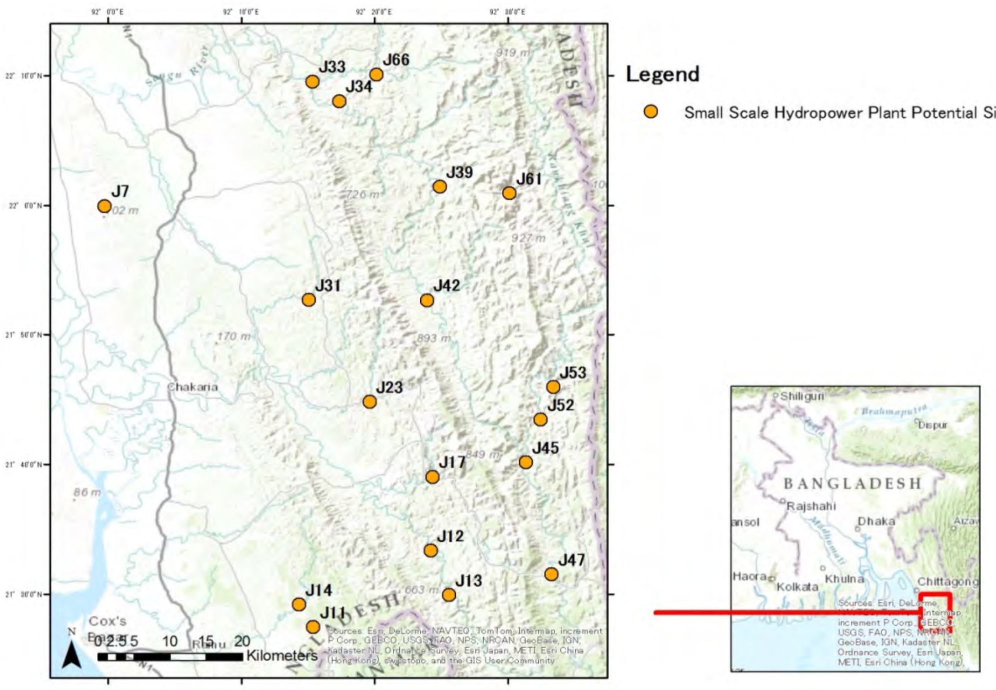


Source: JICA Survey Team

Figure 12-5 PSPP Potential Sites

12.4.2 Selection of ordinary HP /SSHP potential sites for this study

In consideration of attractive scale of hydropower development, the Ordinary HP potential sites in Chittagong hilly area were targeted in this Study.



Source: Study on Prospective Hydropelectricity Generation in Southeast Bangladesh

Figure 12-6 Ordinary HP Potential Sites in Chittagong Hilly Area

12.5 Selection of Target Areas and Site Reconnaissance

The JICA Survey Team selected Chittagong Hilly Area as a target area for site reconnaissance, since most of the potential sites are located in the area. However, accessible potential sites are limited due to peace and order situation, and limited access roads. Therefore, targeted sites for site reconnaissance were not selected in advance. Only accessible sites among all potential sites were surveyed during the site reconnaissance.

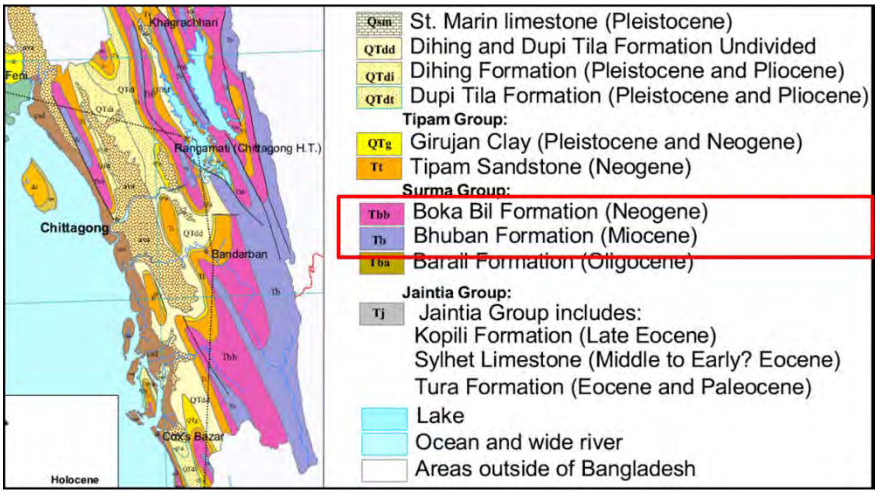
The JICA Survey Team together with an official of BPDB and local consultants carried out the site reconnaissance of the potential sites from June 8 to June 14, 2015. Results of the site reconnaissance are as follows:

12.6 Geology around the Potential Sites

As one of the technical requirements for PSPP development, geology of the project site must be firm and impermeable, since dams and/reservoir are newly created, and a large scale cavern for a powerhouse is excavated in deep underground.

Figure 12-7 shows the geology of Chittagong Hilly Area where hydropower potential sites are located. Geology around the potential sites is Boka Bil Formation (Neogene) or Bhuban Formation (Miocene), which consists of sand stone, mad stone and those alternate layers. Though the rocks are relatively low concreteness, it is assumed possible to construct PSPP on such geology. Active faults near the potential sites are not recognized. Thus, from viewpoints of regional geology around the project sites, PSPP development in the area is possible.


Typical alternate layer of sand stone and mad stone and mad



Source: JICA Survey Team

Figure 12-7 Geological Map of Chittagong Hilly Area

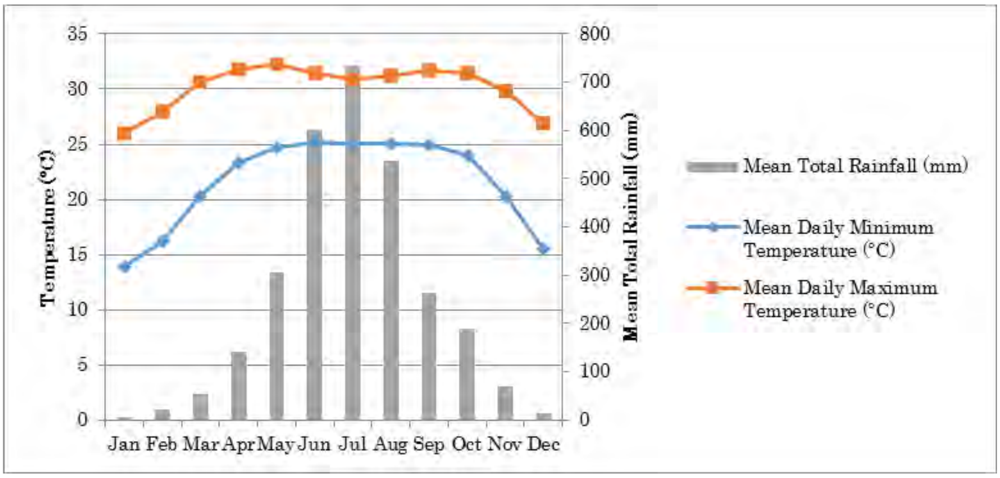
12.7 Environmental and Social Considerations

12.7.1 Baseline of environmental and social information in and around the potential sites

(1) Physical environment

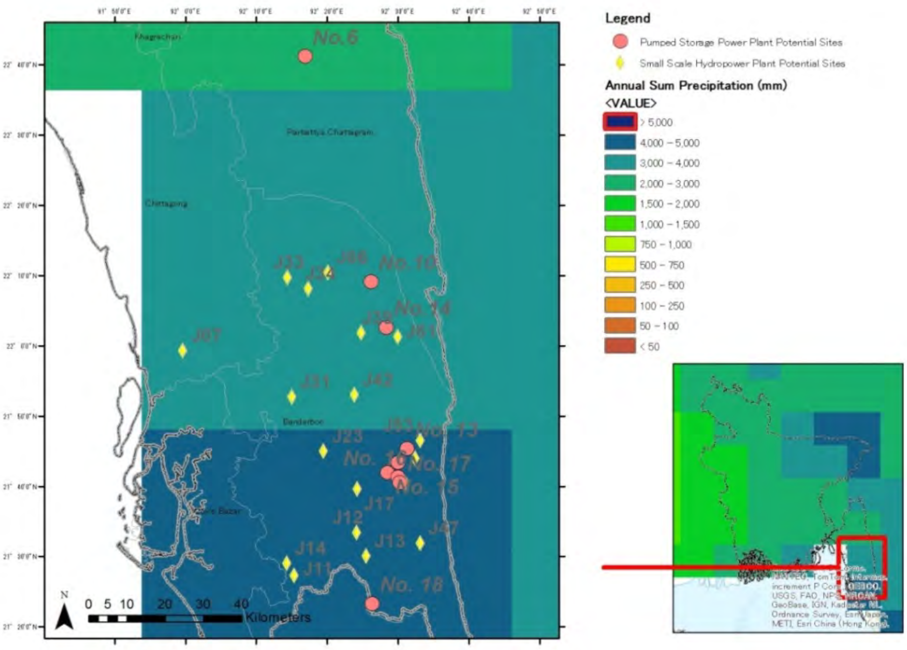
(a) Climate and weather

The climate of Chittagong and Chittagong high land fall in Tropical monsoon climate (Am) by Köppen climate classification. The light dry season is from December to March as shown in Figure 12-8. Amount of precipitation in southern part of Chittagong where many potential project sites are located is greater than northern part as shown in Figure 12-9.



Source: World Meteorological Organization

Figure 12-8 Temperature and Rainfall in Chittagong (average from 1971 to 2000)



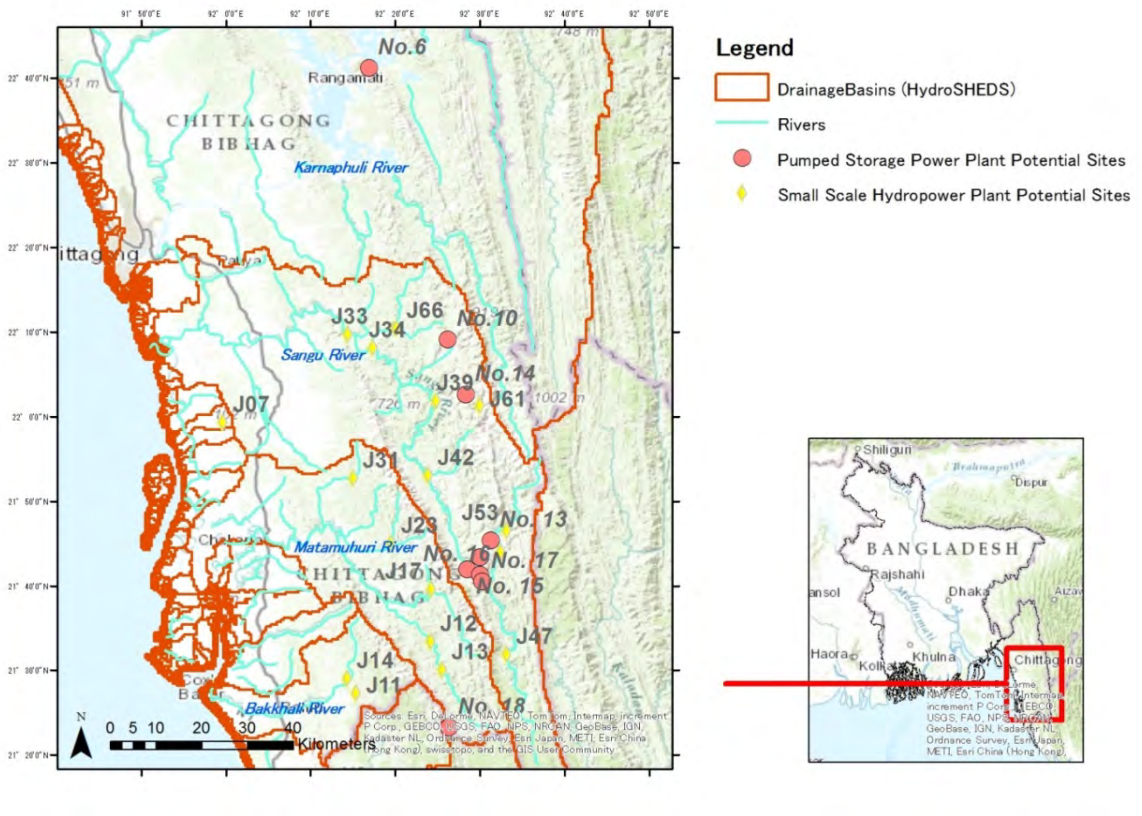
Source: WorldClim bio-climatic variable: BIO12

Figure 12-9 Annual Sum Rainfall around the Survey Area

(b) River system and water quality

River systems in Bangladesh are divided in two, the systems flowing down to sea from north to south including Padma River (Ganges river), Jamuna River (Brahmaputra River) and Meghna River, and systems flowing down from Chittagong high land to Bay of Bengal. Ganges River, Brahmaputra River, and Meghna River are international rivers from contiguous countries. Their total basin is 1.73 million km2 and including Bhutan, Nepal, a part of India and China. Main streams from Chittagong high land to Bay of Bengal are Karnaphuli river, Sangu river, Matamuhuri river, and Bakkhali river. Most of the potential sites are located in three southern systems as shown in Figure 12-10. 15 potential sites are in the Sangu river system and 6 potential sites are in the Matamuhuri river system as shown in See Table 12-4.

The surface river water quality in Bangladesh is not in good condition. Meghna River system in dry season is seriously polluted. Arsenic concentration of underground water in Bangladesh is also high especially in downstream area of Ganges/ Brahmaputra/ Meghna river system and causing health problems. On the other hand arsenic concentration is not confirmed in Chittagong high land other than sea side of northern Chittagong.



Source: Lehner, B., Verdin, K., Jarvis, A. (2006): HydroSHEDS Technical Documentation

Figure 12-10 Main Rivers on Chittagong Hill Tracts

Table 12-4 River System and Potential Sites

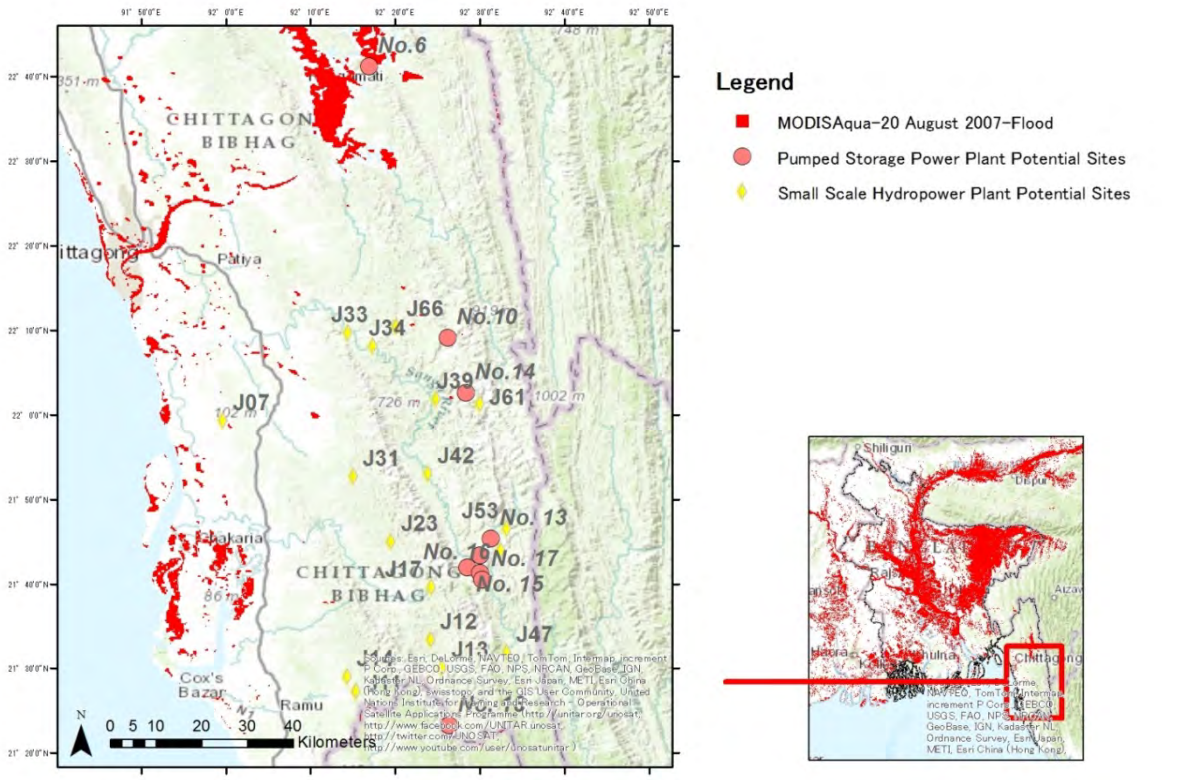
River system	PSPP		SSHP	
	Main Stream	Tributary	Main Stream	Tributary
Bakkhali	-	-	J14	J11
Banshkhali	-	-	-	J7
Kaptai lake	-	No.6	-	-
Matamuhuri	-	No.18	J12, J13	J17, J23, J31
Sangu	-	No.10, No.12, No.13, No.14, No.15, No.16, No.17	J33, J34, J39, J42, J45, J47	J52, J53, J61, J66

Source: JICA Survey Team

(c) Flood and salinity

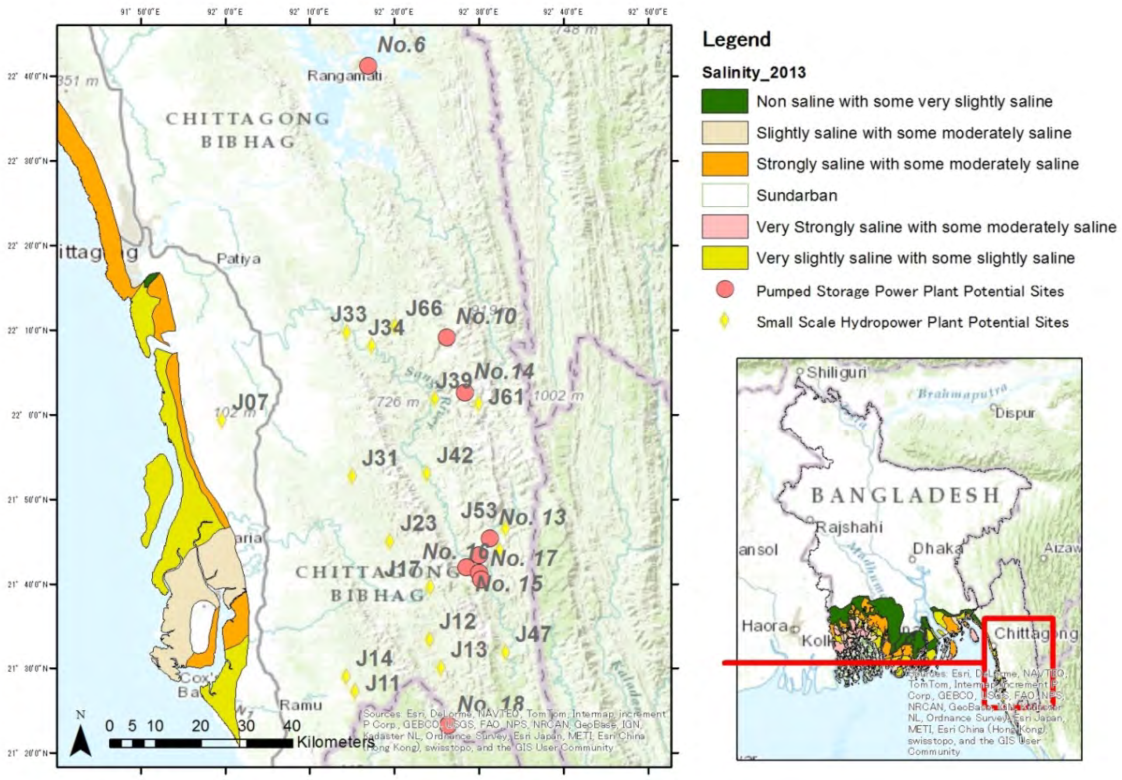
Bangladesh is repeatedly visited by severe floods. One of the biggest floods observed in 20 August 2007 is estimated as 72,972.76 km2 of flooded area based on the analysis of NODIS-Aqua by UNITAR/UNOSAT (See Figure 12-11).

Salinity of underground water is also serious along the coast in Bangladesh. The salinity affected areas are shown in Figure 12-12. None of the hydropower potential sites is located in flood or salinity affected area.



Source: Flood vectors - MODIS-Aqua (20 August 2007), UNITAR/UNOSAT 2014

Figure 12-11 Flood Affected Area in August 2007



Source: Soil Resource Development Institute SRMAF Project

Figure 12-12 Saline Affected Area

(2) Natural environment

(a) Domestic protected area

Domestic protected areas in Bangladesh are National Parks, Wildlife Sanctuary designated by Wildlife Preservation Act (1973), Ecologically Critical Areas by Environment Act (1995), Forest reserve, Protected forest by Forest Act (1927) and Botanical Garden, Eco-parks and Safari Park which are Ex-situ Conservation Areas. Official name, locations will be confirmed later. Some of the Hydropower potential sites might be in the Forest reserve.

Table 12-5 Designated Area by Wildlife (Preservation) Act, 1973

Designation	No.	Name	Location	Area (ha.)	Established	Potential site
National Park	1	Bhawal National Park	Gazipur	5,022.00	11-5-1982	
	2	Madhupur National Park	Tangail/ Mymensingh	8,436.00	24-2-1982	
	3	Ramsagar National Park	Dinajpur	27.75	30-4-2001	
	4	Himchari National Park	Cox's Bazar	1,729.00	15-2-1980	
	5	Lawachara National Park	Moulavibazar	1,250.00	7-7-1996	
	6	Kaptai National Park	Chittagong Hill Tracts	5,464.00	9-9-1999	
	7	Nijhum Dweep National Park	Noakhali	16,352.23	8-4-2001	
	8	Medhakachhapia National Park	Cox's Bazar	395.92	8-8-2008	
	9	Satchari National Park	Habigonj	242.91	15-10-2005	
	10	Khadimnagar National Park	Sylhet	678.80	13-04-2006	
	11	Baroiyadhala National Park	Chittagong	2,933.61	06-04-2010	
	12	Kuakata National Park	Patuakhali	1,613.00	24-10-2010	
	13	Nababgonj National Park	Dinajpur	517.61	24-10-2010	
	14	Singra National Park	Dinajpur	305.69	24-10-2010	
	15	Kadigarh National Park	Mymensingh	344.13	24-10-2010	
	16	Altadighi National Park	Naogaon	264.12	24-12-2011	
	17	Birgonj National Park	Dinajpur	168.56	24-12-2011	
Wildlife Sanctuary	18	Rema-Kalenga Wildlife Sanctuary	Hobigonj	1,795.54	7-7-1996	
	19	Char Kukri-Mukri Wildlife Sanctuary	Bhola	40.00	19-12-1981	
	20	Sundarban (East) Wildlife Sanctuary	Bagerhat	31,226.94	6-4-1996	
	21	Sundarban (West) Wildlife Sanctuary	Satkhira	71,502.10	6-4-1996	
	22	Sundarban (South) Wildlife Sanctuary	Khulna	36,970.45	6-4-1996	
	23	Pablakhali Wildlife Sanctuary	Chittagong Hill Tracts	42,087.00	20-9-1983	
	24	Chunati Wildlife Sanctuary	Chittagong	7,763.97	18-3-1986	J07
	25	Fashiakhali Wildlife Sanctuary	Cox's Bazar	1,302.43	11-4-2007	
	26	Dudpukuria-Dhopachari Wildlife Sanctuary	Chittagong	4,716.57	6-4-2010	
	27	Hajarikhil Wildlife Sanctuary	Chittagong	1,177.53	6-4-2010	
	28	Sangu Wildlife Sanctuary	Bandarban	2,331.98	6-4-2010	
	29	Teknaf Wildlife Sanctuary	Cox's Bazar	11,615.00	24-03-2010	
	30	Tengragiri Wildlife Sanctuary	Barguna	4,048.58	24-10-2010	
	31	Dudhmukhi Wildlife	Bagerhat	170.00	29-01-2012	

Designation	No.	Name	Location	Area (ha.)	Established	Potential site
		Sanctuary				
	32	Chadpai Wildlife Sanctuary	Bagerhat	560.00	29-01-2012	
	33	Dhangmari Wildlife Sanctuary	Bagerhat	340.00	29-01-2012	
	34	Sonarchar Wildlife Sanctuary	Patuakhali	2,026.48	24-12-2011	
	35	Nazirganj Wildlife (Dolphin) Sanctuary	Pabna	146.00	01-12-2013	
	36	Shilanda-Nagdemra Wildlife (Dolphin) Sanctuary	Pabna	24.17	01-12-2013	
	37	Nagarbari-Mohanganj Dolphin Sanctuary	Pabna	408.11	01-12-2013	

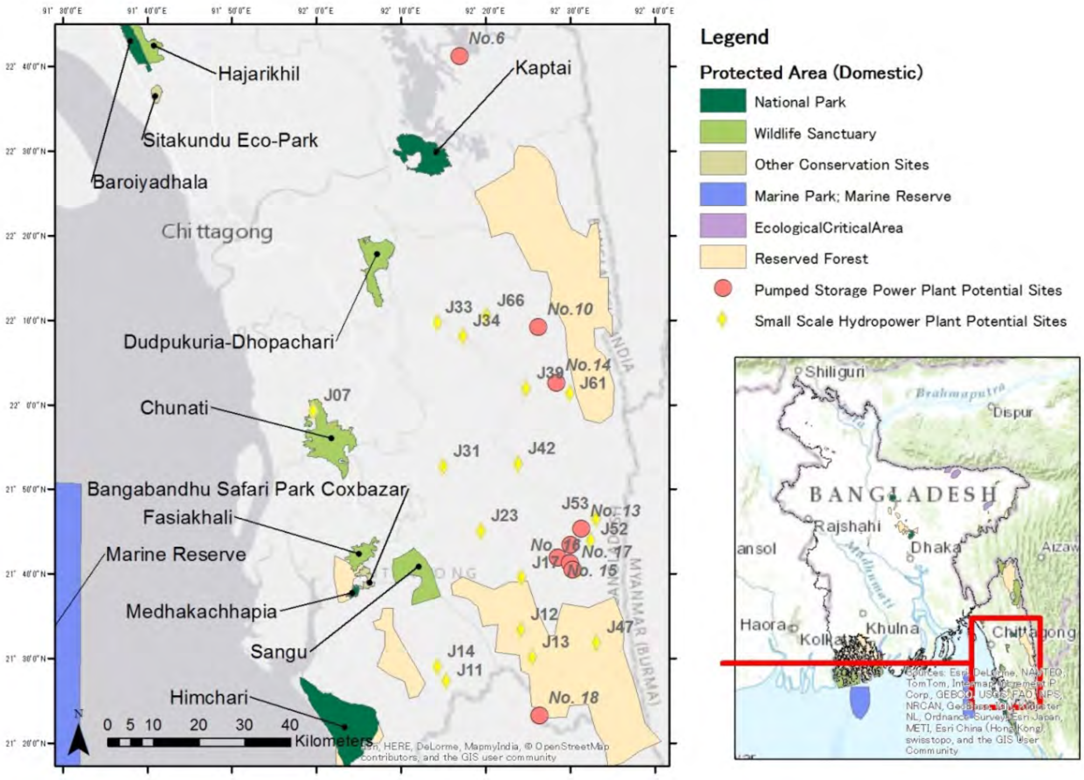
Source: JICA Survey Team

Table 12-6 Designated Area by the Other Acts

Act	Designation	No.	Name	Location	Area (ha.)	Established	Potential sites
Ex-situ Conservation Areas	Botanical Garden	1	National Botanical Garden	Dhaka	84.21	1961	
		2	Baldha Garden	Dhaka*	1.37	1909	
	Eco-parks and Safari Park	3	Madhabkunda Eco-Park	Moulavibazar*	265.68	2001	
		4	Sitakunda Botanical Garden and Eco-park	Chittagong	808.00	1998	
		5	Dulahazara Safari Parks	Cox's Bazar	600.00	1999	
		6	Modhutila Eco-Park	Sherpur	100.00	1999	
		7	Banshkhali Eco-Park	Chittagong*	1,200.00	2003	
		8	Kuakata Eco-Park	Patuakhali	5,661.00	2005	
		9	Tilagar Eco-Park	Sylhet	45.34	2006	
		10	Borshijora Eco-Park	Moulavibazar	326.07	2006	
	Others	1	Swatch of no ground Marine Protected Area	-	-	-	
		2	Marine Reserve	-	-	-	
Environment (Conservation) Act, 1995	Ecologically Critical Areas	1	The Sundarbans	-	-	-	
		2	Cox's Bazar (Teknaf, Sea beach)	*	-	-	
		3	St. Martin Island	*	-	-	
		4	Sonadia Island	*	-	-	
		5	Hakaluki Haor	-	-	-	
		6	Tanguar Haor	-	-	-	
		7	Marjat Baor	*	-	-	
		8	Gulshan-Banani-Baridhara Lake	*	-	-	
		9	Rivers (Buriganga, Bait, Turag, and Sitalakhya)	*	-	-	
Forest Act, 1927	Forest reserve	-	-	*	-	-	No. 18, J12, J13, J47
	Protected forest	-	-	*	-	-	

*: Locations or boundaries are not clear.

Source: JICA Survey Team



Source: WDPA

Figure 12-13 Domestic Protected Areas around the Hydropower Potential Sites

(b) International protected area and Key Biodiversity Area

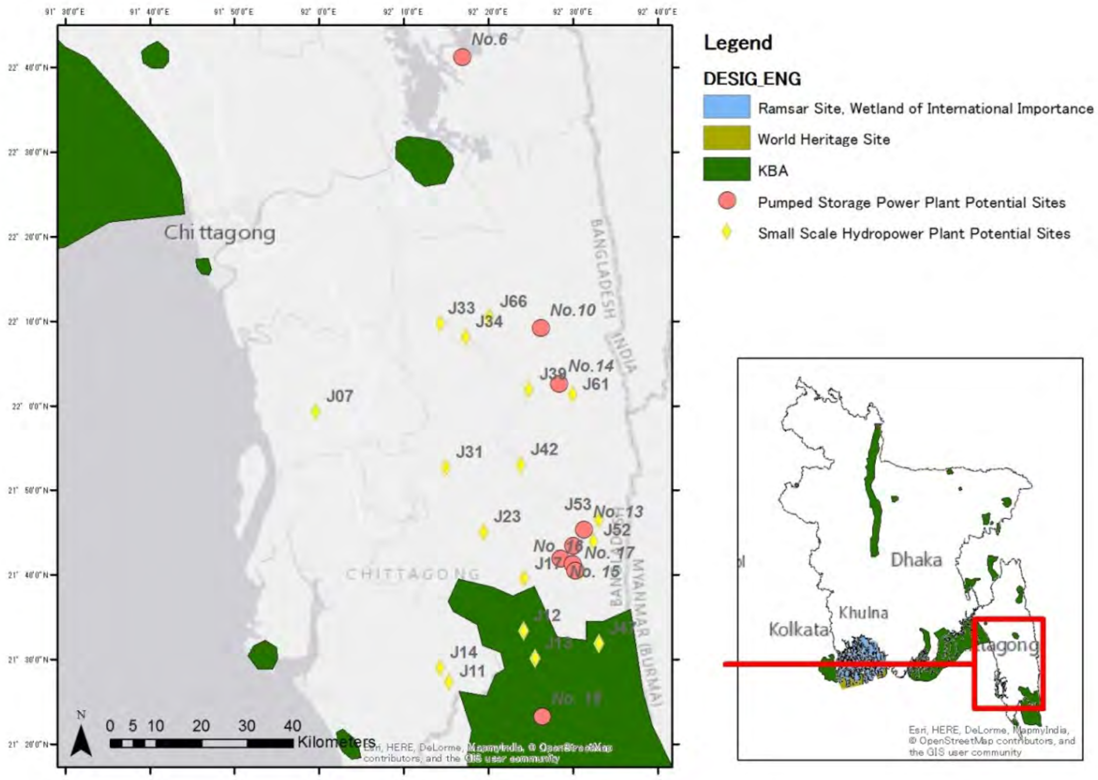
There are three protected areas registered by International treaty in Bangladesh. Registered wetlands under the Ramsal Convention are Subdarbans Reserved Forest in estuary of Khunla District, and Tanguar Haor located at the border northern part of Sylhet District. World heritage area is the Sundarbans next to southern side of the Sundarbans Ramsal wetland. All of the international protected areas are far from the Hydropower potential sites.

There are 20 Key Biodiversity Areas (KBA) in Bangladesh as shown in Table 12-7. None of them are assigned as Alliance for Zero Extinction Sites (AZEs) where are identified to prevent and safeguard key sites, each one of which is the last remaining refuge of one or more Endangered or Critically Endangered species. Some of the Hydropower potential sites fall in the KBA as shown in Figure 12-14.

Table 12-7 Key Biodiversity Areas in Bangladesh

International name	Area (ha)	Potential sites
Aila Beel	160	
Ganges-Brahmaputra-Meghna delta	75000	
Hail Haor	8906	
Hakaluki Haor	20400	
Hazarikhil Wildlife Sanctuary	2903	
Himchari National Park	1729	
Jamuna-Brahmaputra river	200000	
Lawachara / West Bhanugach Reserved Forest	900	
Madhupur National Park	8436	
Muhuri Dam	500	
Pablakhali Wildlife Sanctuary	42087	
Patenga Beach	500	
Rajkandi Reserved Forest	1000	
Rampahar-Sitapahar Wildlife Sanctuary	3026	
Rema-Kalenga Wildlife Sanctuary	1095	
Sangu Matamuhari	20000	No.18,J12, J13, J47
Sonadia Island	4916	
Sunderbans (East, South, West Wildlife Sanctuaries)	139699	
Tanguar Haor and Panabeel	1566	
Teknaf Game Reserve	11615	

Source: JICA Survey Team



Source: IBAT, WDPA

Figure 12-14 KBA around Hydropower Potential Sites

(c) Distribution of the protected species

In total 198 IUCN red list species are recorded in Bangladesh including 21 plants, 43 mammals, 52 birds, 23 reptiles, 1 amphibian, 53 fishes, and 2 invertebrates. In terms of mammals, the known distribution areas around the Hydropower potential sites are of Indian hog deer (Axis porcinus), Asian Elephant (Elephas maximus), Phayre's leaf monkey (Trachypithecus phayrei), Western hoolock gibbon (Hoolock hoolock), and Dhole (Cuon alpinus). All of them are classified as Endangered category (EN). Relatively limited distribution areas are of Indian hog deer and Asian Elephant as shown in Table 12-8. Some of the Hydropower potential sites are in the these distribution areas. It is reported that some kinds of freshwater dorphines are living in Kaptai area (Ahmed et al. 2001)[1]

Table 12-8 Number of IUCN Red List Species Recorded in Bangladesh

Taxonomic group*	EW	CR	EN	VU	NT	Total
Plants		5	3	8	5	21
Mammals		3	13	18	9	43
Birds		8	6	17	21	52
Reptiles	1	3	8	11		23
Amphibians				1		1
Fishes		2	3	15	34	54
Invertebrates			1	1	2	4
Grand Total	1	21	34	71	71	198

* : Extinct in Wild(EW), Critically Endangered(CR), Endangered(EN), Vulnerable(VU), Near Threatened(NT)

Source: IUCN

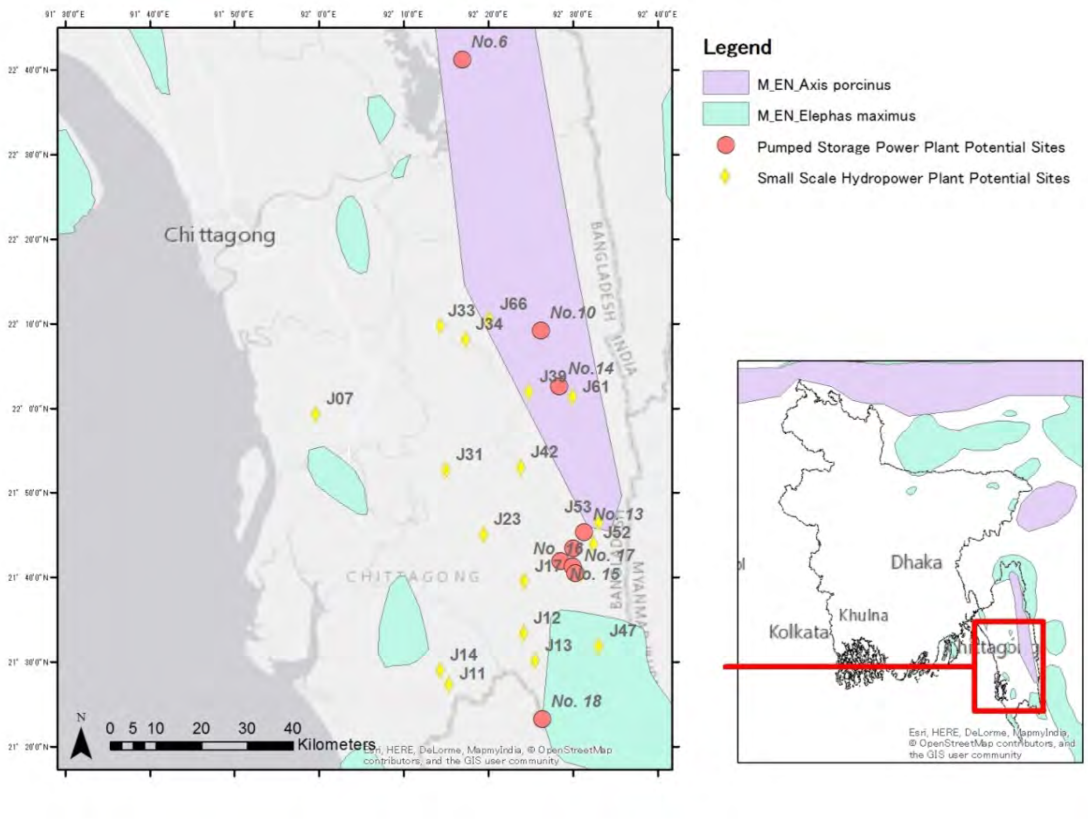
Table 12-9 Known Distribution Area of Endangered Mammals and Potential Sites

Potential sites	Indian hog deer (Axis porcinus)	Asian Elephant (*Elephas maximus*)	Phayre's leaf monkey (*Trachypithecus phayrei*)	Western hoolock gibbon (*Hoolock hoolock*)	Dhole (*Cuon alpinus*)
No.06	*		*	*	
No.10	*		*	*	
No.12			*	*	
No.13			*	*	
No.14	*		*	*	
No.15			*	*	
No.16			*	*	
No.17			*	*	
No.18		*	*	*	
J07			*	*	
J11			*	*	
J12			*	*	
J13			*	*	
J14			*	*	
J17			*	*	
J23			*	*	

[1] 2001, Ahmed, Benazir, Ali, Muhammad Edrise, Braulik, Gill & Smith, Brian D. " Status of the Ganges river dolphin or shushuk *Platanista gangetica* in Kaptai Lake and the southern rivers of Bangladesh" in *Oryx*, Vol. 35, No. 1, January. P. 61-72.

Potential sites	Indian hog deer (Axis porcinus)	Asian Elephant (*Elephas maximus*)	Phayre's leaf monkey (*Trachypithecus phayrei*)	Western hoolock gibbon (*Hoolock hoolock*)	Dhole (*Cuon alpinus*)
J31			*	*	
J33			*	*	
J34			*	*	
J39	*		*	*	
J42			*	*	
J45			*	*	
J47		*	*	*	
J52			*	*	
J53	*		*	*	
J61	*		*	*	
J66	*		*	*	

Source: IUCN

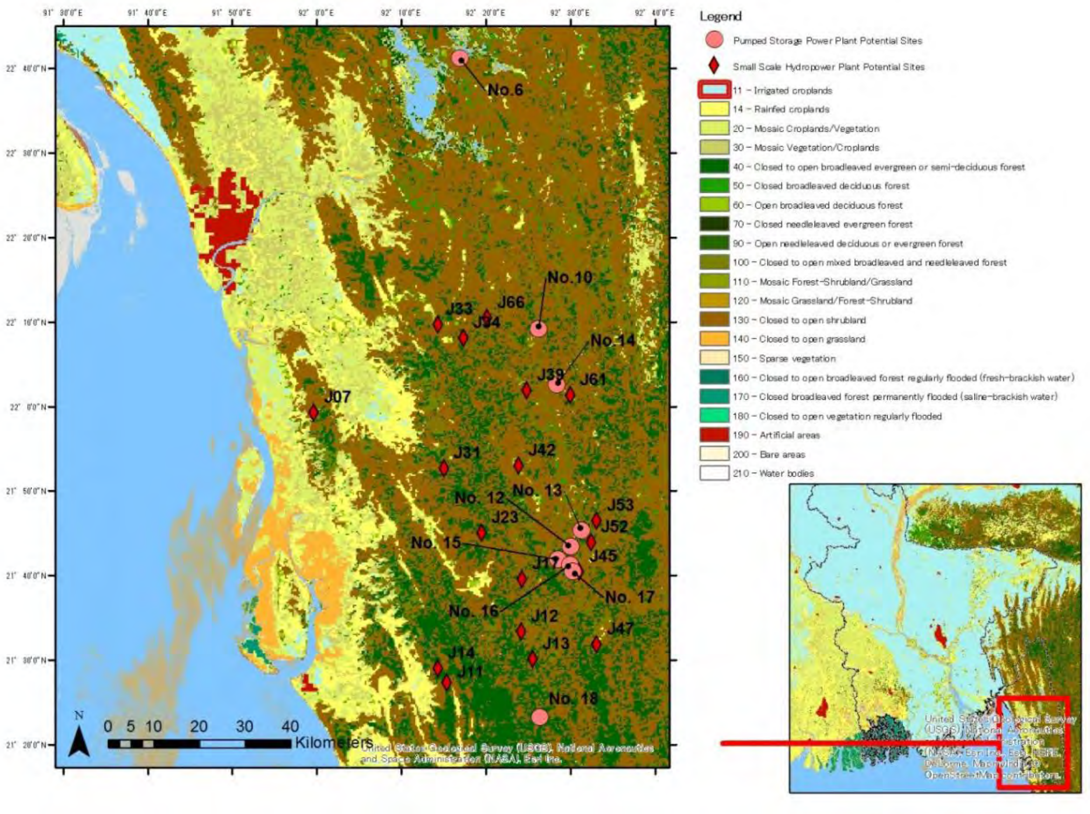


Source: IUCN

Figure 12-15 Known Distribution Area of Indian Hog Deer and Asian Elephant

(d) Vegetation

According to the GlobCover 2009 based on the satellite image, Irrigated croplands (11) are widely spread in Ganges Delta. The Chittagong Hill Tract is coverd by Closed to open broadleaved evergreen or semi-deciduous forest (40), Closed to open shrubland (130), and Mosaic Forest-Shrubland/Grassland (110). Rainfed croplancs (14) spread in the coast area of Chittagong district. Hydropower potential sites are located on the hills dominated by forest and shrubs as shown in Figure 12-16.



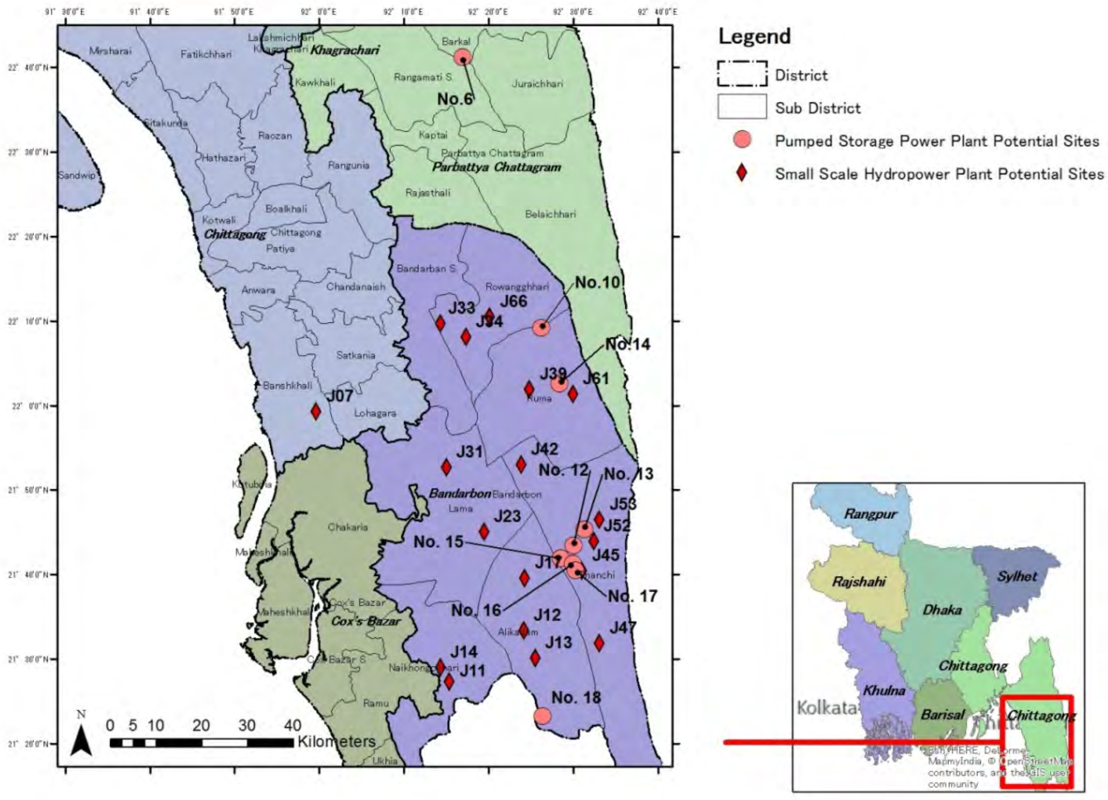
Source: GlobCover 2009 (http://ionia1.esrin.esa.int/)

Figure 12-16 Vegetation around the Hydropower Potential Sites by GlobCover (2009)

(3) Social environment

(a) Administrative sections

The highest administrative sections in Bangladesh are seven Divisions followed by District, Sub-District (Upazila), and Village (Union/Mouza). The hydropower potential sites are located in Chittagong Division including Rangamati District, Chittagong District, Bandarban District, and Cox's Bazar District.



Source: ArcGIS Online, ESRI

Figure 12-17 Administrative Boundaries around the Hydropower Potential Sites

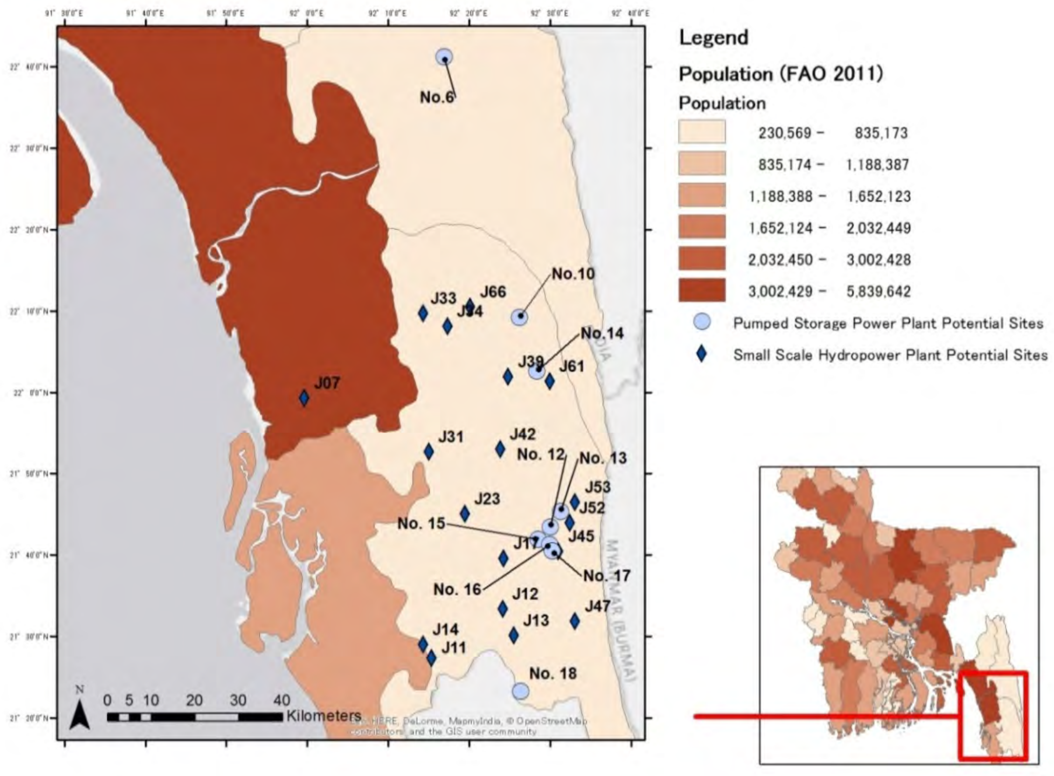
Table 12-10 Administrative Jurisdiction of the Potential Sites

District	Sub-district (Upazila)	Village (Union/Mouza)	Potential Sites	
			PSPP	SSHP
Bandarban	Alikadam	Alikadam	-	J17, J23
		Chokhyong	No.18	J12, J13
	Bandarban	Bandarban	-	J33
	Lama	Rupshipara	-	J31
	Rawangchhari	Rawangchhari	-	J34, J66
	Ruma	Paindu	No.10	
		Ruma	No.14	J39, J61
	Thanchi	Remakri	No.15, No.16, No.17	J45, J47
		Thanchi	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	-	J7
Cox's Bazar	Ramu	Kaoarkhop	-	J11, J14
Rangamati	Barkal	Shuvolong	No.6	

Source: JICA Survey Team

(b) Population

According to the census 2011, the population of Bangladesh is over 150 million (152,518,015: the eighth biggest country in the world). The population density in Bangladesh is 1,238 person/km2 which are more than triple the density in Japan (343 person/km2, 2005) cited by CIA World Fact Book 2012. Hydropower potential sites are located relatively fewer population districts. Apart from J7, all of the potential sites are located in low population area.



Source: FAO 2011

Figure 12-18 Population by Divisions around the Hydropower Potential Sites

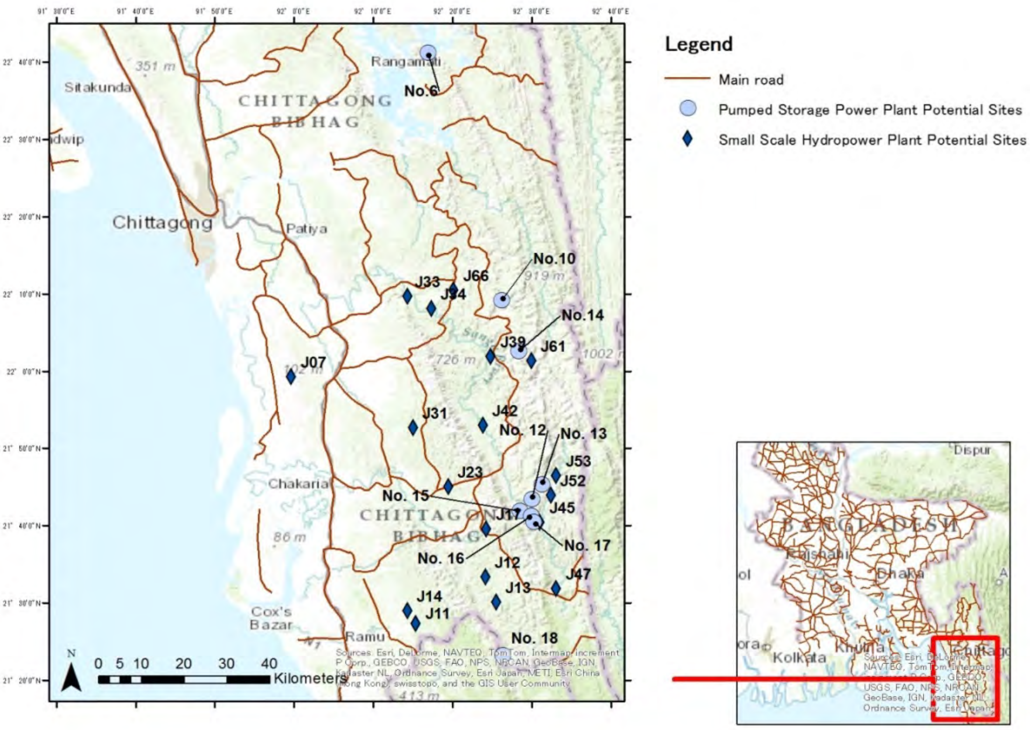
Table 12-11 Village (Union/Mouza) Population of Potential Sites

Village (Union/Mouza)	No of.H/Hs	No of Population	Potential Sites	
			PSPP	SSHP
Alikadam	5,391	28,495	-	J17, J23
Chokhyong	4,031	20,822	No.18	J12, J13
Bandarban	2,023	9,219	-	J33
Rupshipara	2,457	11,565	-	J31
Rawangchhari	1,988	8,804	-	J34, J66
Paindu	1,267	5,803	No.10	
Ruma	2,667	12,417	No.14	J39, J61
Remakri	1,281	6,119	No.15, No.16, No.17	J45, J47
Thanchi	1,547	7,599	No.12, No.13	J42, J52, J53
Silkup	4,075	20,043	-	J7
Kaoarkhop	4,373	24,004	-	J11, J14
Shuvolong	2,501	11,728	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

(c) Traffic and electricity

The road networks in Bangladesh cover whole the country. Main roads near the Hydropower potential sites are road stretching along the coast as shown in Figure 12-10. Although some roads are shown on the hill near the potential hydropower site, the conditions of the roads are not confirmed. Electrification rates around the project sites are under 50%. Following table shows the electricity rates by Villages.



Source: JICA Survey Team

Figure 12-19 Main Roads around the Hydropower Potential Sites

Table 12-12 Percentage of Electrification around the Potential Sites

Administrative section			No of H/Hs	Electricity	Potential sites	
District	Upazila	Union/Mouza			PSPP	SSHP
Bandarban	Alikadam	Alikadam	5,391	18.70%	-	J17, J23
		Chokhyong	4,031	11.07%	No.18	J12, J13
	Bandarban	Bandarban	2,023	34.30%	-	J33
	Lama	Rupshipara	2,457	11.00%	-	J31
	Rawangchhari	Rawangchhari	1,988	27.70%	-	J34, J66
	Ruma	Paindu	1,267	28.60%	No.10	
		Ruma	2,667	42.80%	No.14	J39, J61
	Thanchi	Remakri	1,281	7.08%	No.15, No.16, No.17	J45, J47
		Thanchi	1,547	19.20%	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	4,075	34.60%	-	J7
Cox's Bazar	Ramu	Kaoarkhop	4,373	17.70%	-	J11, J14
Rangamati	Barkal	Shuvolong	2,501	27.10%	No.6	

Source: JICA Survey Team

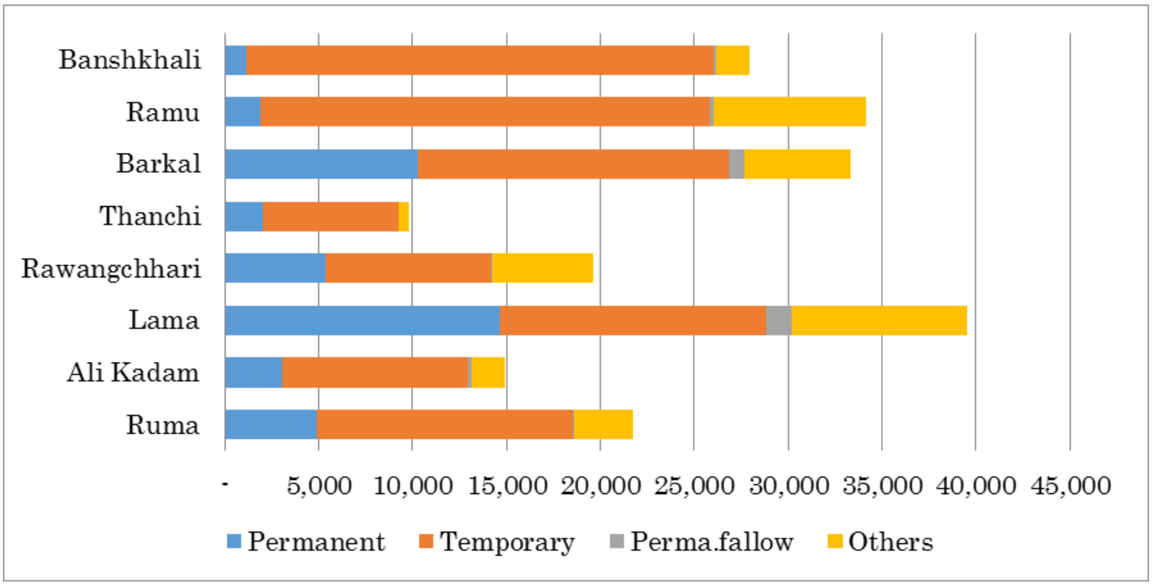
(d) Land use

The villages which potential sites locate are widely developed for farm land for permanent or temporary as shown in Table 12-13. 59% of the farm land is used for Temporary cultivation, and 22% is used for Permanent cultivation.

Table 12-13 Land Use of the Related Sub-district

District	Upazila	Land Use Area (Acre) as per Agriculture Census 2008					Potential sites	
		Operated Area (Total)	Permanent	Temporary	Perma.fallow	Others	PSPP	SSHP
Bandarban	Ruma	21,755	4,860	13,693	64	3,138	No.10, No.14	J39, J61
	Ali Kadam	14,932	3,052	9,908	159	1,813	-	J17, J23
	Lama	39,510	14,652	14,182	1,357	9,319	-	J31
	Rawangchhari	19,613	5,358	8,829	30	5,396	-	J34, J66
	Thanchi	9,806	2,037	7,220	15	534	No.12, No.13, No.15, No.16, No.17	J42, J52, J53, J45, J47
Rangamati	Barkal	32,496	10,256	16,568	811	5,672	No.6	
Cox'Bazar	Ramu	34,172	1,873	23,949	189	8,161	-	J11, J14
Chittagong	Banshkhali	40,603	1,161	24,835	165	1,773	-	J7

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011



Source: JICA Survey Team

Figure 12-20 Land Use around the Potential Sites

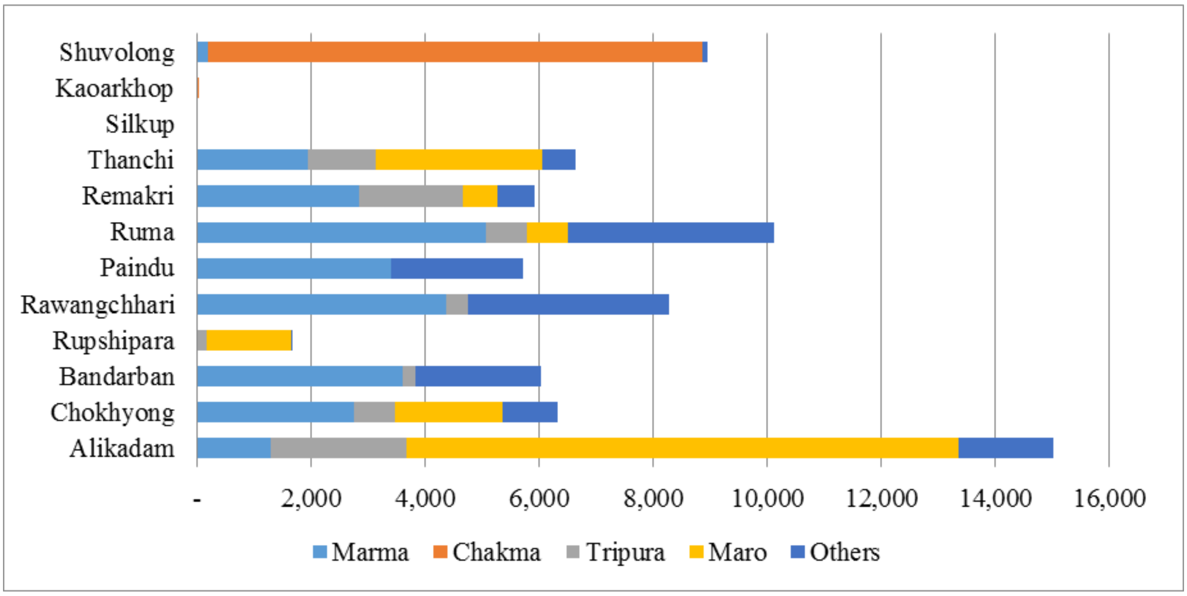
(e) Ethnic minorities and religions

According to the population census (2011) there are 27 indigenous tribes in Bangladesh. They are mainly living in Chittagong Hill Tracts (CHT), Sylhet Division, Rajshahi Division, and Mymensingh District. Majority of Shuvolong Union where No.6 locates are Chakma. Marma is relatively high rate in Bandarban District. Maro is dominated in Alikadam Union where the potential sites of J17 and J23 (See Table 12-14 and Figure 12-21) are located.

Table 12-14 Ethnicity around the Potential Site

Administrative section			Ethnicity						Potential Sites	
District	Upazila	Union/Mouza	Marma	Chakma	Tripura	Maro	Others	Total	PSPP	SSHP
Bandarban	Alikadam	Alikadam	1,286	-	2,374	9,702	1,654	15,016	-	J17, J23
		Chokhyong	2,760	-	705	1,897	949	6,311	No.18	J12, J13
	Bandarban	Bandarban	3,606	-	220	-	2,212	6,038	-	J33
	Lama	Rupshipara	-	-	175	1,469	25	1,669	-	J31
	Rawangchhari	Rawangchhari	4,361	-	395	-	3,517	8,273	-	J34, J66
	Ruma	Paindu	3,402	-	-	4	2,301	5,707	No.10	
		Ruma	5,066	-	714	719	3,609	10,108	No.14	J39, J61
	Thanchi	Remakri	2,835	-	1,822	599	670	5,926	No.15, No.16, No.17	J45, J47
		Thanchi	1,938	-	1,191	2,914	599	6,642	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	-	-	-	-	-	-	-	J7
Cox's Bazar	Ramu	Kaoarkhop	-	7	-	-	-	7	-	J11, J14
Rangamati	Barkal	Shuvolong	182	8,670	-	-	95	8,947	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011



Source: JICA Survey Team

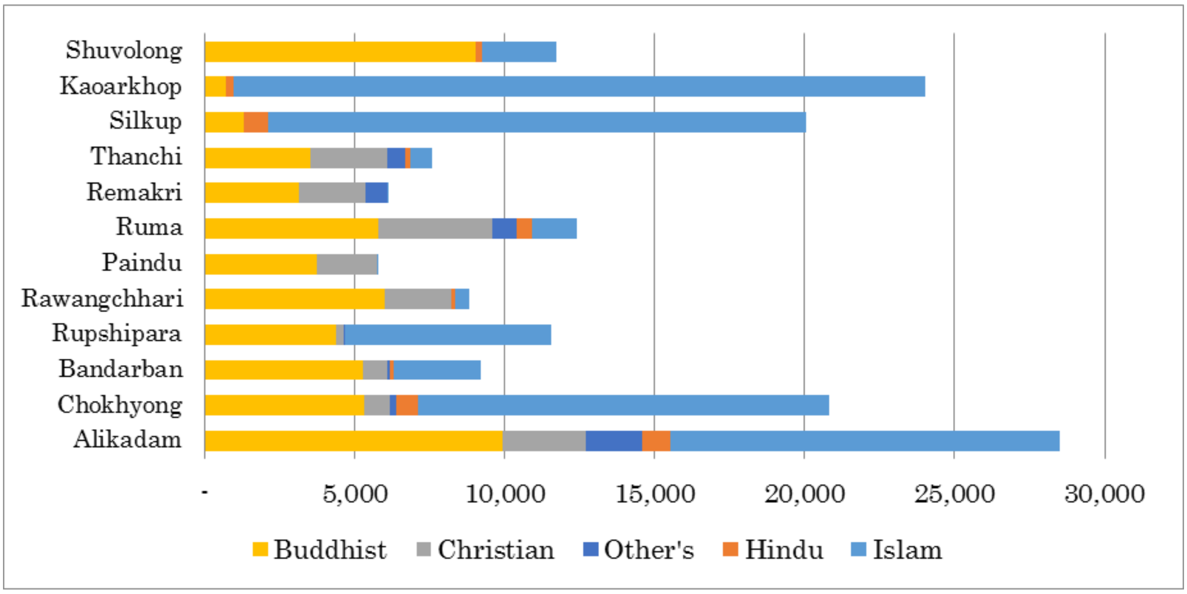
Figure 12-21 Ethnicity around the Potential Sites

According to the population census (2011) more than four religions are confirmed on the hill area. Buddhists are relatively high in Bandarban District. Some villages such as Kaoarkhop, Chokhyong are dominated by Islam as shown in Table 12-15 and Figure 12-22.

Table 12-15 Religions around the Potential Site

Administrative section			Popula-tion	Religion					Potential Sites	
District	Upazila	Union/ Mouza		Islam	Hindu	Christian	Buddhist	Other's	PSPP	SSHP
Bandarban	Alikadam	Alikadam	28,495	12,973	939	2,812	9,912	1,859	-	J17, J23
		Chokhyong	20,822	13,707	716	845	5,321	233	No.18	J12, J13
	Bandarban	Bandarban	9,219	2,921	130	824	5,271	73	-	J33
	Lama	Rupshipara	11,565	6,864	15	259	4,361	66	-	J31
	Rawangchhari	Rawangchhari	8,804	460	118	2,202	6,016	8	-	J34, J66
	Ruma	Paindu	5,803	74	-	1,983	3,746	-	No.10	
		Ruma	12,417	1,520	491	3,813	5,779	814	No.14	J39, J61
	Thanchi	Remakri	6,119	22	1	2,260	3,123	713	No.15, No.16, No.17	J45, J47
		Thanchi	7,599	746	163	2,558	3,537	595	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	20,043	17,938	795	0	1,310	0	-	J7
Cox's Bazar	Ramu	Kaoarkhop	24,004	23,023	256	-	725	-	-	J11, J14
Rangamati	Barkal	Shuvolong	11,728	2,492	201	1	9,033	1	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

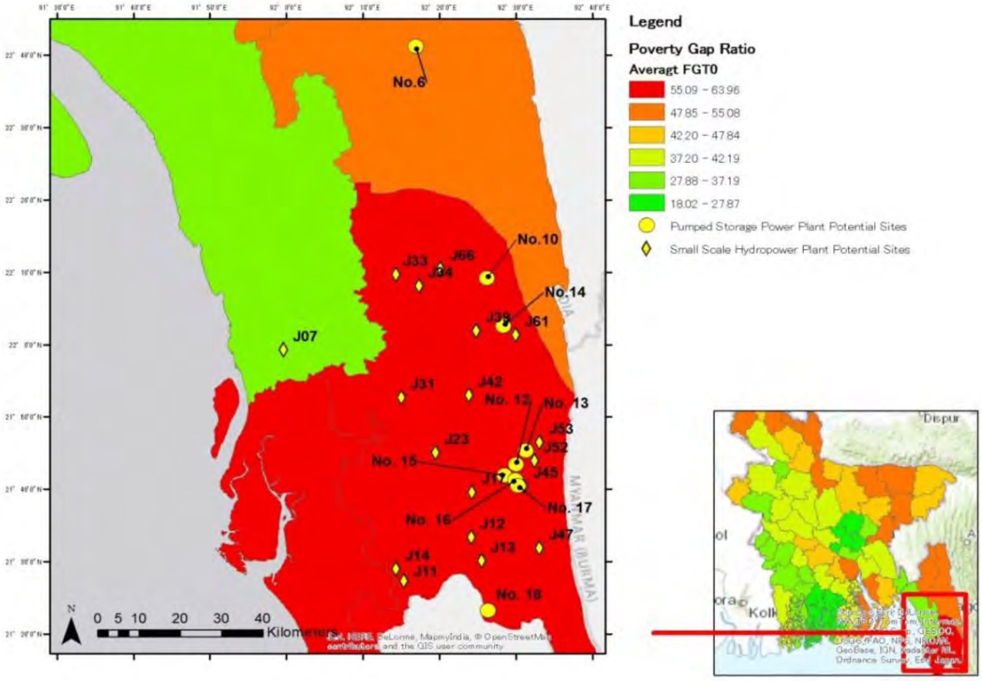


Source: JICA Survey Team

Figure 12-22 Religions around the Potential Sites

(f) Poverty and literacy rate

Poverty gap index (the average poverty gap in the population as a proportion of the poverty line) by District shows that the poverty in Eastern area and Northern area is relatively lower than the other areas as shown in Figure 12-23. The Hydropower potential sites are the most poverty area among these areas.



Source: Feature Service, 2014

Figure 12-23 Poverty Gap Index around the Hydropower Potential Sites

Literacy rate around potential sites are lower than 50%. Literacy rate of Remakri Union/Mouza where No.15m No.16 and No.17 located is 0.00%.

Table 12-16 Literacy Rate around the Potential Sites

Administrative section			Population	Literacy	Potential sites	
District	Upazila	Union/Mouza			PSPP	SSHP
Bandarban	Alikadam	Alikadam	28,495	30.50%	-	J17, J23
		Chokhyong	20,822	32.40%	No.18	J12, J13
	Bandarban	Bandarban	9,219	38.30%	-	J33
	Lama	Rupshipara	11,565	25.80%	-	J31
	Rawangchhari	Rawangchhari	8,804	31.00%	-	J34, J66
	Ruma	Paindu	5,803	21.00%	No.10	
		Ruma	12,417	28.90%	No.14	J39, J61
	Thanchi	Remakri	6,119	0.00%	No.15, No.16, No.17	J45, J47
		Thanchi	7,599	26.09%	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	20,043	34.6%	-	J7
Cox's Bazar	Ramu	Kaoarkhop	24,004	33.70%	-	J11, J14
Rangamati	Barkal	Shuvolong	11,728	48.60%	No.6	

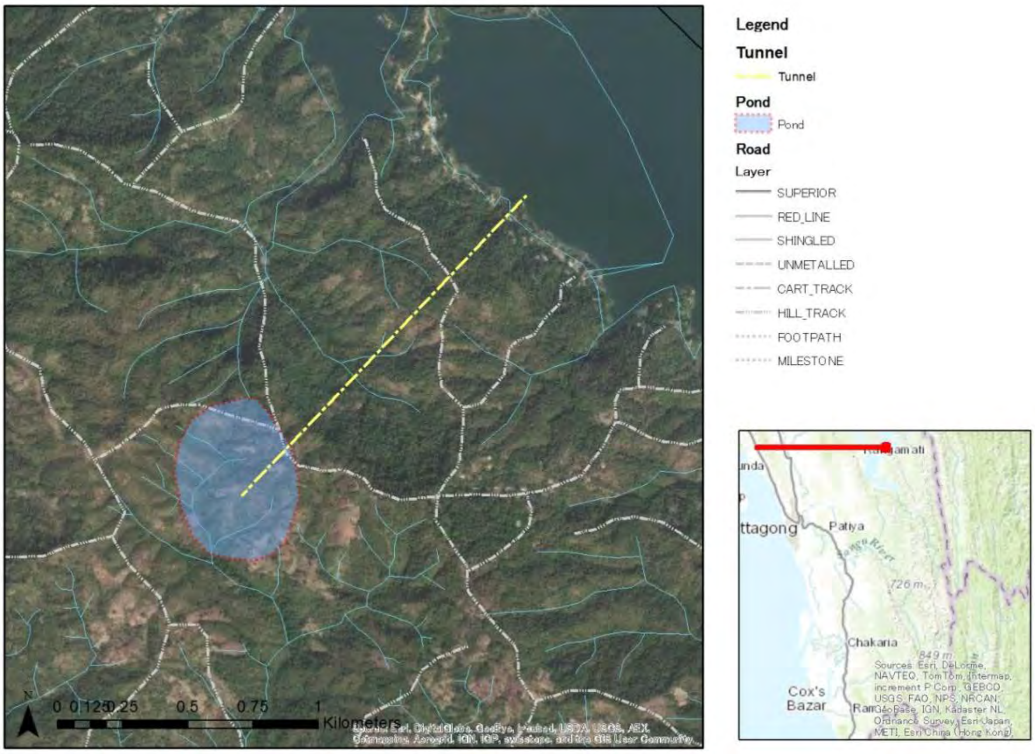
Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

12.7.2 Environmental and social impacts anticipated by project

(1) PSPP potential sites

(a) PSPP No.6

PSPP No.6 is located in Shuvolong village, Barkal sub-district, Rangamati district. Reservoir area is 21.4 ha. Some houses are confirmed at the end of water way. Farm land and Forests are seen in the reservoir area. No big house but small huts can be seen on the image. Relatively good forests are remained at the waterway route. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma and Chakma might be affected by the project.



Source: JICA Survey Team

Figure 12-24 PSPP No.6

Table 12-17 Feature of PSPP No.6

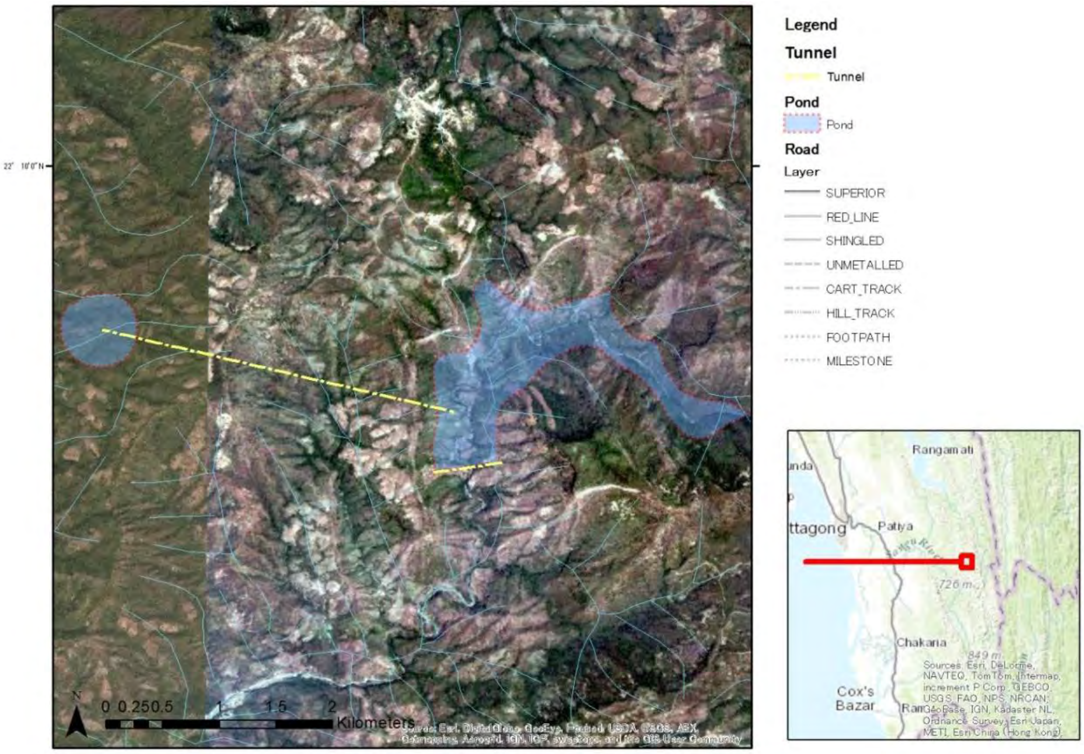
Items	Value
Effective Head (m)	176
Designed Discharge (m^3/s)	330
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	230
LWL of Lower Reservoir (m)	33
Effective Reservoir Volume (m^3)	8,400,000
Length of Waterway (m)	1,640
L/H	8.8

View of PSPP No. 6

Source: JICA Survey Team

(b) PSPP No.10

PSPP No.10 is located in Paindu village, Ruma sub-district, Bandarban district. Upper pond area is around 33.2 ha and Lower pond is 155.8 ha. No big house but small huts can be seen on the image. Forest coverage would be around 70%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-25 PSPP No.10

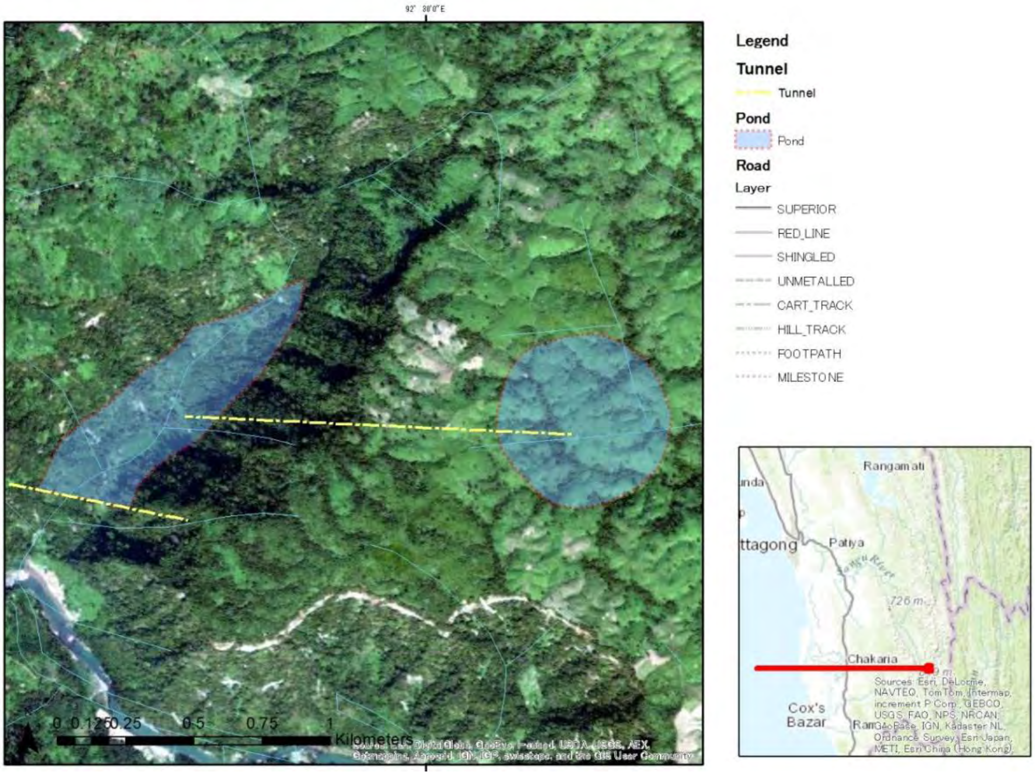
Table 12-18 Feature of PSPP No. 10

Items	Value
Effective Head (m)	185
Designed Discharge (m^3/s)	313
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	360
LWL of Lower Reservoir (m)	143
Effective Reservoir Volume (m^3)	9,400,000
Length of Waterway (m)	2,990
L/H	15.2

Source: JICA Survey Team

(c) PSPP No.12

PSPP No.12 is located in Thanchi village, Thanchi sub-district, Bandarban district. Area of upper pond is 29.2 ha and lower pond is 27.7 ha. No big house is confirmed. Small huts can be seen on the satellite image. Relatively good conserved forests are remained around the lower pond. Forest coverage would be around 60%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-26 PSPP No.12

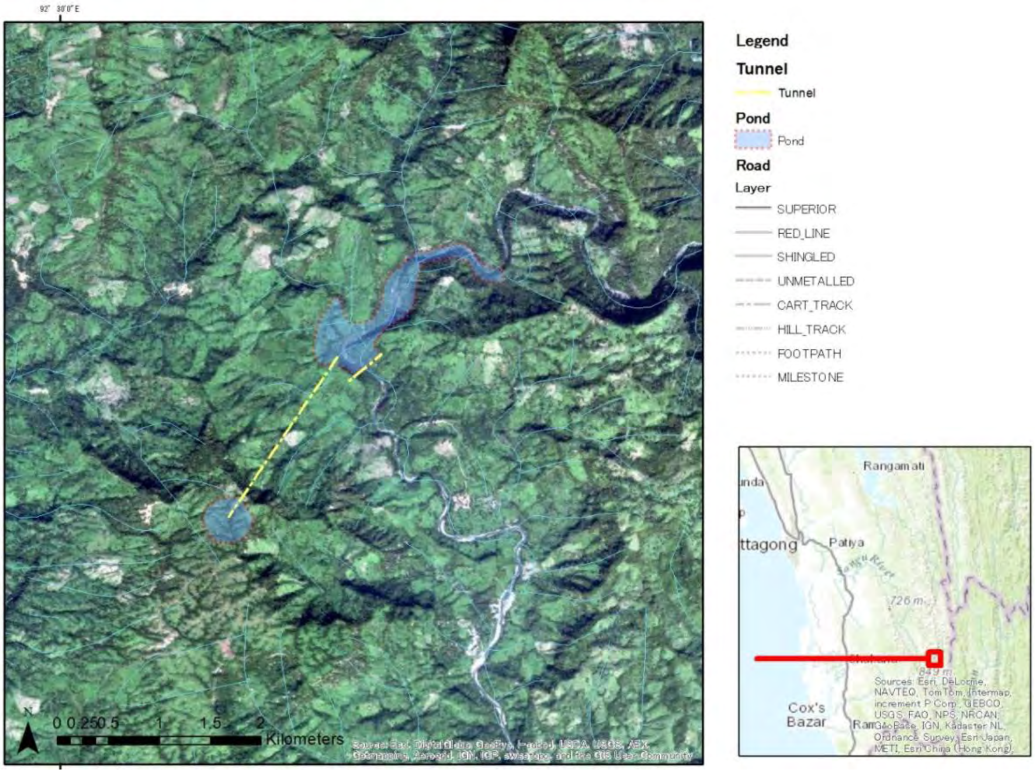
Table 12-19 Feature of PSPP No.12

Items	Value
Effective Head (m)	186
Designed Discharge (m^3/s)	312
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	340
LWL of Lower Reservoir (m)	122
Effective Reservoir Volume (m^3)	7,500,000
Length of Waterway (m)	1,330
L/H	6.7

Source: JICA Survey Team

(d) PSPP No.13

PSPP No.13 is located in Thanchi village, Thanchi sub-district, Bandarban district. Upper pond area is 15.8 ha and Lower pond area is 57.2 ha. No house but small huts are seen on the image. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-27 PSPP No.13

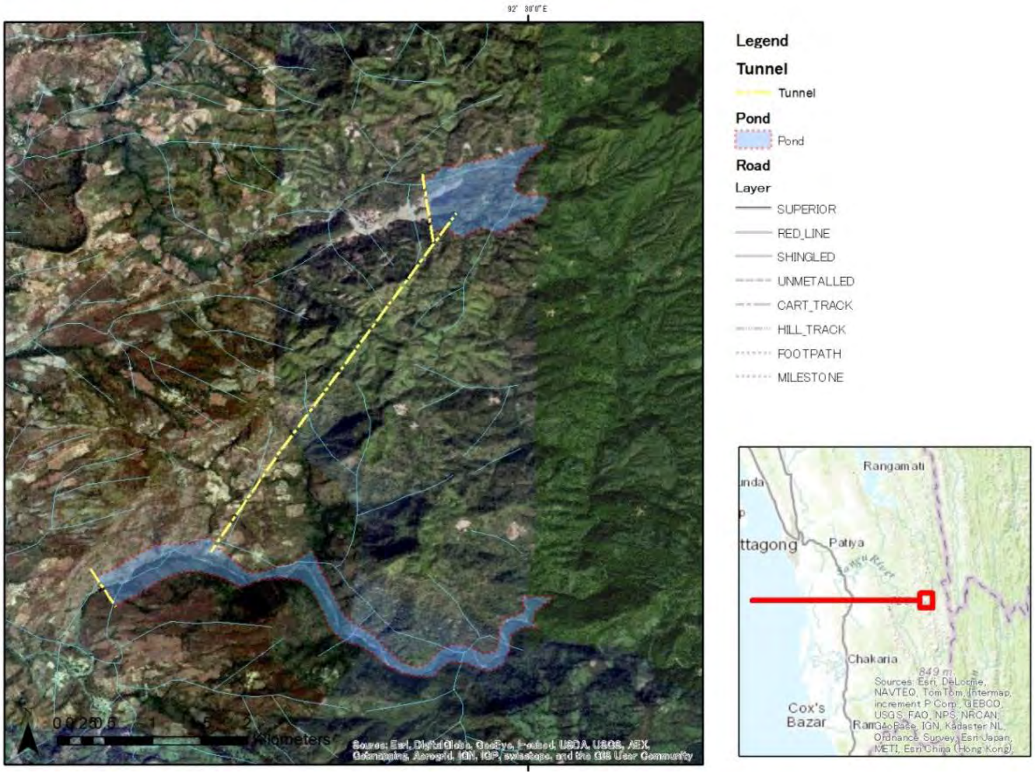
Table 12-20 Feature of PSPP No.13

Items	Value
Effective Head (m)	329
Designed Discharge (m^3/s)	176
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	480
LWL of Lower Reservoir (m)	130
Effective Reservoir Volume (m^3)	4,500,000
Length of Waterway (m)	1,890
L/H	5.4

Source: JICA Survey Team

(e) PSPP No.14

PSPP No.14 is located in Ruma village, Ruma sub-district, Bandarban district. Upper pond area is 74.9 ha and lower pond area is 11.4 ha. No house and hut can be seen on the image. Forest coverage is around 70%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-28 PSPP No.14

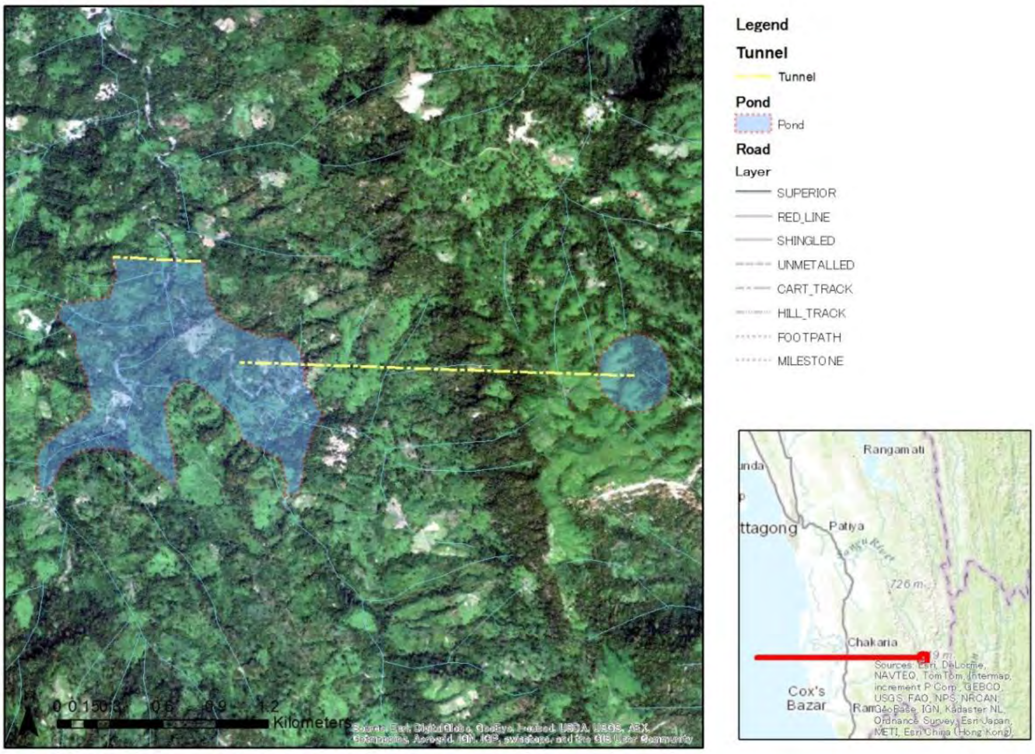
Table 12-21 Feature of PSPP No.14

Items	Value
Effective Head (m)	329
Designed Discharge (m^3/s)	176
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	530
LWL of Lower Reservoir (m)	160
Effective Reservoir Volume (m^3)	4,500,000
Length of Waterway (m)	4,280
L/H	12.2

Source: JICA Survey Team

(f) PSPP No.15

PSPP No.15 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond is 13.6 ha and Lower pond is 105.5 ha. Five houses can be seen on the image. Forest coverage is around 50%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (T*rachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-29 PSPP No.15

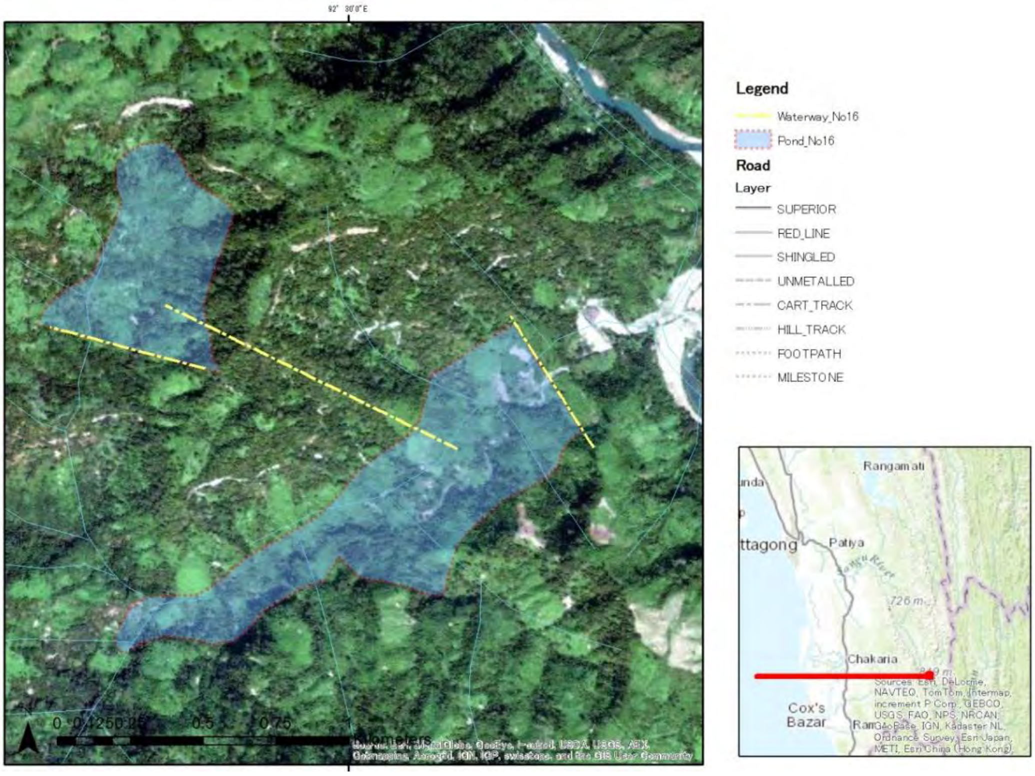
Table 12-22 Feature of PSPP No.15

Items	Value
Effective Head (m)	369
Designed Discharge (m^3/s)	157
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	540
LWL of Lower Reservoir (m)	127
Effective Reservoir Volume (m^3)	4,000,000
Length of Waterway (m)	2,100
L/H	5.3

Source: JICA Survey Team

(g) PSPP No.16

PSPP No.16 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond area is 26.5 ha and Lower pond area is 51.1 ha. No house but some huts can be seen on the image. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-30 PSPP No.16

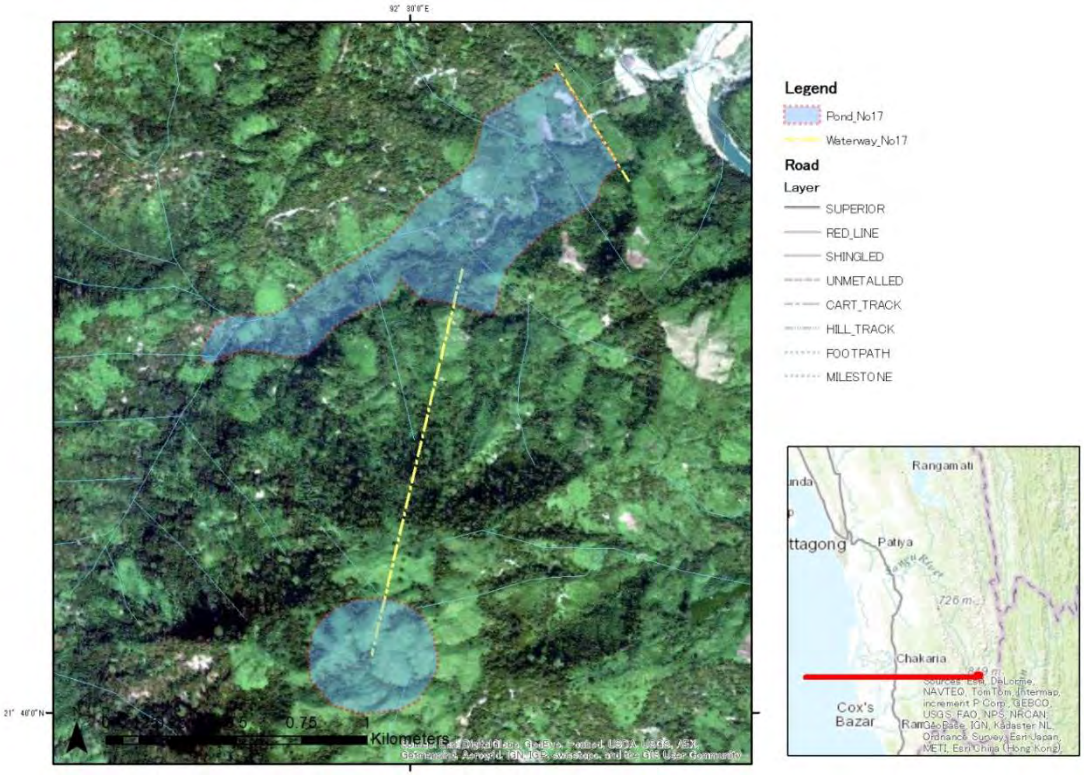
Table 12-23 Feature of PSPP No.16

Items	Value
Effective Head (m)	248
Designed Discharge (m^3/s)	234
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	395
LWL of Lower Reservoir (m)	116
Effective Reservoir Volume (m^3)	5,900,000
Length of Waterway (m)	1,060
L/H	4.0

Source: JICA Survey Team

(h) PSPP No.17

PSPP No.17 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond is 15.1 ha and Lower pond is 16.4 ha. No house and hut can be seen on the image. Forest coverage is around 30%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-31 PSPP No.17

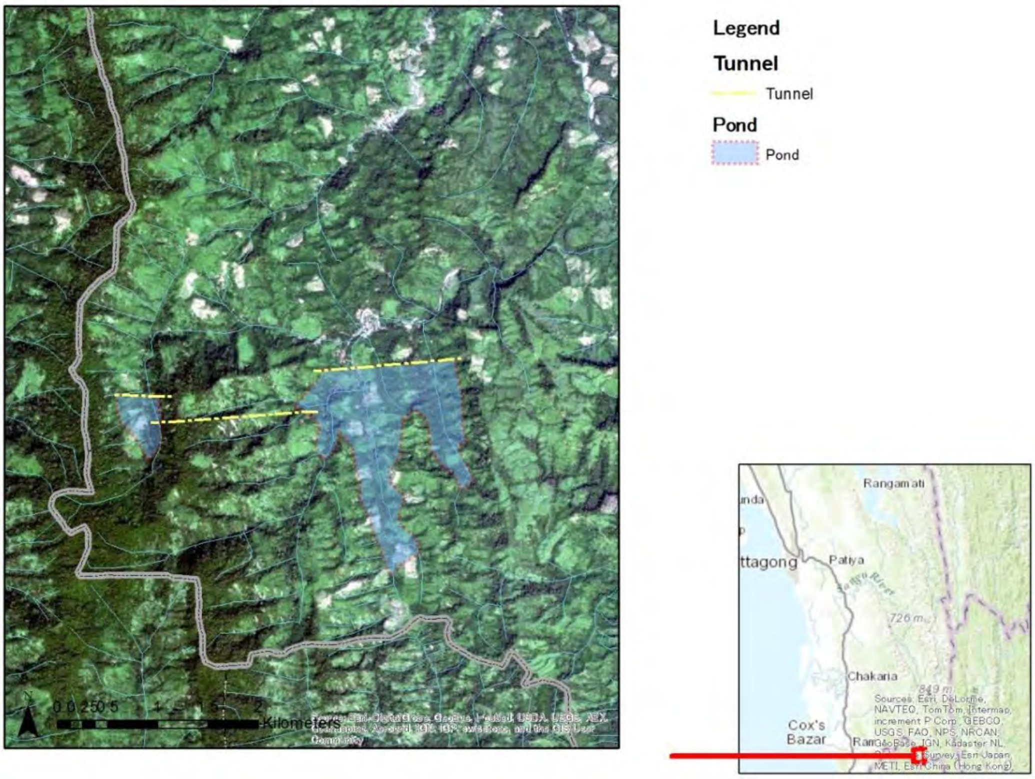
Table 12-24 Feature of PSPP No.17

Items	Value
Effective Head (m)	361
Designed Discharge (m^3/s)	161
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	520
LWL of Lower Reservoir (m)	116
Effective Reservoir Volume (m^3)	8,400,000
Length of Waterway (m)	1,520
L/H	4.0

Source: JICA Survey Team

(i) PSPP No.18

PSPP No.18 is located in Chokhyong village, Alikadam sub-district, Bandarban district. Upper pond is 18.3 ha and Lower pond is 153.6 ha. No house but small hut can be seen on the image. Forest coverage is around 80%. The part of the reservoir covers Forest reserve and all of the area is in the Sangu Matamuhari Key Biodiversity Area. The project sites cover the distribution areas of Endangered mammals such as Asian Elephant (*Elephas maximus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-32 PSPP No.18

Table 12-25 Feature of PSPP No. 18

Items	Value
Effective Head (m)	249
Designed Discharge (m^3/s)	233
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	405
LWL of Lower Reservoir (m)	140
Effective Reservoir Volume (m^3)	5,900,000
Length of Waterway (m)	1,580
L/H	6.0

Source: JICA Survey Team

(2) Ordinary HP/SSHP potential sites

Environmental and social impact of eighteen potential SSHPs is briefly examined. Four of the project sites are located in the protected area. Most of the project sites are located in the distribution area of two or three endangered mammal species. One to five ethnic minority groups might be affected by each ordinary HP/SSHP project.

Table 12-26 Summary of Environmental Impact of SSHPs

SSHP	River	Governorate			Protected Area	No. of affected Endangered Mammals	No. of Ethnic minority groups
		District	Upazila	Union/Mouza			
J07	Banshkhali	Chittagong	Banshkhali	Silkup	Chunati Wildlife Sanctuary	2	0
J11	Bakkhali	Cox's Bazar	Ramu	Kaoarkhop		2	1
J12	Matamuhuri	Bandarban	Alikadam	Chokhyong	Forest reserve, KBA	2	3
J13	Matamuhuri	Bandarban	Alikadam	Chokhyong	Forest reserve, KBA	2	3
J14	Bakkhali	Cox's Bazar	Ramu	Kaoarkhop		2	1
J17	Matamuhuri	Bandarban	Alikadam	Alikadam		2	3
J23	Matamuhuri	Bandarban	Alikadam	Alikadam		2	3
J31	Matamuhuri	Bandarban	Lama	Rupshipara		2	2
J33	Sangu	Bandarban	Bandarban	Bandarban		2	2
J34	Sangu	Bandarban	Rawangchhari	Rawangchhari		2	2
J39	Sangu	Bandarban	Ruma	Ruma		3	3
J42	Sangu	Bandarban	Thanchi	Thanchi		2	3
J45	Sangu	Bandarban	Thanchi	Remakri		2	3
J47	Sangu	Bandarban	Thanchi	Remakri	Forest reserve, KBA	3	3
J52	Sangu	Bandarban	Thanchi	Thanchi		2	3
J53	Sangu	Bandarban	Thanchi	Thanchi		3	3
J61	Sangu	Bandarban	Ruma	Ruma		3	3
J66	Sangu	Bandarban	Rawangchhari	Rawangchhari		3	2

Source: JICA Survey Team

During the site reconnaissance, the JICA Survey Team was able to visit the locations near the five potential sites among 18 sites.

The projects of J33, J39, 42 are planned to hold back water on the Sangu main river by dams. Since many local people are living along the Sangu river, even a small dam may causes large scale of resettlement.

Houses along the Sangu river

Houses along the Sangu river

The project of J61 and J66 are located on the tributary of Sangu River. However, J61 project has too small water flow in dry season in comparison with the planned discharge. As for J66 project is located at the center of the town of Rowanchhari so that it causes large number of resettlement.

Upstream of J66 site

Downstream of J61 site

12.8 Summary of Hydropower Potential Study

12.8.1 PSPP potential sites

In general, preferable PSPP sites have smaller waterway length per gross head (L/H), less environmental and social impacts, shorter access road required and sufficient catchment area for lower reservoir as water source. And also, possibility of expansion of the scale is one of the advantages from viewpoints of economic efficiency in development.

Table 12-27 shows the comparison of PSPP potential sites based on the results of the literature survey and site reconnaissance. The JICA survey team selected PSPP No.17 as the best preferable potential site for the first PSPP project in Bangladesh, PSPP No.13 as the second potential site.

For realization of the projects, some difficulty exists during planning and designing stages. Maps available at this moment are only 1/50,000 maps with 100m contour lines. Those maps cannot be used even for conceptual design. And site reconnaissance and site survey is limited due to security reason in the Chittagong hilly area. In addition, during preparation stage for construction, implementing agency may encounter difficulty in acquisition and compensation of land due to local sentiment against hydropower development.

In this regard, the JICA Survey Team has a concern that immediate project implementation of the PSPP projects in Chittagong hilly area may be difficult.

12.8.2 Ordinary HP/SSHP Potential Sites

The JICA Survey Team was able to visit limited number of ordinary HPs during the site reconnaissance. However, the JICA Survey Team assumes that most of the potential sites along the Sangu main river may cause large scale of resettlement due to relatively gentle slope of the river. Though there are some prospective sites in terms of technical and economic viability, those sites may not be suitable sites for development in consideration of environmental and social impact aspects.

On the other hand, the potential sites on the tributaries of Sangu River are anticipated that they have limited water flow particularly in dry season. Thus, those sites seem not financially viable.

In this regard, those potential sites seem that they are not attractive for development of hydropower projects.

Table 12-27 Comparison of PSPP Potential Sites

Site No.		No.6	No. 10	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18
Upper Reservoir	Type	Artificial Pond	Artificial Pond	Artificial Pond	Artificial Pond	Ordinary	Artificial Pond	Ordinary	Artificial Pond	Ordenary
	Dam Height							80		80
	HWL	230	360	340	480	530	540	395	520	405
	NWL	220	350	330	470	520	530	390	510	395
	LWL	190	320	300	440	500	500	365	480	375
	Net Volume	8,400,000	9,400,000	7,500,000	4,500,000	4,500,000	4,000,000	5,900,000	4,100,000	5,900,000
Lower Reservoir	Type									
	Dam Height	–	70	80	70	70	60	70	70	70
	HWL	33	173	152	160	190	157	146	146	170
	NWL	33	153	132	120	170	137	126	126	130
	LWL	33	143	122	130	160	127	116	116	140
	Net Volume	8,400,000	9,400,000	7,500,000	4,500,000	4,500,000	4,000,000	5,900,000	4,100,000	5,900,000
Waterway	Length (L)	1640	2990	1330	1890	4280	2100	1060	1520	1580
	Diameter	8.4	8.2	8.1	6.1	6.1	5.8	7.0	5.8	7.0
	Length X Diameter	13,724	24,378	10,816	11,561	26,180	12,122	7,466	8,876	11,107
Gross Head	(H)	187.0	197.0	198.0	350.0	350.0	393.0	264.0	384.0	265.0
L/H		**8.8**	**15.2**	**6.7**	**5.4**	**12.2**	**5.3**	**4.0**	**4.0**	**6.0**
Net Head		175.8	185.2	186.1	329.0	329.0	369.4	248.2	361.0	249.1
Discharge		330	313	312	176	176	157	234	161	233
Installed Capacity	(Efficiency=88%)	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
Social Aspects	Resettlement	Several HH Local Sentimental	None	None	None	None	Several Ten HH	None	None	None
Natural Environmental Aspects	Pretected Area	–	–	–	–	–	–	–	–	Shangu–Matamuhuri Wildlife
Access to the Site		52km	24km	18km	30km	29km	15km	21km	21km	
Others		–	–	Too small CA	Expansion Possibility	–	–	No Expansion	Expansion Possibility	Small CA
Comprehensive Evaluation		E	E	D	B	E	D	C	A	E

*CA: Catchment Area

[yellow box] Evaluation Items

Source: JICA Survey Team

12.9 Recommendations for the Next Steps

12.9.1 Possibility of project implementation

The JICA Survey Team assumes that development of some potential sites of PSPP and ordinary HP listed above may be physically possible. However, it is also anticipated that some limitation may make the project implementation difficult during the next stages. Though maps are important for planning and designing stages, the currently available maps are only 1/50,000 maps with 100m contour lines. Those maps cannot be used even for conceptual design. And not only site reconnaissance but also site investigation will be limited due to security reason in the Chittagong hilly area for the moment.

In addition, in consideration of local sentiment against hydropower development in Chittagong hilly area, there is a risk that it may be difficult to obtain local consent about development of PSPPs and ordinary HPs in the area for the moment. Implementing agency may encounter the difficulty on acquisition of land for the projects.

In this regard, the JICA Survey Team has a concern that immediate implementation of hydropower projects in Chittagong hilly area may be difficult. Thus, Hydropower projects are not necessary to be listed in the reviewed PSMP2010.

12.9.2 Reference TOR for the future projects

If the difficulty such as peace and order issues and local sentiment against hydropower development is improved, the PSPP potential sites of PSPP No. 17 and No. 13 would become possible to be implemented at the scale of 500MW to 1,000MW.

As a next step of the project implementation, a feasibility study will be conducted. For reference, the general items of Terms of Reference (TOR) for the feasibility study for PSPP projects are shown in Table 12-28 and Table 12-29.

Table 12-28 TOR for Feasibility Study on PSPP Project (1)

Task 1. Background and Necessity of Pumped Storage Power Plants

- 1-1 Overview of the power development policy in Bangladesh
  - ・To confirm development policy of power facilities
  - ・To confirm position of PSPP in the above policy
- 1-2 Overview of power demand and supply balance, power development plan
  - ・To grasp power demand growth and situation of development of power facilities
  - ・To grasp power demand forecast and development plan of power facilities
- 1-3 Confirmation of the progress of power sector reform
  - ・To confirm action plan of establishment of Balancing Market
- 1-4 Overview of power market

Task 2. Necessity of PSPP projects

- 2-1 Evaluation of necessity and justification of introduction of PSPP projects
  - ・To examine requirements of kW and kWh (peak duration hours) from the power system
  - ・To simulate demand supply balance considering wind power development (capacity and operational status)
- 2-2 Examination of applicability of Adjustable Speed (AS)-PSPP
- 2-3 Validity of finaicial assistance
- 2-4 Optimization of development schedule and transmission connection plan
  - ・To optimize development schedule
  - ・To build transmission connection plan

Source: JICA Survey Team

Table 12-29 TOR for Feasibility Study on PSPP Project (2)

Task 3. Basic design
- 3-1 Hydrological, topographical and geological survey
  - ・To make plan and execute investigations based on the conceptual design
  - ・To carry out topographic survey, borehole drilling, reconnaissance, seismic prospecting, sonic prospecting, laboratory tests
  - ・To install gauging station and measure hydrological and meteorological data
- 3-2 Comparative study on alternatives
  - ・To select location of the upper and lower ponds
  - ・To select types of dams and ponds
  - ・To determine location of powerhouse site and waterway route
  - ・To review the optimal development scale
- 3-3 Basic design of civil structure and steel structure
  - ・To execute basic design of civil structure and steel structures
  - ・To execute basic design of waterway and underground powerhouse
- 3-4 Basic design of electro-mechanical equipment
  - ・To design pump-turbines and motor-generators, including AS system
  - ・To review facilities of switch yard based on transmitting plan such as composition of GSI, layout, yard area
  - ・To review design of main circuit of low voltage, cable, GIS and earthing
- 3-5 Basic design of transmission lines
  - ・To conduct system analysis
  - ・To design transmission method and monitoring control method
- 3-6 Evaluation on the possible application of new technologies

Task 4. Overall Project Implementation Plan
- 4-1 Construction planning
- 4-2 Consulting services
- 4-3 Procurement method and package
- 4-4 Implementation plan
- 4-5 Cost estimation

Task 5. Environmental and Social Considerations
- 5-1 Related laws and regulations, system and organizations
- 5-2 Scoping
- 5-3 Environmental and Social Survey
- 5-4 Support for holding public consultation
- 5-5 Preparation of EIA report
- 5-6 Preparation of Abbreviated Resettlement Action Plan
- 5-7 Preparation of environment management plan and monitoring plan
- 5-8 Technical support and advice to Implementing Agency

Task 6. Project Implementation Structure and Operation and Maintenance Structure
- 6-1 Project Implementation Structure
- 6-2 Operation and Maintenance Structure
- 6-3 Considerations regarding Project Implementation and Operation & Maintenance

Task 7. Evaluation of the Project
- 7-1 Economic and Financial Analysis
- 7-2 Risk Analysis
- 7-3 Index of Operation Efficiency
- 7-4 Necessity of Technical Support

Task 8. Technical Transfer

Source: JICA Survey Team

Chapter 13 Renewable Energy

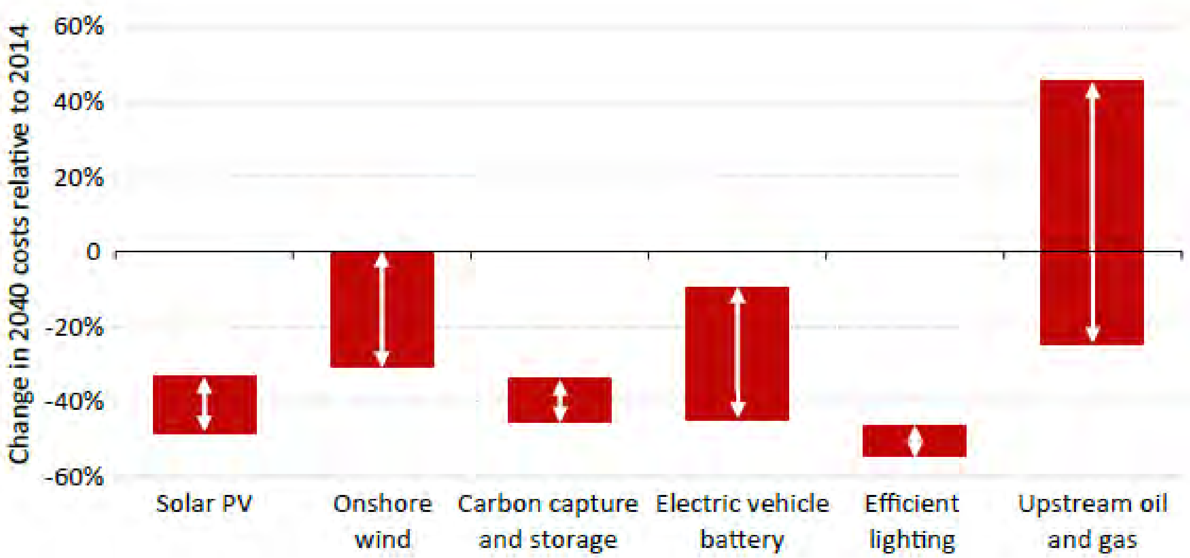
13.1 Environments around Renewable Energy[1]

13.1.1 World trend

As described in Chapter 3, the international community has committed to achieve "Affordable and clean energy - ensure access to affordable, reliable, sustainable and modern energy for all" by 2030. In addition, population and economic growth will lead to the 30% more energy consumption in the world (out of this, India will take one fourth of this additional energy consumption. This energy consumption estimate already includes population decrease in high-income countries and energy consumption decrease by energy efficiency improvement).

These circumstances have promoted the importance of renewable energy technologies ever before, as the solution to materialize economic growth, energy access improvement and the reduction of greenhouse gas emission altogether. IEA estimates that the share of "modern renewable energy" (excluding traditional solid biomass) in the world total energy demand will increase from 14% in 2014 to 19% in 2040 (in 2040, world renewable energy will take up one third out of total electricity generation, one six of thermal source, and 8% out of total fuel for the transport sector).

The cost reduction of renewable energy technologies, and the cost increase of the conventional oil and gas development and production also contributes to the dissemination of renewable energy. While the renewable energy cost reduction and technology dissemination remain uncertain, the remaining oil and gas development diggings would face more technical challenges and therefore P&D cost for gas and oil will increase with certainty.



Source: IEA World Energy Outlook 2015, Figure 1.3

Figure 13-1 Evolution of Energy Technology Costs per Unit in the New Policies Scenario, 2014-2040

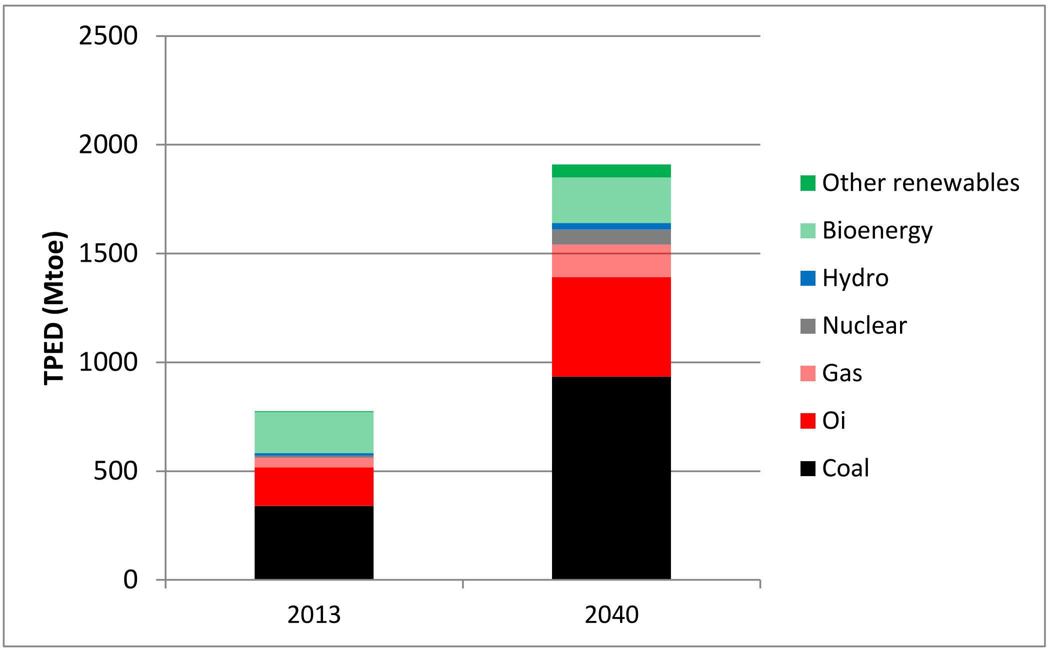
---

[1] IEA, World Energy Outlook, 2015、and IEA Mid-Term Market Report Renewable Energy 2015. In this IEA Report, the word "renewable energy", if without specific note, includes hydro power (regardless of the size), wind, geothermal, solar PV, solar thermal, and tidal power, and solid biomass such as firewood or cow dung.

13.1.2 Renewable energy in India

India's energy demand has sharply increase and has become double since 2000. Especially the household energy demand has shifted from traditional solid biomass to natural gas or LPG, and the dependency on fossil fuel has deepened.

As of 2013, more than 40% of India's total primary energy demand (TPED) comes from coal, while it was 30% in 2000. Thus the dependency on coal has expanded. It is projected that the 50% of the India's TPES will come from coal in 2040.



Source: JICA Survey team, based on the IEA World Energy Outlook 2015, Annexes India: New Policy Scenario

Figure 13-2 India's TPED Breakdown, 2013 (actual) and 2040 (projection)

At the same time, India intends to strengthen its stable energy supply and energy security by actively enlarging renewable energy. In power generation, India plans to develop renewable energy power generations about half of the newly added capacity (MW) by 2040 (see Figure 13-2).

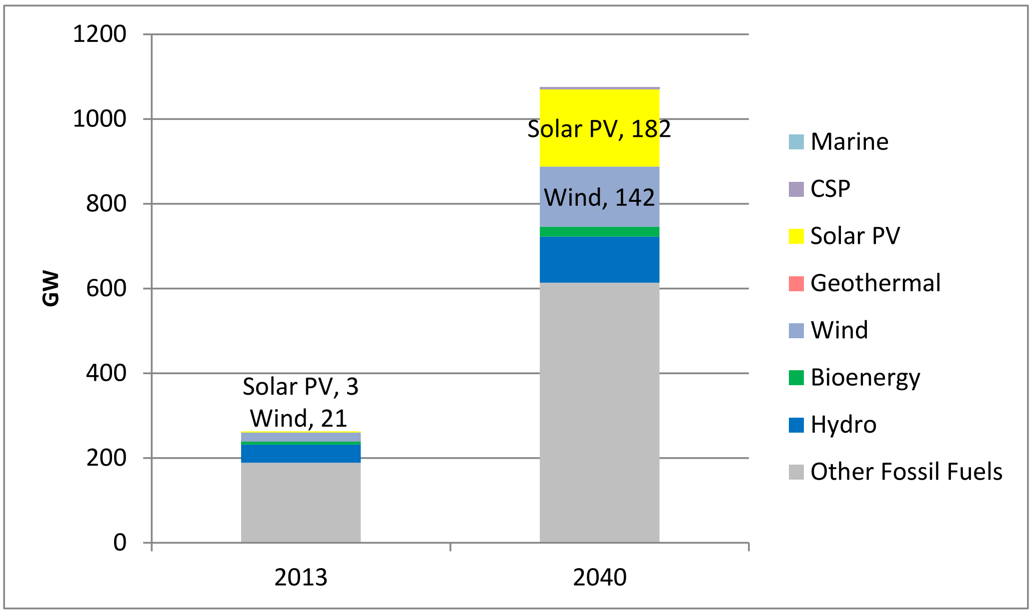
Especially the solar PV generation is considered as the center of the renewable energy deployment in India, where India assumes 3% of its lands are wasteland in each state and can be utilized for utility-scale solar, totaling 750GW. India has launched its national plan, Jawaharlal Nehru National Solar Mission Phase 1 since 2010, and plans to deploy 100GW by 2022 (however, IEA assess that 40GW is the realistic target by 2022, considering many impediments such as finance, solar power purchase by electric companies, land acquisition and transmission line capacity limit[2]).

India's solar PV flagship project is located in Gujarat. Gujarat state administration stipulated the solar PV deployment policy in 2009. This policy includes "exemptions for electricity duties, streamlined the land acquisition process, guaranteed evacuation of power by the Gujarat Energy Transmission Corporation, ensured that no cross-subsidy charges were levied for access within the state and guaranteed tariffs for 25 years. The 500 MW Charanka solar park in Patan – one of the largest in the world –is a notable outcome[3]".

---

[2] IEA WEO (2015) ibid. p.498, Box "Spotlight"
[3] IEA WEO (2015) ibid. p.535, Box 13.4

The Charanka solar park is participated by many solar PV generation companies, and ADB supported the initial feasibility study in 2004.



Source: JICA Survey team, based on the IEA World Energy Outlook 2015, Annexes India: New Policy Scenario

Figure 13-3 India's Power Generation Development (GW)

13.2 Government Policy for Renewable Energy

13.2.1 Government policy and definition

For Bangladesh, renewable energy deployment has been important to diversify energy source, and to complement on-grid rural electrification. In addition, as a low-lying land country and surrounded by the three great rivers, Bangladesh is one of the most vulnerable countries to the sea level raise. Hence renewable energy deployment is critical as climate change mitigation for Bangladesh.
MoPEMR established Renewable Energy Policy in 2008, and defined its goal as renewable energy share 5% of the total installed capacity (MW) by 2015, and 10% by 2020. According to SREDA website, the Bangladesh's total installed capacity is projected to be 13,000MW in 2015 and the renewable energy capacity 650MW by then.

Bangladesh's renewable energy target is defined as follows:

By 2015, 5% out of total generation capacity:

$$\frac{Installed\ renewable\ energy\ capacity\ (MW)\ at\ 2015}{Installed\ all\ generation\ capacity\ (MW)\ at\ 2015} \geq 5\%$$

By 2020, 10% out of total generation capacity:

$$\frac{Installed\ renewable\ energy\ capacity\ (MW)\ at\ 2020}{Installed\ all\ generation\ capacity\ (MW)\ at\ 2020} \geq 10\%$$

As seen in the Table 13-1 , Bangladesh has currently 432 MW installed renewable energy capacity. PSMP2016 projects the total installed generation capacity to be about 21,600MW in 2020, and as seen in the Table 13-2 , the total government plan for additional renewable energy generation deployment to be 3,168 MW, which makes the cumulative capacity:3,600MW. This means that if the government actually implements the renewable energy generation as it plans, the policy target (10% renewable in 2020) would be achieved.

Table 13-1 Installed Renewable Energy Capacity (as of April 2016)

Unit: MW

RE Technology	Off-Grid	On-Grid	Total
Solar	193	1	194
Wind	1	0.9	1.9
Biomass to Electricity	1	0	1
Biogas to Electricity	5	0	5
Hydro	0	230	230
Total	200	232	432

Source: SREDA

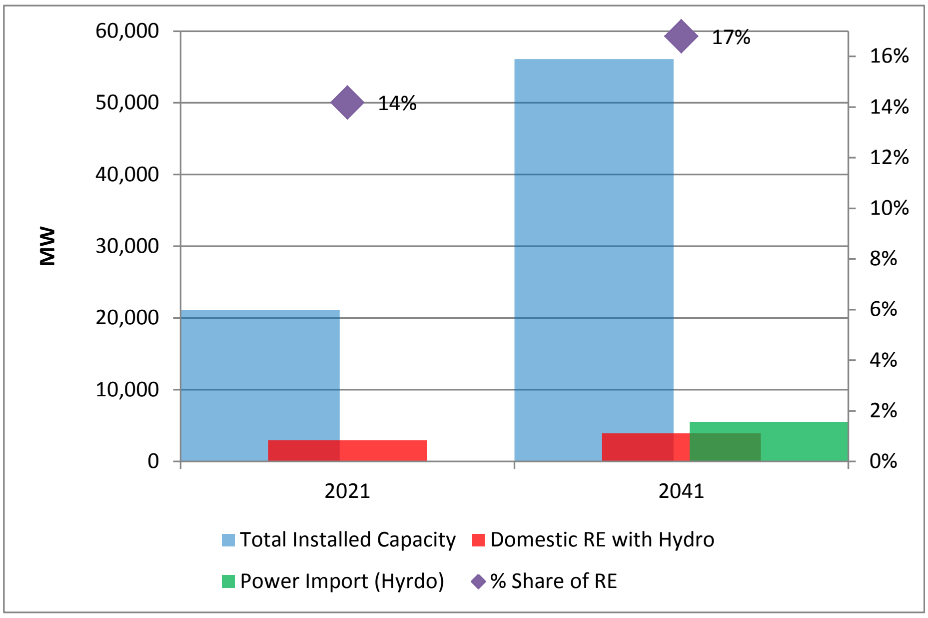
Table 13-2 SREDA Renewable Energy Year-Wise Targeted Plan (Only additions, not cumulative)

RE Technology	2015	2016	2017	2018	2019	2020	2021	Total
Solar	222	253	421.75	237	195	203	208	1739.8
Wind	0	20	250	350	350	200	200	1370
Biomass	1	16	6	6	6	6	6	47
Biogas	1	1	1	1	1	1	1	7
Hydro	0	2	2	0	0	0	0	4
Total	224	292	680.75	594	552	410	415	3167.8

Source: SREDA

Beyond 2020, GoB intends to extend the 10% renewable target by 2041, though not stipulated in the existing policy[4]. In the latest power development plan, Bangladesh will have more than 56,000 MW in 2041. To meet the 10% target, Bangladesh will need to install 5600 MW renewable energy. As described in the later section, Bangladesh may have difficulty to meet this target its domestic (within its boundary) renewable potential. However, if cross-border power import from hydro power generation is counted as hydropower, Bangladesh could have in total more than 9,000 MW (some 4,000 MW from domestic renewable, and 5,000 MW from cross-border hydropower) and easily meet the policy target, as seen in the Figure 13-4 .

[4] Interview with SREDA, June 2016.



Source: JICA Survey Team

Figure 13-4 Share of Renewable Energy Projection

It should be noted, however, that specifically regarding the variable renewable energy power generation, discussion of installed capacity does not mean much to meet the actual demand, especially given the current Bangladesh's daytime peak and technical limits[5]. This topic is further elaborated in the section 13.6 .

13.2.2 Renewable energy promotion policy and regulation

In Bangladesh, renewable energy deployment has been heavily concentrated on micro-scale off-grid SHS, except for the Kaptai Hydropower plant. However, Bangladesh is planning to deploy utility-scale (mega) solar power and wind power, accompanied with promotion policy and regulation. The current status and policy is well documented in SREDA's "Scaling Up Renewable Energy in Low Income Countries (SREP), Investment Plan for Bangladesh (October 2015)", supported by World Bank.

According to this SREDA document, utility-scale solar and wind projects will have following model and power purchase pricing mechanism:

Table 13-3 RE Project Models and Power Purchase Pricing Mechanism Plan

No.	Development Pattern (Project + Land Ownership)	Power Purchase Pricing Mechanism
1	Government Investment on Public Land	N/A
2	Private Investment (IPP) on Public Land	Auction
3	Private Investment (IPP) on Private Land	Fixed tariff for 20 years to cover levelized cost (through negotiation)

Source: SREDA Scaling Up Renewable Energy in Low Income Countries (SREP), Investment Plan for Bangladesh (October 2015)

[5] Because battery and related technologies are still uncertain at this moment, they are not factored in to the capacity projection of this Survey.

It should be noted that the FIT (feed-in-tariff), currently drafted by BERC, would be considered for those utility-scale renewable generations, but mainly for small generation or micro-grid generation. This is based on the recognition that, even though Bangladesh has decent track record for renewable deployment, it is heavily SHS-focused and not grid-connected utility-scale generations, and it would be difficult for Bangladesh to set a "proper" pricing for power purchasing from utility-scale renewable generations in the early stage.

Moreover, it is also recognized that the absence of transparent competitive bidding process has hindered the private investment for utility-scale renewable generation. Therefore, IPP's participation and pricing through transparent process is the most prioritized action for utility-scale renewable generation deployment. In December 2015, GoB achieved the closing of the Jamalpur IPP 3MW solar park project, and successfully set the tariff at 18.7 Tk/kWh. Other private-owned projects are expected to follow.

On the other hand, Bangladesh has also regulation on land usage for utility-scale solar PV. As discussed in detail later in this Chapter, utility-scale solar PV requires a vast area land. The government stipulates the policy prohibiting private projects from using agriculture or cultivable land for a utility-scale solar PV project. According to the SREDA document mentioned above, utility-scale solar PV potential becomes only 1400MW with this land-usage regulation, while 19,000MW would be possible without such regulation. However, it is appropriate for the government to take up this regulation, considering the food security for the increasing population, as well as the potential of agri-business in the future economic growth discussed in the Chapter 5. If GoB wishes to pursue further potential of solar park, it should be well reminded that pursuing the solar park potential is the trade-off of the food security and employment opportunity in rural areas.

Other incentives to be provided for renewable energy projects are listed below. Most of them are financial/accounting incentives:

- Fiscal Incentives for project investors and operators.
- Import Duty Exemption (Full/ Partial) for certain technology and equipment.
- Duty exemption for 16 items of solar panel [SRO No. 100- Law/2000/1832/Duty, Date-18/04/ 2000].
- Plants & equipments [full value] & spare parts [10% of original plant cost] without payment of customs duties, VAT & any other surcharges.
- Exemption from corporate income tax for 10 years.
- Tax exemption & repatriation facilities on royalties & technical assistance fees.
- Repatriation of equity along with dividends.
- Avoidance of double-taxation on the basis of bilateral agreements.
- Implementation Agreement [IA] & PPA ensure fair and reasonable risk allocation and payment by the purchaser is guaranteed by the GoB.
- Special Act for processing project proposals.

13.3 Organization for Renewable Energy Deployment

Governmental organizations for renewable energy promotion are, mainly SREDA, IDCOL, BREB and BPDB, which are implementing solar PV projects. The details of these organizations are described in Chapter 2.

"Partner Organizations" or POs, are non-governmental organizations working under IDCOL program. They are actually setting up renewable energy generation facilities in rural villages. Major POs are: Grameen Shakti、Rural Services Foundation (RSF), and BRAC. These three NGOs have developed more than 70% of SHS and biogas projects. These POs have been active in micro credit activities, and accumulated know-hows for door-to-door loan collection and installment management. The know-hows help for the world-fastest SHS roll-out and also technical guidance for rural areas.

Rural household can afford Taka 13,000~35,000 SHS for three years repayment (36 installment) (more precisely, in general 5% of the installment cost is met by grant from development partners, and end-user bares 40% as the down payment, and repay the rest as installment).

In addition to the POs, many local private companies have gone for the SHS market, such as Rahimafrooz, Siemens Bangladesh, ARMCO, Micro-Electronics and FirstBangladesh Solar[6].

13.4 Renewable Energy Potential in Bangladesh

13.4.1 Overview

In the SREDA's document mentioned above, Bangladesh's renewable energy potential is also assessed as seen in the Table 13-4 . It is estimated that the renewable energy potential in Bangladesh has approximately 3,700MW (in energy-wise 7,000GWh per year) to be added. It should be noted , however that this "3700MW" is still tentative number and has room to update, hence there are some inconsistencies between the potential listed in Table 13-4 and renewable energy deployment plan up to 2020 (Table 13-2).

Solar Park potential in the table below indicates the potential under the "non-agricultural land use policy" (discussed in 13.2.2). Wind park potential in the below table is only based on the existing study and still waiting for an assessment to be completed for update. Waste to Energy indicates only the accumulation of existing plans, mainly due to the difficulty to assess the scale of waste available for plants. For mini hydro, PSMP2016 conducted its site survey and details can be referred in Chapter 12.

Table 13-4 Renewable Energy Potential in Bangladesh

Technology	Resource	Capacity (MW)	Annual Generation (GWh)
Solar Park	Solar	1,400*	2,000
Solar Rooftop	Solar	635	860
Solar Home Systems (SHS)	Solar	100	115
Soar Irrigation	Solar	545	735
Wind Park	Wind	637**	1,250
Biomass	Rice Husk	275	1,800
Biogas	Animal Waste	10	40
Municipal Waste	Municipal Waste	1	6
Mini Hydro	Hydropower	60	200
Mini Grid, Micro Grid	Hybrid	3***	4
Total		3,666	7,010

*Case 1 (agricultural land excluded) estimate **Case 1 (flood-prone land excluded) estimate ***Based on planned projects only, not a theoretical maximum potential, because there is potential overlap with off-grid solar systems. Either could be used to serve off-grid demand.

Source: SREDA-World Bank "Scaling Up Renewable Energy in Low Income Countries (SREP) Investment Plan for Bangladesh", October 2015

[6] JETRO Report "BOP Potential Needs Survey, Bangladesh Energy Sector" (Japanese only), March 2011

13.4.2 Solar

Solar and wind power resource assessment in 2007, supported by UNEP and GEF confirmed the vast potential of solar PV generation in Bangladesh[7], and the explosive deployment of SHS has been observed.

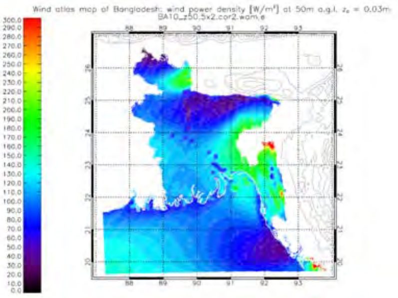
However, Bangladesh has also a major obstacle to deploy large-scale solar PV, which is land availability. Solar PV technology has low energy-intensity and requires large area land. For SHS, the land availability did not matter. On the other hand, 30MW solar generation for example requires approximately 60ha. land. This means that the 30MW solar generation would require 200 farmers' farmland (an average Bangladesh small-scale farmer's farmland is 0.3ha[8]) .Bangladesh government has already stipulated a policy prohibiting farmland use for private solar projects, which limits the solar park potential to 1,400MW.

The SREDA document also estimates the solar rooftop potential (on-grid) and solar irrigation potential (off-grid), 634MW and 545MW respectively. Details of SHS can be referred in 16.4.4 "Off-Grid Electrification" Section of this Report.

13.4.3 Wind

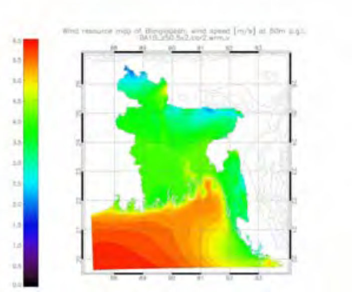
Even though Bangladesh quite often encounters cyclones, the development of wind power generation is yet limited (there are only two points, Muhuri Dam 900 kW and Kutubdia 1000 kW). The above mentioned SREDA document estimates the Bangladesh's wind potential as 624MW, based on the desk-top review of available study and data.

The above "potential" is yet finalized and has much room to change. Wind power potential was studied in the past; however, detail was not enough for investment opportunity identification. Currently USAID-supported Wind Resource Assessment is being conducted and will be completed in 2018.



Source: SREDA homepage

Figure 13-5 Wind Power Density



Source: SREDA homepage

Figure 13-6 Wind Speed

Source: JICA Survey Team

13.4.4 Biomass and biogas power generation, and waste to energy

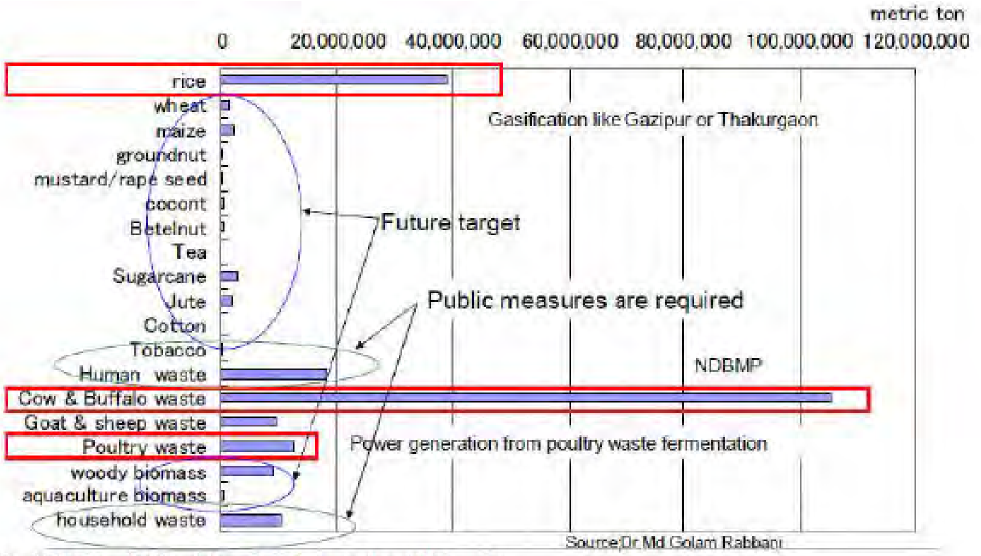
Bangladesh biomass resource has characteristics of having rich animal waste from livestock industry, but little forest resource (e.g. firewood) available due to protection against deforestation. Among these,

---

7 United Nations Environment Program (UNEP) and the Global Environment Facility (GEF) ,"Solar Wind Energy Resource Assessment (SWERA)", February 2007

8 FAO "Characterisation of small farmers in Asia and Pacific", April 2010 http://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/APCAS23/documents_OCT10/APCAS-10-28_-Small_farmers.pdf

it has been pointed out that rice husk has good potential as biomass generation resource in terms of the production amount and resource availability throughout year (JICA past studies also pointed out the risk husk potential). IDCOL has two rice husk power plants in Gazipur and Thakurgaon.



Source: Dr Md Golam Rabbani, Bangladesh Agricultural University
Note: The original metric volume data of biomass are as of following time; 1) rice in 2009,2) cow and buffalo in 2005,3) human census in 2001, 4) forests and wood processing in 2003, 5) aquaculture in 2008 ,and 6) municipal and solid waste in 2008.

Source: JICA Preparatory survey on renewable energy development project, Final Report (November, 2012)

Figure 13-7 Biomass Energy Potential in Bangladesh and IDCOL's Program and Projects

The SREDA-World Bank document estimates the biomass power generation potential as 274MW.

In addition, out of biogas potential to be discussed in detail later, biogas power generation potential is quite limited only to 9.4MW (i.e. 1,131MWh/day) . JICA Biogas survey, to be discussed in the next section, has even less estimate 73MWh/day.

In order to promote biogas power generation, it should also be noted that hydrogen sulfide generated under anaerobic fermentation is quite harmful and technical barrier. The hydrogen sulfide, if not properly removed from the biogas, is highly corrosive for generator-connected turbine. This gas is also highly harmful to human/animal body. Therefore, hydrogen sulfide removal technology and cost reduction is also one of the barriers to promote biogas power generation.

Furthermore, it should be noted that, despite the huge volume of municipal waste is produced daily in Bangladesh (over 13,000 tons in Bangladesh, and 4,400 tons in Dhaka), there are multi-folded issues to overcome, in order to materialize the "waste-to-energy" potential. Specifically material collection and transport to plant (both power plant and gasification)are the issue-baring processes. In order to collect waste and transport in a proper and sustainable manner, many factors such as municipal governments' capacity, financial situation and citizen's awareness need to be appropriate[9]. In this sense, "waste-to-energy" project can be attainable only after when solid waste management is properly implemented. Also, a nature of waste (e.g. low calorific value) can be an issue for efficiency and economic viability of a waste-to-energy project. Therefore, it is difficult to estimate the potential of waste-to-energy project solely based on the volume of municipal waste, and project-to-project feasibility study needs to be carried out to specify the potential.

9 JICA, Strategy Paper on Solid Waste Management, March 2015

13.4.5 Hydropower

Refer to the Chapter 12, including mini/micro hydro power potential

13.4.6 Biogas as cooking fuel

In this subsection, the potential and importance of biogas as a cooking fuel is discussed based on JICA supported study “Biogas Generation and Demand Survey in Bangladesh (March, 2015)”. Especially in the context of SDG Goal 7 “Affordable and clean energy”, biogas in Bangladesh has great potential to serve as a cooking fuel in rural areas, though it has a limited impact to meet the entire gas demand.

<<Definition and History>>
Biogas can be obtained through anaerobic fermentation of high-water containing organic waste, such as animal waste, food waste and sewage sludge. Biogas contains approximately 60% of methane, where natural gas contains almost 100% of methane. The appropriate range of air temperature for the anaerobic fermentation is between 25 degree to 45 degree Celsius, and Bangladesh fits to the atmospheric condition. In fact, Bangladesh started its biogas study in the late 1970s.

<<Positioning and Current Status>>
In the early stage of biogas deployment, the purpose of the biogas plant (digester) construction was to improve the living environment of livestock businesses and their surroundings, and biogas energy supply was just a “sub product”. From this point, the biogas project in Bangladesh should not be evaluated merely by the economic comparison with other energy alternatives. Currently, Bangladesh produces biogas 190,000 m3/day. The substantial roll-out of biogas digester has started since the late 1990s, and so far approximately 80,000 biogas digesters have been developed and more than 60,000 have been under operation (reasons why nearly 20,000 digesters suspend operation are such as difficulty to collect animal wastes, loss of animals due to illness, or manufactures unable to maintain damaged/broken digesters).

<<Biogas Plant Type and Sales Channel>>
Biogas digester types vary from a small and suitable for one household to a large and suitable for livestock business. A typical small size is to produce biogas 1.2m3/day from 3-4 cattle heads, and can be used for one cooking burner. The most popular biogas digester is 3.2m3/day type, capable to supply cooking fuel for 6-8 people. A Large size digester plant is as large as 1,000m3/day, developed within a daily farm. The plant is supplying cooking energy, as well as fuel for generating power (if the entire gas is used for power generation, the plant can generate 260kW). The produced gas and electrical power are being supplied to the owner’s house, as well as surrounding households. The proportion of gas and electrical power are determined by the local needs, and not fixed.

The 48 POs are selling biogas digesters nationwide. The produced biogas is currently being supplied only to the digester-adjacent households, and not connected to the grid mainly due to the impurities of the biogas. However, cylinder bottling is technically possible, and economically viable if the biogas digester has a production capacity more than 500m3/day. Cylindered biogas could be reached to remote areas.

<<Price and Plant Life>>
The price of the biogas plant construction ranges from 13,000 Taka, including a 1.2m3/day digester and civil work. For a rural household, this price is even expensive and the initial investment is one of the bottlenecks for biogas digester roll-out to be addressed. The most popular digester, 3.2m3/day production capacity, prices 36,000 Taka. Most of plant construction is subsidized by the government about 30% of its cost (13,500 Taka is subsidized the government for 3.2m3/day digester construction).

Many of the biogas digester currently marketed in Bangladesh have in fact poor quality and get cracks only after a few years of operation. However, the above-mentioned JICA Biogas survey shows that the biogas users (current and potential) expect 20-30 years of plant life.

<<Impact of Biogas Deployment>>
The above-mentioned JICA Biogas study suggests that Bangladesh has biogas potential at firm 1.2 million m3/day, six times more than the current 190,000 m3/day from some above 60,000 plants. This 1.2 million m3/day gas has as much energy as 25 mmcfd natural gas. This is derived from the below:

- According to the JICA Biogas survey, 65% of biogas is methane, and calorific value per m3 of biogas is estimated to be 5500 k cal., equivalent to 23.02740 MJ/m.
- Bangladesh natural gas has calorific value 39.59 MJ/m3, which means the biogas has 58.1% calorific value of the natural gas.
- According to the JICA Biogas survey, about 110,000 poultry and daily farms are positive to construct biogas digester if a decent subsidy is provided for plan construction, while 80,000 poultry farms and 70,000 daily farms exist in Bangladesh.
- From the 110,000 poultry and daily farms, approximately 1.2 million m3/day biogas could be produced.
- 1.2 million m3 biogas /day = 1.2 *0.581 million m3 natural gas / day = 1.2 * 0.581 * 35.3147 million cubic feet natural gas /day [10]= 24.61 mmcfd

This approximately 25 mmcfd "natural gas equivalent" seems small to the country's total demand to the natural gas, 2,500 mmcfd. However, the biogas directly from a digester contains impurities and grid connection is not appropriate without investment to purification facilities. Thus the biogas is suitable for off-grid cooking fuel for households. The Bangladesh's household demand for natural gas (mainly as cooking fuel) is estimated to be 290 mmcfd. In this sense, the biogas has potential to meet roughly 10% of the households' natural gas demand.

Moreover, it should be noted that only 8% of entire population in Bangladesh has access to the grid gas. The grid gas users are quite Dhaka-centric (out of 2.4 million contracts of grid gas in Bangladesh, 1.7 million or 70% of the national grid gas connections are in Dhaka area), and very few population have access to grid gas outside of Dhaka area. According to the BBS statistics in 2014, more than 94% of the rural population in Bangladesh uses traditional solid biomass for cooking[11]. If the solid biomass users can gain access to the biogas, its social impact is enormous.

One example of the social impact is the liberation from the respiratory diseases caused by the incomplete combustion of solid biomass. According to the World Health Organization (WHO), solid biomass incomplete combustion by using inefficient traditional cook stove produces toxic substances, so called "black carbons", such as mono dioxide and particle matters, and these substances cause respiratory diseases. WHO warns that 3 billion still need to depend on solid biomass, and 1.5 million die from the respiratory diseases caused by the indoor air pollution (and many of the victims are women and children, because they cook inside of the house or more exposed to the toxic substances for their low height) [12]. WHO claims that the indoor air pollution is the second major cause of illness in low income countries, next to the poor access to the safe water and incomplete sanitary environment. Bangladesh Department of Environment estimates 30 million for the replacement need of indoor cooker in the rural areas in the next 5 years[13].

In addition, using biogas improves combustion efficiency, reduces time to collect solid biomass and enable

---

[10] The unit converter is referred in IEA website: https://www.iea.org/statistics/resources/unitconverter/
[11] Bangladesh Bureau of Statistics, "Statistical Pocket Book Bangladesh", 2014
[12] WHO, "Fuel for Life, Household Energy and Health", 2006
[13] Meeting with Department of Environment and Survey Team, April 2016.

people to allocate more time for more value-added activities (such as supervising child study or side work). The JICA Biogas survey indicates that the potential need for biogas is quite high in rural areas, and estimates that about 60% of rural household (approximately 15 million households out of 25 million) perceive solid biomass very inconvenient If biogas is affordable, the potential demand for biogas could be 25 million m3/day, roughly equivalent to 500 mmcfd of natural gas (approximately 5,000 ktoe). This is about twice more than the current natural gas demand for Residential (household) sector (approximately 2,700 ktoe).

Furthermore, the JICA survey suggests the maximum potential of Bangladesh biogas production capacity could be 9 million m3/day, if utilizing municipal wastes as well. Out of this maximum potential, JICA Biogas survey proposes 3 million m3/day (equivalent to 63mmcsd natural gas, or 602ktoe/year) is technically feasible. The 3million m3/day biogas could meet the 10% of natural gas projected demand of the household sector in the 2030s (the 10 years average household sector's natural gas demand of 2030s is projected to be about 6,200ktoe/year). The earlier mentioned SREDA-World Bank document also estimates Bangladesh's biogas potential 3.4 million m3/day (or 950,000 biogas plant x 3.2m3/day).

<<Economic Comparison with LPG (1) >>
Even though the biogas has much more potential than just "cooking fuel", economic analysis shows the affordability of biogas to the users and to the national coffer, especially compared with LPG.

- Suppose 110,000 poultry and daily farms construct biogas plants and produce 1.2million m3/day biogas. This means that an average plant capacity is about 11m3/day.
- Based on the current biogas plan construction cost 36,000 Taka for 3.2m3/day digester, 11m3/day model digester construction cost could be 120,000 Taka. 110,000 plants construction would cost 110,000 * 120,000 = 13.2 billion Taka (JICA Biogas survey shows that many biogas experts perceive biogas plant cost 10,000 ~ 15,000 per 1m3/day to be appropriate).
- IDCOL's financial model for biogas program would be as follows, provided with development partner's grant:

  a) Subsidy: 40%
  b) Loan: 40%
  c) Down payment: 20%
  Total : 100%

- Here, a household bares the 60% of the total cost (loan and down payment), plus interest rate 5-8% (depending on PO's program). Hence the "macro" charge to the user would be at most 13.2 billion*(0.2+0.48)=8.98 billion Taka. The charge to the national coffer is the subsidy part, financed mainly by the development partners, and would be 13.2 billion * 40% = 5.28 billion (interest rate from the development partners is negligible).
- Therefore the macroeconomic total cost of biogas digester deployment is 8.98+ 5.28 = 14.26 billion Taka.

If the 1.2 million m3/day biogas equivalent (in terms of calorific value) LPG is purchased, the LPG cost would be 47.5 million Taka/day, from the below conversion chart.

LPG Price per Heat Value

Item	Value	Source
LPG Unit Cost for Sale	1050 Tk/cylinder (12kg)	JICA Survey Team. This is not an official price, but observed marketed price
LPG Unit Cost for kg	87.5 Tk/kg	From calculation
LPG Heat Value per kg	50.8 MJ/kg	JICA Consultant information to JICA, 2014
LPG Price per Heat Value	1.72 Tk/MJ	From calculation

Biogas Heat Value

Item	Value	Source
Biogas in Bangladesh Heat Value	5500 kcal/m3	JICA Survey team
Biogas in Bangladesh Heat Value in MJ	23.02740 MJ/m3	From calculation (1 kcal = 0.0041868 MJ)

The equivalent calorific value of LPG would cost: 1.72 Tk/MJ * 27,633 MJ/day = 47,528,554 Taka/day = 47.5 million Taka/day

14.26 billion Taka / 47.5 million Taka/day≈300 days.

Therefore, biogas plant construction would cost as same as the "one-year" LPG purchase cost.

<<Economic Comparison with LPG (2) >>
Another analysis suggests the affordability of biogas digester for "a user (farm)", compared with LPG.

As already mentioned in the section 11.4.6, the affordability issue of LPG, an average household consumes two cylinders of LPG per month. Hence the LPG purchase cost would be 2,100 ~ 2,600 Taka per month. This is approximately 25% of the average rural household's monthly income. Compared with the fact that the average rural household's expenditure trend of fuel (conventional solid biomass, such as firewood) is 2~6% of its monthly income, the LPG cost is unsustainably higher (for further detail, see Chapter 10).

On the other hand, if a farm installs a biogas digester, household members can produce biogas for their self-consumption, and can sell the residual gas to neighbouring households. The willingness to pay for the biogas is assumed to be somewhere between the conventional solid biomass and LPG, and the sales profit of the biogas can be an additional income to the digester-installed farm (In the model 11 m^3/day digester, approximately 280m^3=330 cubic feet per month could be sold). In addition, slurry as a bi-product of digester can be used as organic fertilizer (after drying process). The digester-installed farm can reduce the cost of chemical fertilizer, and also sell the residual organic fertilizer.

More in-detailed financial and economic feasibility analysis requires further study on the willingness to pay to the biogas and many other factors. For example, financial IRR requires the cost of biogas installation, repayment terms and conditions, operation and maintenance cost of biogas digester. Economic IRR (internal rate of return) further requires the value (willingness to pay) of the biogas and organic fertilizer, and the cost of solid biomass and chemical fertilizer as the economic benefits. However, the study in the past and other analysis suggest the biogas digester installation is both economically and financially viable[14].

<<Is a high-spec digester a panacea?>>
By recognizing the poor quality issue of the conventional ceramic biogas digester, SREDA is currently negotiating with National Board of Revenue to exempt the duties on imported glass fiber digester materials, to promote glass fiber digester as the new generation one to roll out.

However, the glass-fiber digester also shows many issues – installation, operation and maintenance – and should not be seen as "panacea". For example, a glass-fiber digester costs 1.5 times higher than the conventional one, and the down payment and monthly repayment for a user is obviously more. Furthermore, a glass-fiber digester dorm has thickness (4-6mm) and prone to prone to cracking during transportation, and susceptible to bear loads and tensile stress in the worst conditions. It also has a large size dorm (for example, the 11 m3/day model could have 3-4m diameter) and would be difficult to transport with a Bangladesh's traditional truck (capable to carry more than 5 tons, and approximately the head to tail length and outer width of a traditional truck are 5.5 m and 2.4 m respectively); hence would not be cost effective.

Therefore, it is recommended to conduct a survey to analyze pros and cons of both conventional and glass-fiber digester, and develop a flexible deployment program to respond to various users' needs (for example, various digester sizes, dorm materials, financial programs depending on the down payment).

Regarding the macro-economic impact of the glass-fiber digester, the construction cost would be 50,000 Taka for the most popular 2.4m3/day capacity[15]. With this figure, the above analysis would be modified as follows:

- The 11m3/day production capacity digester would be 220,000 Taka, based on the 2.4m3/day digester price. The 110,000 plant construction cost would be 10,000 * 220,000 = 24.2 billion Taka.
- Here, a household bares the 24.2 billion *(0.2+0.48)=16.46 billion Taka. The charge to the national coffer is the subsidy part, financed mainly by the development partners, and would be 24.2 billion * 40% = 9.68 billion.
  (16.46+ 9.68) billion Taka / 47.5 million Taka (for LPG) =550 days

Therefore, higher model biogas plant construction would cost as same as the "a year and half" of LPG purchase cost.

It should be noted that the charge to the national coffer, 5.28 billion Taka (conventional ceramic digester) to 9.68 billion Taka (glass fiber digester), is much less than the subsidy to BPC which once reached 86 billion Taka in FY2012. Biogas plant does not only bring energy access, but also better hygiene and healthier environment to rural people. Biogas also is carbon neutral fuel, which is LPG is not.

<<Barriers to Biogas Deployment>>
Biogas deployment could bring many impacts, however, there are some barriers to address. The development partners are currently identifying the major barriers and countermeasures for biogas deployment, and the followings are the potential reasons[16]: 1) POs have less experience in handling

[14] IDCOL and Netherlands Development Organization (SNV), "Final Report on Technical Study of Biogals Installed in Bangladesh," December 2005 (https://cleancookstoves.org/binary-data/RESOURCE/file/000/000/77-1.pdf). In this study, FIRR counts the cost reduction of solid biomass and chemical fertilizer as benefits and it should be in fact EIRR. However, the value shows some 50% (with subsidy) and some 20-30% (without subsidy). Furthermore, the sales profit of residual biogas or organic fertilizer is not counted as benefit. If the benefit were factored-in, the FIRR could be well above the threshold (e.g. the interest rate for the loan 8%).

[15] According to the World Bank Dhaka Office.

[16] Based on the information provided by the World Bank Dhaka Office.

biogas digester than SHS, 2) Bangladesh society have negative perception to biogas digester from the past experiences (cracks after a few years usage, etc.), 3) few manufactures can properly maintain biogas plants. The IDCOL financial model may not have much room to improve.

In addition, the above-mentioned glass-fiber digester is higher cost, and the financial barrier and other issues should be addressed according to the in-depth analysis and countermeasures.

13.4.7 Biofuel

In a global trend, consumption of biofuel is growing significantly, mainly as a substitute of transport (road transport) fuel. In 2005 biofuel consumption was 19 Mtoe (1.2% of total road transport fuel), but it grew to 64 Mtoe in 2013 (3.3% of the same). Obviously this trend stems from the need of CO2 emission reduction, and energy security enhancement by diversifying transport fuel mix (and reduction of oil import). More than 60 countries now have policy on biodiesel blending mandates has supported its growth[17].

India also has policy to promote biofuels (biodiesel). The National Policy on Biofuels (2009) has an indicative target on 20% by the end of 2017, where conventional gasoline and diesel would be replaced by E20 (20% of bioethanol blended gasoline) and B20 (20% of biodiesel blended diesel). India's R&D for biofuel has launched recently and yet made any substantial progress. However, it was announced that Indian Oil Corporation (IOC) succeeded in producing bio-hydrogenated diesel by catalytic hydrotreatment of non-food oil. Central Salt Marine and Chemical Research (CSMCR) and National Environmental Engineering Research Institute (NEERI) are doing R&D for algae biodiesel[18]. Also, India's energy company Reliance Power is active on financing biofuel business overseas (e.g. US and Malaysia) especially on algae fuel technology.

In Bangladesh, on the other hand, biofuel policy has yet placed, and university/industry R&D is still in nascent stage. Though further detailed on-site survey is required for better recommendation, based on the general knowledge, it seems that if Bangladesh wishes to pursue the biofuel potential, algae technology for biodiesel is one (and maybe the best) option.

The main reasons are 1) food-versus-fuel concern, 2) Technology and cost, and 3) limited and availability in Bangladesh (summary can be seen in the Figure 13-8 .)

Among various biofuel, bioethanol are mostly produced in Brazil and USA, where vast land and high quality cultivating conditions are available for large amount of sugarcane and corn production for bioethanol (and food production). In such countries, land use for food OR fuel does not matter. On the other hand Bangladesh has limited land and also growing population. In addition, as Bangladesh keeps economic development and per capita income increases, demand on food also will increase. Therefore, in terms of agricultural land usage, Bangladesh should prioritize food security over bioethanol production.

Furthermore, non-food bioethanol sources, such as agriculture residue, wood materials or used oil are currently having technological issues thus cost and/or energy balance challenges. For example, cellulose separation process from these non-food sources for bioethanol production may require more cost and/or energy than food sources.

Provided that bioethanol seems to have little feasibility for Bangladesh, biodiesel could be an option. ASEAN countries such as Malaysia or Indonesia produce industrial scale biodiesel (e.g. palm and

[17] IEA WEO (2015) ibid., pp.362-363
[18] New Energy Foundation, Asia Biomass Office "Status of Biodiesel Fuel in India" https://www.asiabiomass.jp/english/topics/1310_02.html

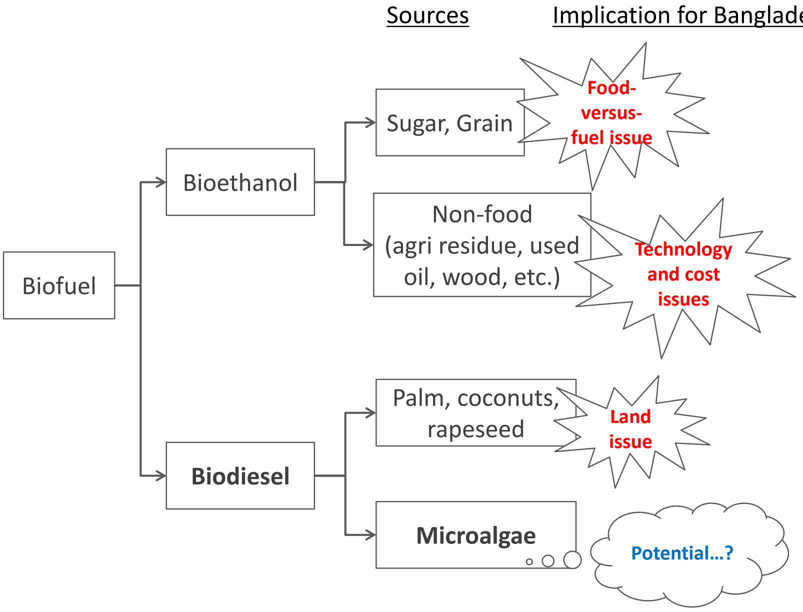
coconut) from plantations with some thousand hectare areas, based on a long tree plantation history. On the other hand, Bangladesh has little plantation background, nor available land for mass scale of plantation. Therefore, conventional material based biodiesel seems not feasible for Bangladesh.

The rest option is algae-based biodiesel. It is known that algae have better productivity (oil yield) per unit area than other conventional biodiesel sources[19]. As a country with limited available land, algae-based biodiesel may a good option.

However, it should be noted that in the last decade, many biofuel ventures entered the microalgae biodiesel R&D and now most of them have exited. The main reason is the difficulty to cultivate microalgae for the industrial production scale.

Botryococcus braunii is one kind of microalga, known for is nature to produce oil, almost 50% of its dry weight and easiness to obtain crude oil from it (i.e. little external energy is required for crude oil). In theory, if a large amount of Botryococcus braunii can be cultivated, a good amount of crude oil (i.e. half of the algae's dry weight) could be produced. However, this alga is by nature very slow to grow, hence difficult to produce at industrial scale.

One potential of the technological breakthrough is to breed a high-speed growing subspecies of Botryococcus braunii, through stupendous R&D process (e.g. one or two subspecies could be successfully bred out of more than ten million strains).



Source: JICA Survey Team

Figure 13-8 Biofuel Sources and Implication to Bangladesh

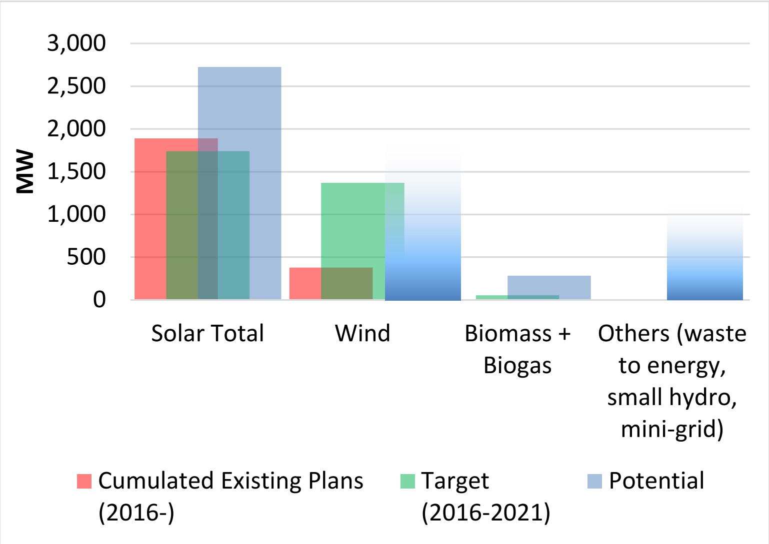
[19] In Y. Chisti's "Biodiesel from microalagae"(http://www.massey.ac.nz/~ychisti/~yc.html) is one of the most well-known paper to address the potential of microalgae as biodiesel source, indicating that algae have 10-20 times higher productivity than other sources. However, it should be noted that the algae productivity indicated in this paper is based on a test tube in a lab, not in the actual outdoor environment.

13.5 Gap between Planning and Potential

13.5.1 Approaches to closed the gap (RE technologies other than biogas and biofuels)

In this section, the difference between the existing plans provided by SREDA in June 2016 (see the Table 13-2), and the potential discussed in the previous section is analyzed. The details of deployment plan (renewable generation) can be referred in the Appendix.

As seen in the below figure and discussed in the previous section (13.4) , Bangladesh's renewable energy potentials are yet fully identified. Despite this issue, it is obvious that the current project pipelines overly concentrate on solar PV technologies, and other renewable technologies, such as wind, biomass, biogas, waste to energy and mini hydro are tunneled and far distance to utilize its potential (Figure 13-9).

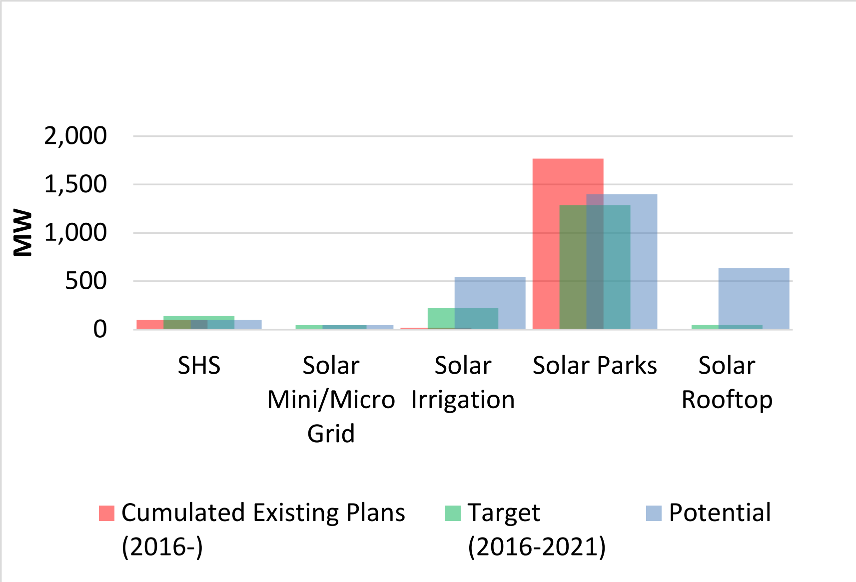


Source: JICA Survey Team

Figure 13-9 Gap among Project Pipeline, Target and Potential)

As observed in the Figure 13-10 , although solar irrigation pump has big potential, installation is small. It is supposed that power will be supplied to irrigation pump from the grid in the electrified area, and installation capacity will not reach the potential. Installation speed is assumed to the half of existing plan's speed.

Solar park plans on the other hand exceed the potential and will be screened with established procedures in SREDA, based on the investor's financial soundness, technical soundness, land use and tariff proposed from the project side.



Source: JICA Survey Team

Figure 13-10 Solar PV Gap among Project Pipeline, Target and Potential

Barriers to the other renewable energy projects and countermeasures are described in the SREDA's "SREP" document, "3.4 Barriers to RE" and later.

13.5.2 Biogas

Since 1996 to 2004, the Government took initiative to roll out 22,000 biogas digesters, in which NOGs such as Grameen Shakti and BRAC, and Local Government Engineering Department (LGED) played a central rolls for implementation. From 2005, Netherland (SNV) supported biogas digester.

As of today, there are in total 80,000 biogas digesters installed but only 62,400 digesters under operation and producing 190,000 m3/day biogas. The reasons of roughly 20,000 digesters not operating are multifold; insufficient (collected) row materials (animal waste), loss of cattle due to illness, or insufficient maintenance for broken digester.

As discussed in the previous section, JICA Biogas study and SREDA-World Bank document estimate the Bangladesh's biogas potential 3 to 3.4 million m3/day by 2041. JICA Survey Team suppose this potential is attainable based on the following assumptions:

- Mid-term target is the additional 0.6 million m3/day in the mid 2020s (accumulated total 0.8 million m3/day).
- By 2025, if the 55,000 farms, the half of the previously discussed 110,000 farms with willingness to introduce biogas digester, introduce digesters, the additional biogas production can reach 0.6 m3/day.
- The 550,000 digesters between 2021 to 2025 can be constructed in each Upazila (there are in total 64 Upazilas in Bangladesh).

In order to materialize this construction speed, specifically the number of capable contractors and their capacity, as well as the availability of domestic manufactures, is the key to success.

13.5.3 Biofuel

Based on the assumption that Bangladesh is in a nascent stage of R&D for biofuel, the following table could serve as a reference on how to reach biodiesel industrial production. It should be well reminded that microalgae-based biodiesel production is not attainable without sound agricultural experience of breeding microalgae. In addition, it should also be reminded that biofuel is low unit price business and large scale production and market is required to make the biofuel business economically feasible. Therefore, it is recommendable to start from breeding microalgae to produce a small amount of high-value added products, such as high-function substances.

Table 13-5 Roadmap to Microalgae-based Biodiesel Sustainable Production (Reference)

	Short term	Medium Term	Long Term
Purposes	**High-function substances** Phycocyanin, astaxanthin, high-concentration DHA/EPA, beta carotene, **Medical, Cosmetics** Polysaccharide, radioisotope, antibody drugs, etc. **Others** Food, feed additive, etc.	**Nutritional supplements** Omega3 fatty acid, vitamin supplement, etc. **Health food** Spirulina pill, Chlorella pill, etc. **Food with palatability**	**Biofuels** Bioethanol, biodiesel, jet fuel, etc. **Biochemical materials** Biopolymer
Unit Price (USD per kg dry material)	> 100	10 – 100	< 5
Market Scale (1 million USD)	< 1,000	> 1,000	> 10,000
Production Scale (ha)	< 10	< 1,000	> 1,000
Initial Investment (USD 1 million)	< 10	10-1,000	> 1,000

Source: Chitose Laboratory Corporation

The following is an image of large volume of microalgae cultivation for biodiesel production in Japan. In this pond with 1500 m^2 surface area, under suitable climate conditions and over the year cultivation, at least a few tons of crude oil can be produced.

Source: Chitose Laboratory Corporation

Figure 13-11 Microalgae Biofuel Cultivation Image

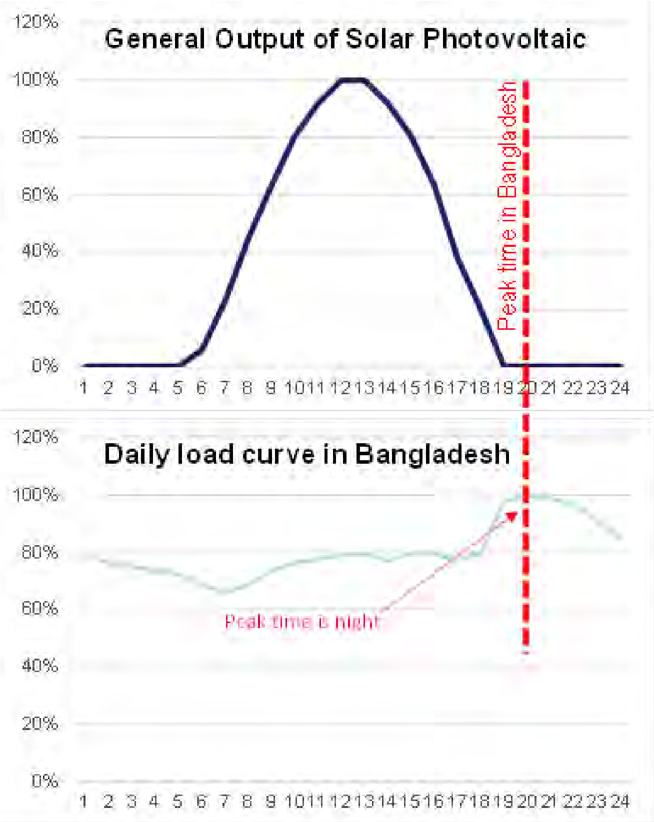
13.6 Integration of the Renewable Energy into Power Development Planning

In Japan, the supply capacities of renewable energy such as solar or wind are calculated by actual values from the site. The JICA Survey Team proposes that the following coefficients can adopted until enough actual values are gathered from renewables in Bangladesh.

Solar: 0 - 21% x Total installed capacity
(Coefficient is changed each month)

Wind: 0 - 7% x Total installed capacity
(Coefficient is changed each month)

But the Power Development Plan is a plan for peak time and the peak time of electricity demand in Bangladesh is night, so the Solar Photovoltaic does not work at peak time. Therefore, electric power (kW) from solar is not considered in the power development plan and electric energy (kWh) is considered. If daily load curve is changed from night peak to day peak in future, electric power (kW) from solar will be considered in the power development plan.



Source: JICA Survey Team

Figure 13-12 Peak of Solar Supply and Electricity Consumption

13.7 Substantial Renewable Energy into Grid Connections

13.7.1 Variable renewable energy grid connections

In Bangladesh, it is estimated that the potential of grid-connected Variable Renewable Energy (VRE) such as solar and wind, of which power output can vary in the short period, can be 4,200GWh/year (SREDA-World Bank, 2015). In comparison with the total power generation of 82,000GWh in 2020 and 307,000GWh in 2040, the impact of grid-connected VRE is limited and does not require a drastic transformation of the conventional power system development planning.

In fact, IEA discuss that if the VRE is within the 5-10% of the annual total grid-connected power generation (GWh), because such output variation and unpredictability can occur by load change or unplanned power plant outage, and is manageable by the conventional power network planning and operation[20].

However, Bangladesh is still under development phase of power generation and network. Therefore grid-connected utility-scale VREs should be properly integrated in to the power system development plan to ensure appropriate reserve margin and network capacity. Also, currently Bangladesh does not have technical regulation or standard for grid-connected utility-scale VREs. Hence these regulations and standards need to be developed and implemented.

[20] IEA, "The Power of Transformation - Wind, Sun and the Economics of Flexible Power Systems", 2014

13.7.2 Large hydro via cross-border power import

Outside of its boundary, Bangladesh has a huge potential to exploit renewable energy: a regional hydropower potential in the South Asia. It is estimated that Bangladesh can import about 5,000 MW hydropower mainly from Nepal and north-west India around 2041. Further details are discussed the Chapter 14.

Chapter 13 Attachment

Details of Renewable Energy Deployment Plan (Power Generation) by 2021

Attachment Details of Renewable Energy Deployment Plan (Power Generation) by 2021

※It is assumed that renewable energy generation development, of which installation year is not identified, will be installed till 2021.

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2015	11,513		11,513						
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2016	17,500			17,500					
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2017	18,000				18,000				
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2018	17,500					17,500			
IDCOL	Solar(Solar Home Systems)		SHS @existing	113,662	113,662							
IDCOL	Solar(Solar Home Systems)		SHS @2015	6,709		6,709						
IDCOL	Solar(Solar Home Systems)		SHS @2016	15,500			15,500					
IDCOL	Solar(Solar Home Systems)		SHS @2017	15,000				15,000				
IDCOL	Solar(Solar Home Systems)		SHS @2017	16,036					16,036			
IDCOL	Solar(Solar Mini Grid)	Complete	100 kWp PGEL solar mini grid project	100	100							
IDCOL	Solar(Solar Mini Grid)	Complete	100 kWp GHEL Solar Mini Grid project	100		100						
IDCOL	Solar(Solar Mini Grid)	Complete	141 kWp Shouro Bangla Ltd mini grid	141		141						

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Mini Grid)	Complete	141 kWp Hydron Bangladesh Pvt. Ltd. Solar Mini Grid	141		141						
IDCOL	Solar(Solar Mini Grid)	Under Construction	148.5 kWp AVA Development Society Solar Mini Grid	149		149						
IDCOL	Solar(Solar Mini Grid)	Under Construction	158.3 kWp GRAM er Alo Ltd. solar mini grid	158		158						
IDCOL	Solar(Solar Mini Grid)	Under Construction	177 kWp Solar Electro Bangladesh Ltd Solar Mini Grid	177		177						
IDCOL	Solar(Solar Mini Grid)	Committed	167 kWp Baraka Renewable Energy Limited Solar Mini Grid	167		167						
IDCOL	Solar(Solar Mini Grid)	Committed	130 kWp Solargao Limited Solar Mini Grid	130		130						
IDCOL	Solar(Solar Mini Grid)	Proposed	Tauras Energy Limited solar mini grid	150		21	21	21	21	21	21	21
IDCOL	Solar(Solar Mini Grid)	Proposed	161.75 kWp G-Tech Solutions Ltd Solar Mini Grid	162		23	23	23	23	23	23	23
IDCOL	Solar(Solar Mini Grid)	Proposed	187.5 kWp Parasol Energy Ltd Solar Mini Grid	188		27	27	27	27	27	27	27
IDCOL	Solar(Solar Mini Grid)	Proposed	200 kWp Superstar Renewable Energy Limited Solar Mini Grid	200		29	29	29	29	29	29	29
IDCOL	Solar(Solar Mini Grid)	Proposed	200 kWp Intraco Limited Solar Mini Grid	200		29	29	29	29	29	29	29

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Mini Grid)		SMG @existing	0								
IDCOL	Solar(Solar Mini Grid)		SMG @2015	994		994						
IDCOL	Solar(Solar Mini Grid)		SMG @2016	2,257			2,257					
IDCOL	Solar(Solar Mini Grid)		SMG @2017	1,603				1,603				
IDCOL	Solar(Solar Irrigation)	Complete	GRAM 01 (05)	36	36							
IDCOL	Solar(Solar Irrigation)	Under Construction	GRAM 02 (18)	36		36						
IDCOL	Solar(Solar Irrigation)	Complete	SDRS (3)	36	36							
IDCOL	Solar(Solar Irrigation)	Complete	ARS (7)	36	36							
IDCOL	Solar(Solar Irrigation)	Under Construction	Solargao 01 (34)	36		36						
IDCOL	Solar(Solar Irrigation)	Under Construction	Solargao 02 (10)	36		36						
IDCOL	Solar(Solar Irrigation)	Complete	RDF-1	80	80							
IDCOL	Solar(Solar Irrigation)	Complete	RDF-1	0								
IDCOL	Solar(Solar Irrigation)	Complete	RDF-2	350	350							
IDCOL	Solar(Solar Irrigation)	Complete	RDF-2	0								

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	1,259		1,259						
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	0		0						
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	0		0						
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	380	380							
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	0								
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	0								
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-2	100		100						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-2	0		0						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-3	220		220						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-3	0		0						
IDCOL	Solar(Solar Irrigation)	Complete	Grameen Shakti	11	11							
IDCOL	Solar(Solar Irrigation)	Complete	RCNSL	2	2							
IDCOL	Solar(Solar Irrigation)	Complete	AVA (6)	64	64							
IDCOL	Solar(Solar Irrigation)			0								

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)	Complete	NUSRA	39	39							
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)	Under Construction	RREL (10)	196		196						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)	Complete	4SL	63	63							
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)	Complete	GHEL-6	32	32							
IDCOL	Solar(Solar Irrigation)	Under Construction	GHEL-15	148		148						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)	Under Construction	GHEL-25	361		361						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)	Under Construction	AID-1	76		76						
IDCOL	Solar(Solar Irrigation)	Under Construction	AID-2	170		170						
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)		SIPS @existing	0								

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)		SIPS @2015	0		0						
IDCOL	Solar(Solar Irrigation)		SIPS @2016	3,830			3,830					
IDCOL	Solar(Solar Irrigation)		SIPS @2017	3,653				3,653				
IDCOL	Bio	Under Construction	KKT	100	100							
IDCOL	Bio	Complete	Phenix	450	450							
IDCOL	Bio	Under Construction	SEAL	400	400							
IDCOL	Bio	Under Construction	United	25	25							
IDCOL	Bio	Under Construction	Zobaida	25	25							
IDCOL	Bio	Under Construction	Ummi Kulsum Agro Ltd.	36	36							
IPP(SunEdision Energy Holdings (Singapore) Pvt Ltd.)	Solar(Solar Parks)	Planning	200 MW (AC) Solar Park on BOO Basis at Teknaf, Coxes Bazar	200,000				40,000	40,000	40,000	40,000	40,000
IPP(Beximco Power Co. Ltd & TBEA XinJiang SunOasis Co. Ltd)	Solar(Solar Parks)	Planning	200 MW (AC) Solar Park at Gaibandha District, Bangladesh	200,000				40,000	40,000	40,000	40,000	40,000
IPP(HETAT-DITR OLIC- IFDC Solar)	Solar(Solar Parks)	Planning	50 MW (AC) Solar Park at Sutiakhali, Mymensingh District	50,000				10,000	10,000	10,000	10,000	10,000

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IPP(EDISUN – Power Point & Haor Bangla-Korea Green Energy Ltd.)	Solar(Solar Parks)	Planning	32 MW (AC) Solar Park, Dharmapasha, Sunamganj	32,000				6,400	6,400	6,400	6,400	6,400
IPP(Intraco CNG Ltd & Juli New Energy Co. Ltd.)	Solar(Solar Parks)	Planning	30 MW (AC) Solar Park, Gangachora, Rangpur	30,000				6,000	6,000	6,000	6,000	6,000
IPP(JPL)	Solar(Solar Parks)	Planning	20 MW (AC) Solar Park, Coxbazar	20,000				4,000	4,000	4,000	4,000	4,000
IPP(Eiki Shoji Co. Ltd. Japan & Sun Solar Power Plant Ltd)	Solar(Solar Parks)	Planning	10 MWp Grid-Tied Solar Power Project, Gowainghat, Sylhet	10,000				2,000	2,000	2,000	2,000	2,000
IPP(Blue Mountain Ltd.)	Solar(Solar Parks)	Planning	100 MW (AC) Solar Park Baradi , Naryanganj	100,000				20,000	20,000	20,000	20,000	20,000
IPP(Beximco Power Co. Ltd)	Solar(Solar Parks)	Planning	30 MW (AC) Solar Park Panchgarh	30,000				6,000	6,000	6,000	6,000	6,000
IPP(Golden Harvest and DREPL Consortium)	Solar(Solar Parks)	Planning	10 MW (AC) Solar Park Gowainghat, Sylhet	10,000				2,000	2,000	2,000	2,000	2,000
IPP(Green Housing & Energy Ltd.)	Solar(Solar Parks)	Planning	5 MW (AC) Solar Park, Patgram, Lalmonirhat	5,000				1,000	1,000	1,000	1,000	1,000
IPP(Greenswitch Elcon Bangladesh Ltd)	Solar(Solar Parks)	Planning	50 MW (AC) Solar Park, Bhola	50,000				10,000	10,000	10,000	10,000	10,000
BPDB	Solar(Solar Parks)	Planning	Installation of a 100 MWp Solar PV based grid connected Power generation plant at Sonagazi, Feni District	100,000				100,000				

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
BPDB	Solar(Solar Parks)	Planning	In Chittagong district at Rangunia near Karanafuli river 60 MW Solar park on BOO basis	60,000				60,000				
BPDB	Solar(Solar Parks)	Planning	Gangachara Solar Park	55,000			55,000					
BPDB	Solar(Solar Parks)	Planning	Dharala 30 MW Solar park on BOO basis near Dharala river of Kurigram District	30,000			30,000					
BPDB	Solar(Solar Parks)	Planning	Sarishabari, Jamalpur 3 MW grid connected solar PV power plant	3,000		3,000						
BPDB	Solar(Solar Mini Grid)	Planning	Tough to reach Haor area R/E based pilot project at Salna of Sunamganj of 650 KW Mini grid system	650				130	130	130	130	130
BPDB	Solar(Light)	Planning	Solar street lighting in 8 City Corporation (SSLPCC) project					0				
BPDB	Solar(Solar Rooftop)	Planning	Rooftop solar on govt buildings at Jamalpur District	813				163	163	163	163	163
BPDB	Waste	Planning	Keraniganj Municipal waste to Electricity Project	7,000				1,400	1,400	1,400	1,400	1,400
BREB	Solar(Solar Irrigation)	Planning		7,000				1,400	1,400	1,400	1,400	1,400
NWPGCL	Solar(Solar Parks)	Planning	Faridpur Solar Park	100,000				20,000	20,000	20,000	20,000	20,000

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
NWPGCL	Solar(Solar Parks)	Planning	Sirajganj Solar Park, Sirajgonj	7,600		7,600						
EGCB	Solar(Solar Parks)	Planning	Sonagazi 200 MW Wind Solar Hybrid Power Plant	200,000				200,000				
APCL	Solar(Solar Parks)	Planning	Ashuganj Solar Park	80,000				16,000	16,000	16,000	16,000	16,000
RPCL	Solar(Solar Parks)	Planning	Mollarhat 200 MWp Solar PV Power plant project	200,000				40,000	40,000	40,000	40,000	40,000
RPCL	Solar(Solar Parks)	Planning	Padma's Char Solar Park	200,000				40,000	40,000	40,000	40,000	40,000
RPCL	Wind	Planning	200 MW Wind based Power Project	200,000				40,000	40,000	40,000	40,000	40,000
DPDC	Solar(Solar Rooftop)	Planning	Solar rooftop system at other Government buildings rooftop as per Secretariat bldg. model					0	0	0	0	0
DESCO	Solar(Solar Rooftop)	Planning	Rooftop solar system installation at DESCO's distribution area Government organization					0	0	0	0	0
IPP(consortium of PIA group & Bangladesh Alternative Energy System Ltd.)	Wind	Planning	100 MW wind power project by consortium of PIA group & Bangladesh Alternative Energy System Ltd. At Anwara Chittagong	100,000				20,000	20,000	20,000	20,000	20,000

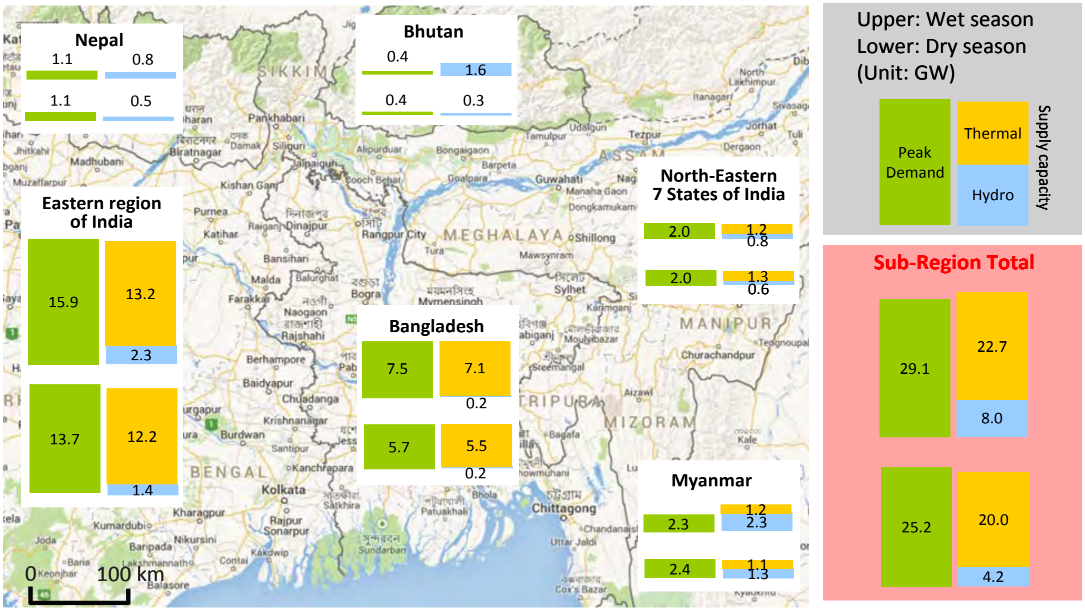
Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IPP(US-DK Green Energy (BD))	Wind	Planning	60 MW wind power project at Cox's bazar by US-DK Green Energy (BD)	60,000				12,000	12,000	12,000	12,000	12,000
IPP(M/s. ReGen Powertech Limited)	Wind	Planning	M/s. ReGen Powertech Limited solar-wind hybrid Power project	18,000				3,600	3,600	3,600	3,600	3,600
	Wind	Planning	Wind resourse Assesment project by Vestas Asia Pacific Wind Technology Pvt Ltd					0	0	0	0	0
BADC	Solar(Solar Irrigation)	Planning	Solar Irrigation Project by BADC	3,750				750	750	750	750	750
SREDA	Solar(Solar Home Systems)		SREDA Existing	0	28,338							
SREDA	Solar(Solar Irrigation)		SREDA Existing	0	430							
SREDA	Solar(Solar Rooftop)		SREDA Existing	0	11,000							
SREDA	Solar(Solar Rooftop)		SREDA Existing	0	2,300							
SREDA	Solar(Solar mini grid)		SREDA Existing	0	900							
SREDA	Wind(Wind)		SREDA Existing	0	2,000							
SREDA	Bio(Bio)		SREDA Existing	0	3,964							

Chapter 14 Power Import and Nuclear Power

Industrial diversification and advancement are essential in order to achieve further economic development in Bangladesh. To this end, improvement of the quality of the power supply, such as stabilization of network voltage and frequency, is a prerequisite. In addition, in anticipation of the growing share of coal-fired thermal power generation in the medium and long term, the exploitation of renewable energy resources with low environmental burden under the climate change perspective is envisaged.
On-grid large-scale hydropower development seems to be an effective measure to overcome the aforementioned issues. However, due to its flat geographical features, Bangladesh lacks prospective hydropower potential over 1 MW apart from the existing Kaptai hydro power plant (230MW). In contrast, there is abundant water power resource potential in the countries surrounding Bangladesh, namely Bhutan, Nepal, Myanmar, and the Indian States of the North East and West Bengal (collectively "neighboring countries"). Thus, it is expected that Bangladesh imports electricity out of such hydropower generation via power interconnections with such neighboring countries for stable base load supply, energy fuel diversification, and climate change mitigation.

14.1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh

The neighboring countries of Bangladesh have rich hydropower potential. However, the amount of development at present is small, and a great amount of development can be expected in the future.
The electric power supply and demand situations in the rainy season and dry season in 2014 in the neighbouring countries (Eastern region and Northeastern states in India) of Bangladesh are shown as follows.

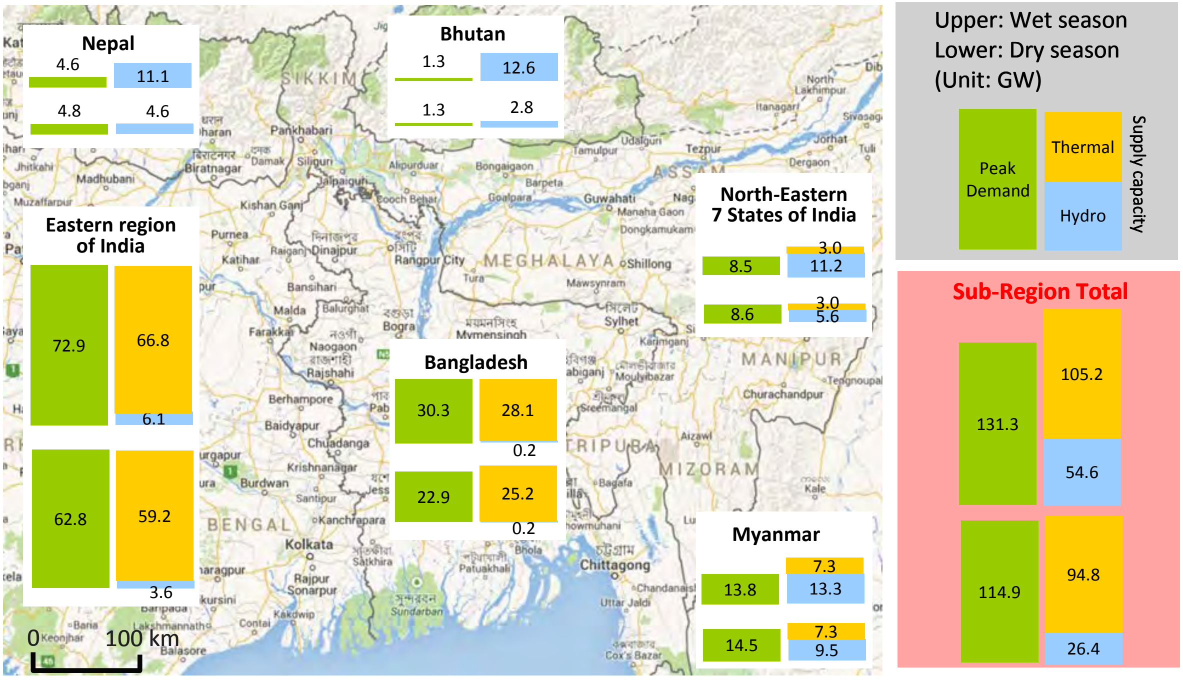


"Map data©2014 AutoNavi Google" Source: JICA Survey Team

Figure 14-1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh (2014)

The supply capacity from hydropower is about 25% of the whole supply capacity in this area at present because there is not a lot of hydropower development yet. Because a lot of hydroelectric power plants in these regions are the run-of-river type, the amount of power generation decreases below half in the dry season, though a lot of power generation can be expected in the rainy season. Therefore, the supply capacity is slightly insufficient in the dry season because the supply capacity from hydropower decreases remarkably, though power demands also decrease a little.

The electric power supply and demand situation forecast in 2030 is shown below in addition to that mentioned above.



"Map data©2014 AutoNavi Google"

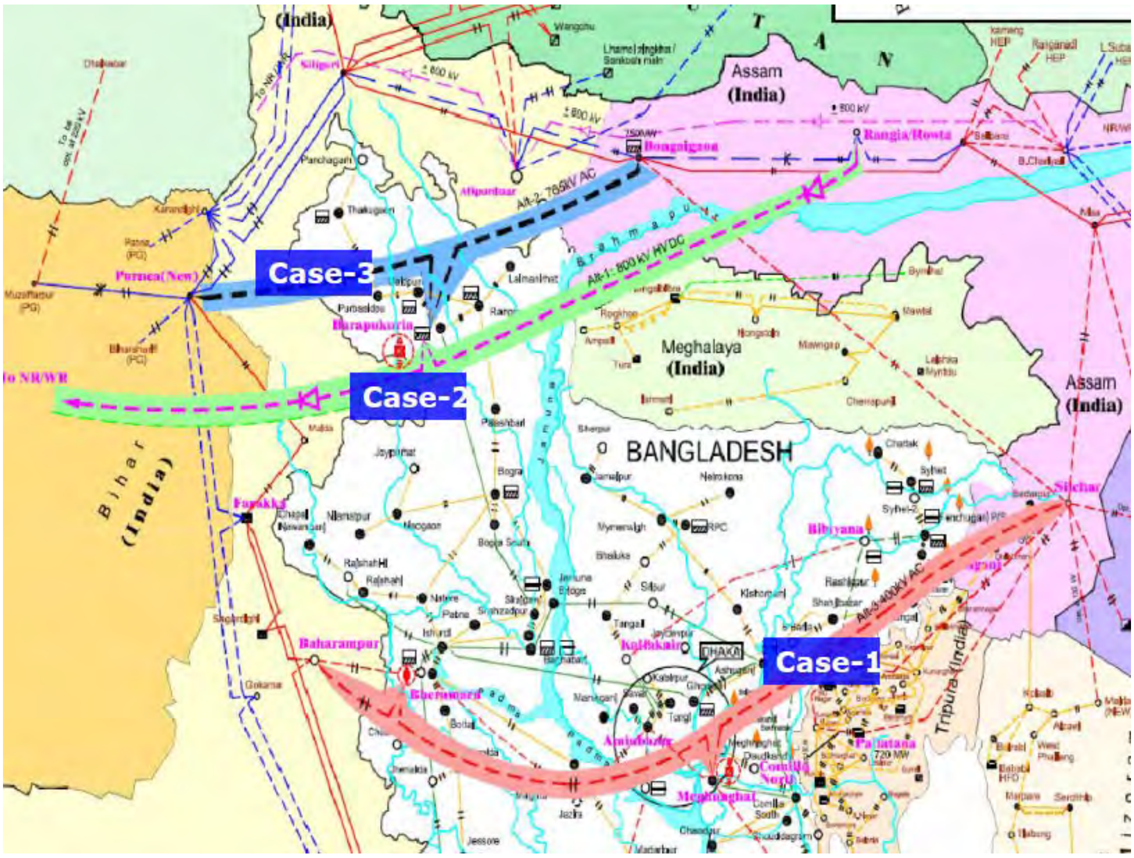
Source: JICA Survey Team

Figure 14-2 Electric Power Supply and Demand Situation in the Neighbouring Countries of Bangladesh (2030)

Hydropower development can be actively executed in Nepal, Bhutan, India's northeastern states, and Myanmar, and the capacity of the hydropower plants is expected to increase approximately by 10GW in each. As a result, the supply capacity from hydropower will increase to about 35% of the whole supply capacity in the rainy season. On the other hand, the supply capacity of hydropower in the dry season decreases below half, and a lack of supply capacity is feared in Nepal, which mainly supplies electricity by hydropower. However, because demand decreases greatly and the reserve capacity of thermal power can be secured in Bangladesh, which mainly supplies electricity by thermal power, enough supply capacity can be secured in the region as a whole.

14.2 Possibility of International power trading in Bangladesh

Transmitting hydropower from Bhutan and Nepal to Bangladesh is impossible without the consent of India, which is geographically located between Bangladesh and these countries. In order to tackle this problem, three new cases of inter-connection have begun to be planned.



Source: JTT Report

Case 3	765 kV HVAC Line from Bongaigaon (Assam) to Purnia of India via Jamalpur or Barapukuria dropping 500-1000 MW to Bangladesh by HVDC BTB Station.
Case 2	±800 kV HVDC 6000 MW Bi-pole Line from Rangia/Rowta (Assam) to NR/WR of India Via Jamalpur or Barapukuria dropping 500-1000 MW Power to Bangladesh by HVDC Station.
Case 1	Shilchar-Meghnaghat/Bhulta-Bahrampur High Capacity 400kV Line (Dropping of 500 MW by HVDC BTB Station at Meghnaghat/Bhulta)

Figure 14-3 Grand Design of Bangladesh – India Interconnection Line

In June 2015, Bangladesh and India published a joint declaration, following a summit meeting between Prime Ministers from each country. Among other things, both PMs welcomed the consensus between Bangladesh and India to evacuate power from the North-eastern region of India (Rangia/Rowta) to Muzaffarnagar of India through Bangladesh, constructing a ±800 kV, 7000 MW HVDC multi-terminal bi-pole DC grid line with suitable power tapping points at Barapukuria in Bangladesh. Prime Minister Modi agreed in principle to consider Bangladesh's request to provide adequate power from this line for Bangladesh keeping in view the grid security of both countries. Noting Bangladesh's interest in importing power in the BBIN framework, the Indian PM agreed to favorably consider such imports subject to grid security, transmission, interconnection and the applicable laws, rules and regulations of the respective countries.

14.3 Selection of Hydropower Development Candidate Area for Bangladesh

14.3.1 Evaluation Criteria Setting

The JICA Survey Team proposes a set of evaluation criteria for the selection of candidate areas for hydropower development for Bangladesh, as is shown in the following table.

Table 14-1 Evaluation Criteria for Candidate Area Selection for Hydropower Development

	Evaluation Items	Evaluation Viewpoint	Importance
1	Political willingness for power trades with Bangladesh	Including hydropower development policy and institutional supporting measures	High
2	Demand-Supply Balance in hydropower development host country	The more surplus energy (even during the dry season) the host country secures, the more points earned. (with more opportunity to receive energy for Bangladesh)	Medium
3	Hydropower development potential volume	The more potential there is, the more opportunity to identify economically viable sites. Thus, higher score earned.	Medium
4	Interconnection modality with Bangladesh	Direct connection to Bangladesh is preferable over indirect connections through other network systems.	Medium
5	Proximity to the connection point in Bangladesh	The closer the better. This criterion includes ease of transmission line construction.	High
6	The value of electricity at the receiving point in Bangladesh	Connection to an area where there are fewer power sources is favored.	Low

Source: JICA Survey Team

All these evaluation items are of great importance in selecting candidate areas for hydropower development for Bangladesh. However, "political willingness for power trades with Bangladesh" and "proximity to the connection point in Bangladesh" are considered to be the most important.

14.3.2 Possible Candidate Areas for Hydropower Development to be connected with Bangladesh

(1) Possible Areas for Interconnection

The JICA Survey Team considers the following six areas to be possible candidate areas for hydropower development to be connected with Bangladesh.

Table 14-2 Candidate Areas for Hydropower Development to be Connected with the Bangladesh System

	Hydropower Development Area	Connecting point in Bangladesh	Connection Modality
1	Eastern Nepal	West (Bheramara)	To transmit energy to the closest substation in India and to connect the existing BTB in West Bangladesh through the Indian domestic network.
2	Western Bhutan	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
3	Eastern Bhutan	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
4	Meghalaya State, India	East (Bibiyana)	To directly connect with Bibiyana S/S
5	Arunachal Pradesh State, India	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
6	Western Myanmar	South (Anowara)	To directly connect with Anowara S/S

Source: JICA Survey Team

(2) Connection Illustration of Potential Hydropower Development Areas

The following map shows an illustration of the connection of hydropower development areas with Bangladesh.

Source: JICA Survey Team

Figure 14-4 Connection Illustration of Hydropower Development Areas with Bangladesh

14.3.3 Screening Based on the Evaluation Criteria

(1) Political Willingness for Power Trades with Bangladesh
In all the areas except Myanmar, the Governments are very much willing to undertake power trading with Bangladesh. It should be noted that the Government of Bhutan has the intention to prioritize hydropower development in the eastern area over the western area, where hydropower development is rather active, in order to seek balanced economic development in the country.

(2) Demand-Supply Balance in hydropower development host country
Nepal currently faces severe power shortages due to its lack of supply capacity, exercising rotational load shedding routinely. It is expected that large hydropower plants will start operating in the near future, improving the demand-supply situation in the wet season. However, as this will not solve the demand-supply balance in the dry season, the securing of an energy surplus to sell to the rest of the region would not be envisaged. On the other hand, both in Bhutan and the State of Arunachal Pradesh, where there is enough supply capacity, it is possible to sell their surplus capacities to the rest of the region. In the State of Meghalaya, where it sells wet season surplus to other states and purchases power back in the dry

season on a regular basis, surplus capacity in the dry season cannot be expected.

(3) Hydropower development potential volume
There is huge hydropower development potential in all the areas except for the State of Meghalaya. However, from the viewpoint of pumped-storage, there is prospective potential in Meghalaya.

(4) Interconnection modality with Bangladesh
It is possible to connect with the Bangladesh power system directly from the State of Meghalaya and Myanmar. On the other hand, transmitting energy through the Indian grid is prerequisite when Bangladesh receives power from Nepal or Bhutan. In the case that Bangladesh imports hydro energy from Bhutan or Arnachal Pradesh, Bangladesh can tap energy at the northern receiving point though a proposed ±800kV HVDC link between Northeast and Central India via Bangladesh. When Bangladesh purchases energy from Nepal, it would receive it at Bheramara BTB, where capacity augmentation is envisaged, passing a long way through Indian domestic power transmission network.

(5) Proximity to the connection point in Bangladesh
If hydropower in the State of Meghalaya is connected directly to Bibiyana S/S in Bangladesh, only 50km of transmission I lines are required. In the case of smaller capacity, such as 132kV transmission, the distance to the nearest substation may be approximately 20 to 30km. In transmitting hydro energy from Bhutan or Arunachal Pradesh, it will be prerequisite to be connected to Rangia S/S where an eastern AC/DC conversion station is located for the proposed ±800kV HVDC link between Northeast and Central India via Bangladesh. Because eastern Bhutan is close to Rangia S/S, transmission distance is within 100km. However, in evacuating hydro energy from western Bhutan, the transmission distance may exceed 200km. Also, receiving hydro energy from Arunachal Pradesh may require transmission lines over 200km. In the case of receiving hydro energy from Nepal, connection to the nearest substations in India allows Bangladesh to use the Indian domestic power networks. Therefore, transmission distance is considered to be less than 100km. Connection of hydro energy from Myanmar may require a transmission distance of over 200km.

(6) The value of electricity at the receiving point in Bangladesh
Connection to the load center may be the most valuable. However, each of the hydropower potential target areas in question is distant from the load center in Bangladesh. The next favorable case is connection to areas with supply capacity deficit. Because power plants are concentrated to the east of the Jamuna River, any supply capacity west of the Jamuna River will be highly appreciated. The currently proposed power receiving point along the proposed ±800kV HVDC link between Northeast and Central India is located at Barapukuria, east of the Jamuna River. Therefore, the value of electric power with this link is considered to be a little bit higher than that of electricity to be received east of the Jamuna River from the Indian State of Meghalaya or Myanmar. The value of hydro energy from Myanmar in particular may be relatively lower at the power receiving point because thermal power development at a larger scale is envisaged in southern Bangladesh.

(7) General Evaluation

The results of the screening mentioned above are summarized in the following table.

Table 14-3 Screening Results

		Weight	Nepal	Bhutan		India		Myanmar
			East	West	East	West	Arunachar	West
1	Political will for electricity export	3	5	3	5	2	5	2
2	Demand & supply balance	2	2	5	5	2	5	2
3	Hydro power potential	2	5	5	5	4	5	4
4	Connection method	2	3	2	2	5	2	5
5	Distance to connecting point	3	4	2	4	2	2	2
6	Value of electricity at connecting point	1	4	4	4	2	4	2
	Total		51	43	55	36	49	36

Source: JICA Survey Team

As a result of the above comparison, it is considered that hydropower development in the Indian State of Meghalaya and Bhutan is relatively promising. As for Nepal, when its supply-demand situation improves, the area would become promising.

With regard to Myanmar, without having an opportunity to visit, the JICA Survey Team can hardly confirm detailed information such as the Government's willingness to undertake power trading with Bangladesh. However, depending on the results of the confirmation on local situations, Myanmar may become a good candidate area for hydropower development for Bangladesh.

14.4 Selection of Hydropower Development Candidate Sites

Previous Chapter confirms two areas, namely East Bhutan and the Indian State of Meghalaya, as the most prioritized areas for hydropower development for Bangladesh.

14.4.1 Evaluation Criteria Setting

The following table shows a set of evaluation criteria to score potential hydropower sites and select development candidate sites.

Table 14-4 Evaluation Criteria for Hydropower Development Candidate Sites

	Items to be evaluated	Evaluation Viewpoint	Weight
1	Preference of the Government of Bangladesh	Larger generation capacity is preferable	5
2	Economy of the potential site	Evaluated by unit construction cost (USD/MWh) based on computation of construction cost and annual generation volume	5

	Items to be evaluated	Evaluation Viewpoint	Weight
3	Required construction cost of dedicated transmission lines for energy evacuation	Unit transmission cost (USD/MWh) being calculated with construction cost estimate based on transmission line length and voltage level	2
4	Environmental issues	Evaluated on whether there is an existence of environmentally protected areas, endangered species or indigenous population nearby	4
5	Geological issues	Evaluated on whether there is a possibility of landslide during construction and sedimentation during operation	4
6	Issues for power export to Bangladesh	Evaluated by possibility of utilization of related transmission lines for power transmission to Bangladesh and energy output volume	3
7	Ease of construction and implementation	Status for construction access road, and availability of utilities/infrastructure such as electricity for construction	2
8	Operational flexibility	Evaluated by water storage capacity – the point is higher in the case of seasonal output adjustment	1
9	Project status	Evaluated by credibility of project feasibility based on progress of project preparation	1
10	Prospects for future JICA assistance	Evaluated on whether there is another sponsor for development funding and on total project cost (size)	3

Source: JICA Survey Team

Each of the potential sites is evaluated and scored alongside each of the above evaluation criteria with the highest score being five points. However, any potential sites with their scores in 4) Environmental issues and 5) Geological issues being two points or below will not be selected as candidates due to serious risk exposure, even if the total scores are relatively larger than others.

14.4.2 Comparison and Screening of Hydropower Development Sites alongside the Evaluation Criteria

(1) East Bhutan

In the eastern part of Bhutan, there are three sites and five power plants, Kuri-I (formerly known as Rotpashong), Gamri-I, Gamri-II, Nyera Amari-I and Nyera Amari-II for which pre-feasibility studies (Pre-F/Ss) have been conducted. The following table summarizes the techno-economic comparison among these five proposed power plants.

Table 14-5 Hydropower Development Potential Candidate Sites in East Bhutan

	Kuri-I	Gamri I	Gamri II	Nyera Amari I	Nyera Amari II
Installed caopacity Unit size × Units	1,230MW (205MW×6)	45MW (22.5MW×2)	85MW (42.5MW×2)	125MW (62.5MW×2)	317MW (105.67MW×3)
Design annual energy	5,265GWh	215.69GWh	399.90GWh	614GWh	1,556GWh
Construction cost (million)	USD 1,686.5	BTN 3,620 (USD 56.6)	BTN 5,587 (USD 87.3)	BTN 12,490 (USD 195.2)	BTN 22,291 (USD 348.4)
Unit construction cost per annual energy	USD 320/MWh	USD 262/MWh	USD 218/MWh	USD 318/MWh	USD 224/MWh
Length of T/L	400kV 140km	132kV 8km	132kV 36km	220kV 16km	220kV 66km
Construction cost of T/L	USD 70 million	USD 11 million		USD 22 million	
Unit construction cost	USD 13.3/MWh	USD 17.9/MWh		USD 10.1/MWh	

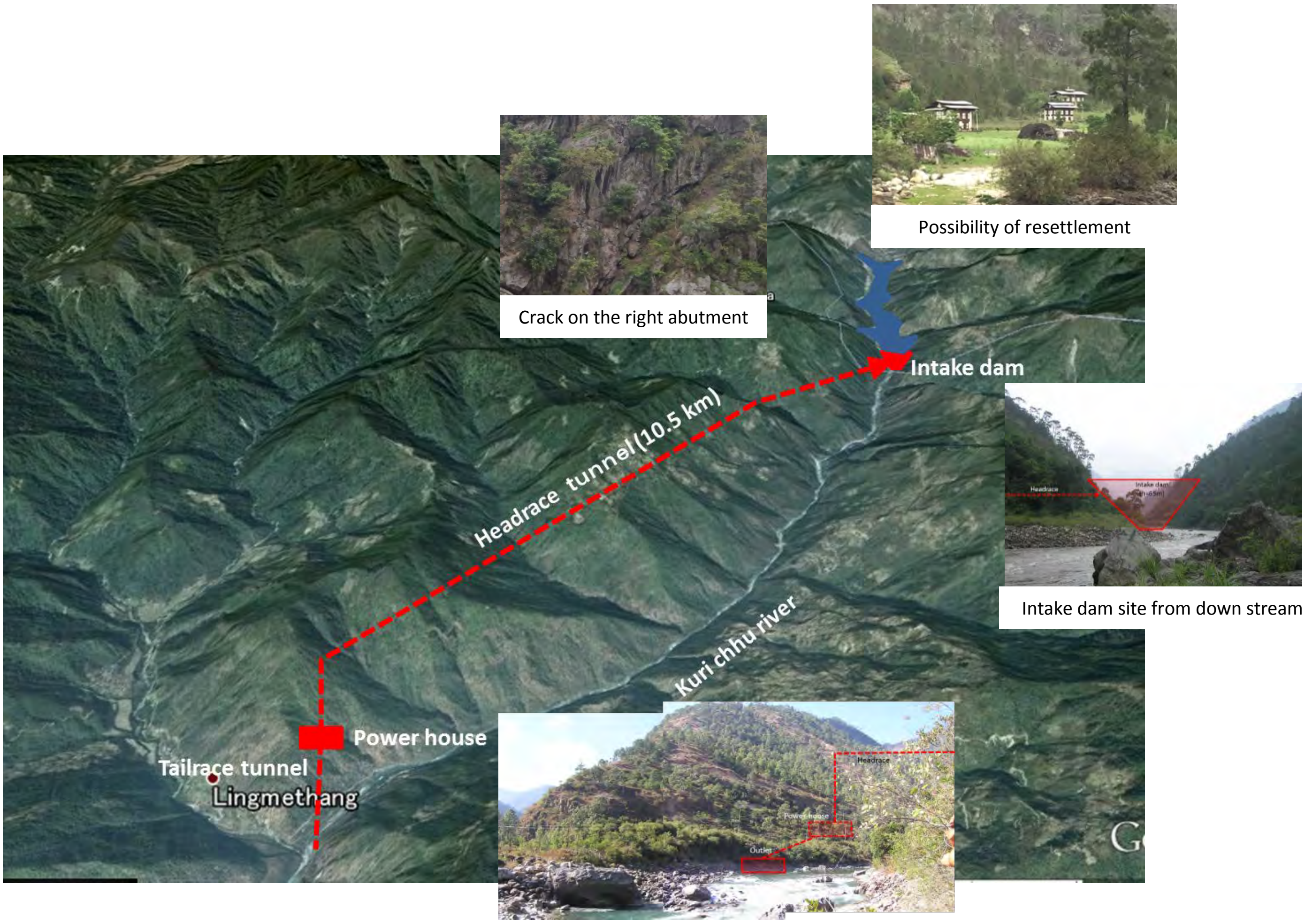
Source: JICA Survey Team

Table 14-6 Evaluation Results for Potential Hydropower Sites in East Bhutan

	Evaluated items	Weight	Kuri-I	Gamri I, II	Nyera Amari I, II
1	Preference of the Government of Bangladesh	5	5	1	3
2	Economy of the potential site	5	3	4	4
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	4	4
4	Environmental issues	4	3	2	3.5
5	Geological issues	4	4	3	2
6	Issues for power export to Bangladesh	3	3	2	3
7	Ease of construction and implementation	2	4	2	3
8	Operational flexibility	1	2	2	2
9	Project status	1	4	3	3
10	Prospects for future JICA assistance	3	2	4	3
	Total (weighted)		105	80	94

Source: JICA Survey Team

Kuri-I records the highest total score, followed by Nyera Amari and, in turn, Gamri. Kuri-I fits the expectation of the GOB in terms of its larger scale of development. Because there seem to be no significant impediments to development, the JICA Survey Team selects Kuri-I as the most prioritized development candidate.



"Image©2015CNES/Astrium, Image© 2015AutoNavi, Image ©2015Google" Source: JICA Survey Team

Figure 14-5 Outline of Kuri I Project

- All the facilities except the intake dam are constructed underground. However, the JICA Survey Team considered that a ground or semi-underground type powerhouse would be possible, so placement position of the powerhouse is an essential study point at the detailed design stage.
- Numerous trends of joints and cracks are seen on the rock surface on both the right and left river side. Detailed investigation and examination for these cracks on the right bank should be conducted in the FS stage.
- There are no settlements at the dam site, but part of the highway along the reservoir near the intake dam needs to be relocated due to the reservoir, and 3 permanent houses and other small facilities in Autsho village need to be resettled.

(2) The Indian State of Meghalaya

In the State of Meghalaya, there are three potential sites for conventional hydropower development with sizable capacity and considerable progress in project preparation, namely Mintdu Leshka-II, Umngot and Nongkohlait. The following table summarizes the techno-economic comparison among the three proposed power plants.

Table 14-7 Hydropower Development Potential Candidate Sites in Meghalaya

	Mintdu Leshka II	Umngot	Nongkohlait
Installed caopacity Unit size × Units	280MW (70MW x 4)	240MW (80MW x 3)	120MW
Design annual energy	895.29 GWh	838.73 GWh	379.34 GWh
Construction cost	INR 29,400 million (USD 460.5 million)	INR 15,646 million (USD 245 million)	INR 3,262 million*1) (USD 51.1 million)
Unit construction cost per annual energy	USD 514/MWh	USD 292/MWh	USD 135/MWh*1)
Length of T/L	220kV 98km	220kV 111km	220kV 95km
Construction cost of T/L	USD 27 million	USD 31 million	USD 27 million
Unit construction cost	USD 30.2/MWh	USD 37.0/MWh	USD 71.2/MWh

*1): Data from Pre-F/S in 2004 Source: JICA Survey Team

The southern part of Meghalaya state has very steep geographical features, and has a lot of appropriate site of PSPP. Moreover, it is assumed that the optimal scale of the power plant will be 1,500MW class because it can expect a high head that exceeds 600m. However, a concrete site survey has not been done for the PSPP of Meghalaya state up to now.

Table 14-8 Evaluation Results for Potential Hydropower Sites in Meghalaya

	Evaluated items	Weight	Mintdu Leshka II	Umngot	Nongkohlait	PSPP
1	Preference of the Government of Bangladesh	5	3	3	2	5
2	Economy of the potential site	5	2	3	4	4
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	3	2	4
4	Environmental issues	4	4	3	2.5	4
5	Geological issues	4	2	4	4	4
6	Issues for power export to Bangladesh	3	4	4	4	4
7	Ease of construction and implementation	2	4	3	3	3
8	Operational flexibility	1	2	4	2	5
9	Project status	1	4	4	3	1
10	Prospects for future JICA assistance	3	4	4	4	3
	Total (weighted)		95	102	95	118

Source: JICA Survey Team

When the hydropower of Meghalaya state is developed, it will be difficult for Bangladesh to import the whole quantity of power in order to transmit part of it to Meghalaya state and states in the vicinity. In short, because Bangladesh can only receive almost half of the amount of development, the development of a larger scale site is more preferable. Conventional hydropower is a development scale of about 200MW, so the amount of receipt in Bangladesh is only about 100MW. On the other hand, because the

PSPP is a development scale of 1,500MW class, almost 1,000MW can be expected for receipt in Bangladesh.
Based on the above-mentioned view, the JICA Survey Team selects PSPP as a development priority site in Meghalaya state.

The JICA Survey Team has conducted site surveys of candidate pumped storage power plant sites, and the three potential sites are proposed as suitable sites for a pumped storage power plant site in Meghalaya. However, this proposal is based on visiting and watching from the road on the plateau and desk study.

Location	Facility	Crest length	Dam height	High Water Level	Effective head	Waterway length	Remarks	Rank
No.1 PSPP	Upper dam 1	900m	100m	1,530m	550m	3.2km	Large upper dam	3
	Lower dam 1	500m	110m	950m				
No.2 PSPP	Upper dam 2	550m	40m	1,550m	690m	3.2km	Excavation of upper pond	2
	Lower dam 2	300m	140m	830m				
No.3 PSPP	Upper dam 3	450m	100m	1,500m	640m	4.1km		1
	Lower dam 2	300m	140m	830m				

“Image©2015DegitalGlobe, Image©2015CNES/Astrium, Image Landsat©2015Google” Source: JICA Survey Team

Figure 14-6 Three Candidate Sites for PSPP in Meghalaya

Because of the very steep geographical features, there are many suitable sites which satisfy the conditions of a location for the PSPP in the southern part of Meghalaya state, and a high head that exceeds 600m can be expected. Therefore, it is assumed that the optimal scale of the power plant will be 1,500MW class. However, no concrete survey on PSPP in Meghalaya state has been performed up to now at all. That is to say, sites that have geological issues or environmental issues etc. can be excluded, and an excellent, economical site can be selected.

A 400kV double-circuit transmission line with a length of 90km from the power plant to Bibiyana S/S in Ba Transmission Line Development Plan will be constructed. If the line is connected to the India system, it is an option to extend it to Killing substation in India by constructing an additional 100 km transmission line in a northerly direction.

14.5 Recommendations on Regional Power Interconnection

14.5.1 Challenges and Countermeasures of Power Imports

The challenges arising from importing power and their countermeasures are as follows.

(1) Energy Security

In the case of importing power from other countries, the risk of supply interruption caused by adverse relationships between the two countries needs to be considered. Electric power, which is different from other types of supply, is technically easy to shut down even in minutes. So it is necessary to avoid excessive reliance on other countries in order not to place oneself in a serious situation. Specifically, the capacity of imported power from one country should be within the limit of generating reserve margin and also 10% of all supply capacity in order to continue the supply in the event of supply interruption. In the case of Bangladesh, imported power from Bhutan and Nepal has to be transmitted through India. Therefore, imported power from Bhutan and Nepal should be within 10% of all supply capacity.

(2) Compliance with Commissioning Timing of the Transmission Lines in India

The power import plan through India hinges on commercial operation of the Case 2 HVDC (±800kV) interconnection line or the Case 3 HVAC (765kV) interconnection line. These interconnection lines shall be constructed in close cooperation with India after fully understanding and confirming India's needs. When hydropower capacity exceeds 3,000MW in Arunachal Pradesh, the ±800kV inter-state transmission line currently under construction reaches its full transmission capacity, giving rise to a need for the construction of the Case 2 interconnection line. On the other hand, there seems to be no reason for India to realize the need for the Case 3 line for the time being. However, need for the Case 3 line's construction will arise if construction of the Case 2 line is delayed due to a delay in the hydro power development in Arunachal state, or high construction costs etc.

(3) Massive blackout due to large scale power loss of supply

It is desirable to import as much power as possible through one connecting point from the viewpoint of economic efficiency. However, if a huge amount of power is transmitted through one connecting point, it can lead to the risk of massive blackout, such as blackout across the entire country during the shutdown of the connecting line. Massive blackout occurred on 1st November 2014, triggered by 500MW power loss of the BTB break down on the inter-connection line from India. In order to avoid this risk, the limit of the power loss level needs to be worked out, by checking sufficiently continuous power generators' operation during frequency drop and the load shedding scheme during large scale power supply loss. Based on this result, the maximum level of import capacity in one inter-connection point has to be decided. In concrete terms, it is preferable that the amount of imported power through one connecting point is within 10% of the demand.

(4) Mutual Interference due to Grid Accidents

Conducting power trading means transmission lines are connected between two neighboring countries, which will lead to the threat of mutual interference due to grid accidents. But it is possible to minimize the influence by connecting DC lines. Current inter-connection lines between India and Bangladesh apply DC lines or non-connected lines by switching the load. There will be a few mutual interferences due to grid accidents in these two cases.

14.5.2 Proposals on Power Import Planning

Reflecting the aforementioned issues, the Survey Team proposes the following two power import plans for Bangladesh.

(1) High Case Scenario

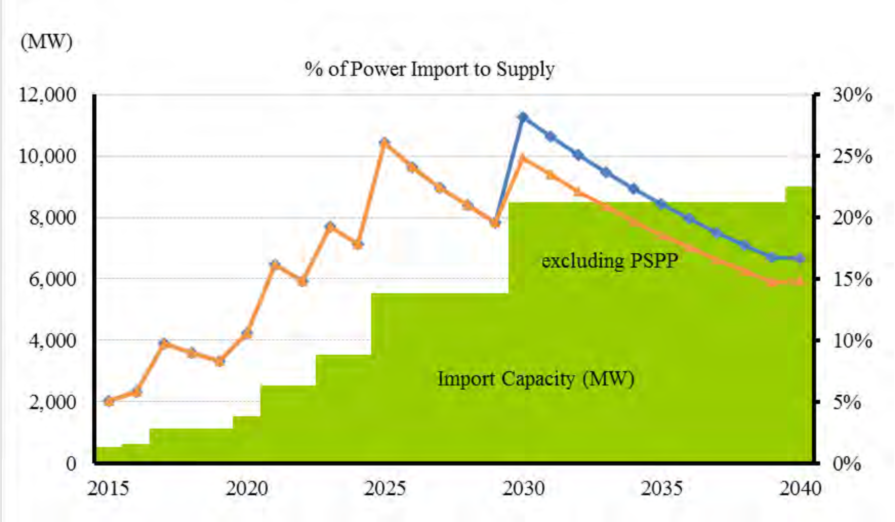
The High Case Scenario, in which more electric power can be expected due to operation of the Case 2 line and Case 3 line starting on schedule, is shown below.

Table 14-9 Power Import Plan (High Case Scenario)

		MW	Year	Remarks
1	Bheramara - Baharampur	500	2013	Existing
2	Tripura - Comilla	100	2016	Some load (100MW) in Comilla (N) S/S will be connected to Indian system.
3	Bheramara - Baharampur	500	2017	Extension of Bheramara HVDC.
4	Bheramara - Baharampur	1,000	2021	Additional extension of Bheramara HVDC Power import from Nepal (including GMR)
5	Tripura - Comilla	400	2020	Construction of HVDC (500MW) in Comilla (N) S/S. Some load (100MW) in Comilla (N) S/S will be disconnected from Indian system.
6	Rangia/Rowta - Barapukuria	1,000	2023	Power import by using Case 2 T/L (±800kV DC)
7	Rangia/Rowta - Barapukuria	1,000	2025	Power import by using Case 2 T/L (±800kV DC)
8	From Nepal (Purnea - Barapukuria)	1,000	2025	Power import by using Case 3 T/L (initially 400kV AC)
9	Bongaigaon/Rangia - Jamarpur	1,000	2030	Power import from Bhutan
10	Bibiyana - Meghalaya (PSPP)	1,000	2030	PSPP in Meghalaya State
11	From Nepal	1,000	2030	Power import by using Case 3 T/L (upgrade to 765kV AC)
12	Cox's Bazar - Myanmar	500	2040	Power import from Myanmar
	Total	9,000		

Source: JICA Survey Team

The following figure shows the import volume and its share against the total supply capacity in the high case scenarion power import plan.



Source: JICA Survey Team

Figure 14-7 Future Power Import Volume and its Share (High Case Scenario)

The share of power imports against the total supply capacity will be between 20% and 25% within the permissible range, albeit a little bit large.

(2) Low Case Scenario

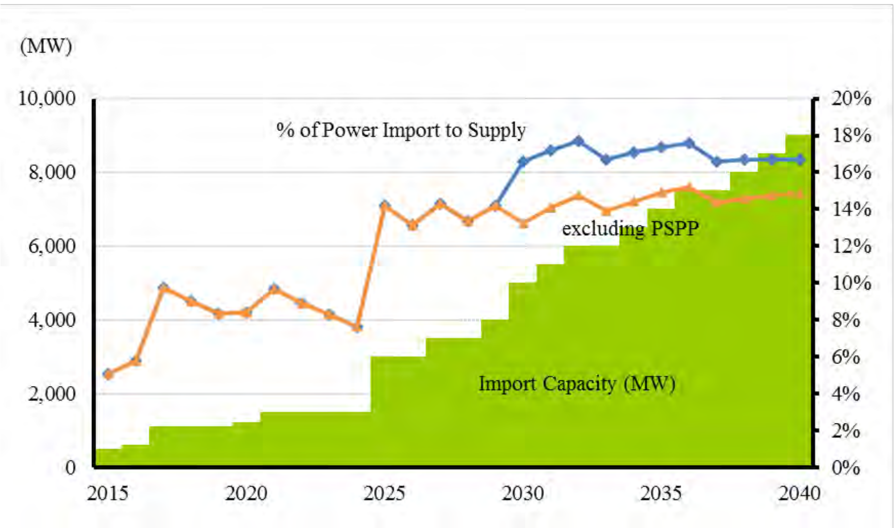
The Low Case Scenario, in which excessive import of electric power from neighboring countries is not expected, is shown below.

Table 14-10 Power Import Plan (Low Case Scenario)

		MW	Year	Remarks
1	Bheramara - Baharampur	500	2013	Existing
2	Tripura - Comilla	100 100	2016 2020	Some load (100MW+100MW) in Comilla will be connected to Indian system.
3	Bheramara - Baharampur	500	2017	Extension of Bheramara HVDC.
4	Bheramara - Baharampur	500 500	2027 2031	Additional extension of Bheramara HVDC Power import from Nepal
5	Tripura - Comilla	300	2020	Construction of HVDC (500MW) in Comilla. Some load (100MW+100MW) in Comilla will be disconnected from Indian system.
6	Rangia/Rowta - Barapukuria	1,000	2025	Power import by using Case 2 T/L (±800kV DC)
7	Rangia/Rowta - Barapukuria	500 500	2036 2039	Power import by using Case 2 T/L (±800kV DC)
8	From Nepal (Purnea - Barapukuria)	500 500	2025 2029	Power import by using Case 3 T/L (initially 400kV AC)
9	Bongaigaon/Rangia - Jamarpur	500 500	2032 2034	Power import from Bhutan
10	Bibiyana - Meghalaya (PSPP)	1,000	2030	PSPP in Meghalaya State
11	From Nepal	500 500	2035 2038	Power import by using Case 3 T/L (upgrade to 765kV AC)
12	Cox's Bazar - Myanmar	500	2040	Power import from Myanmar
	Total	9,000		

Source: JICA Survey Team

The following figure shows the import volume and its share against the total supply capacity in the low case scenarion power import plan.



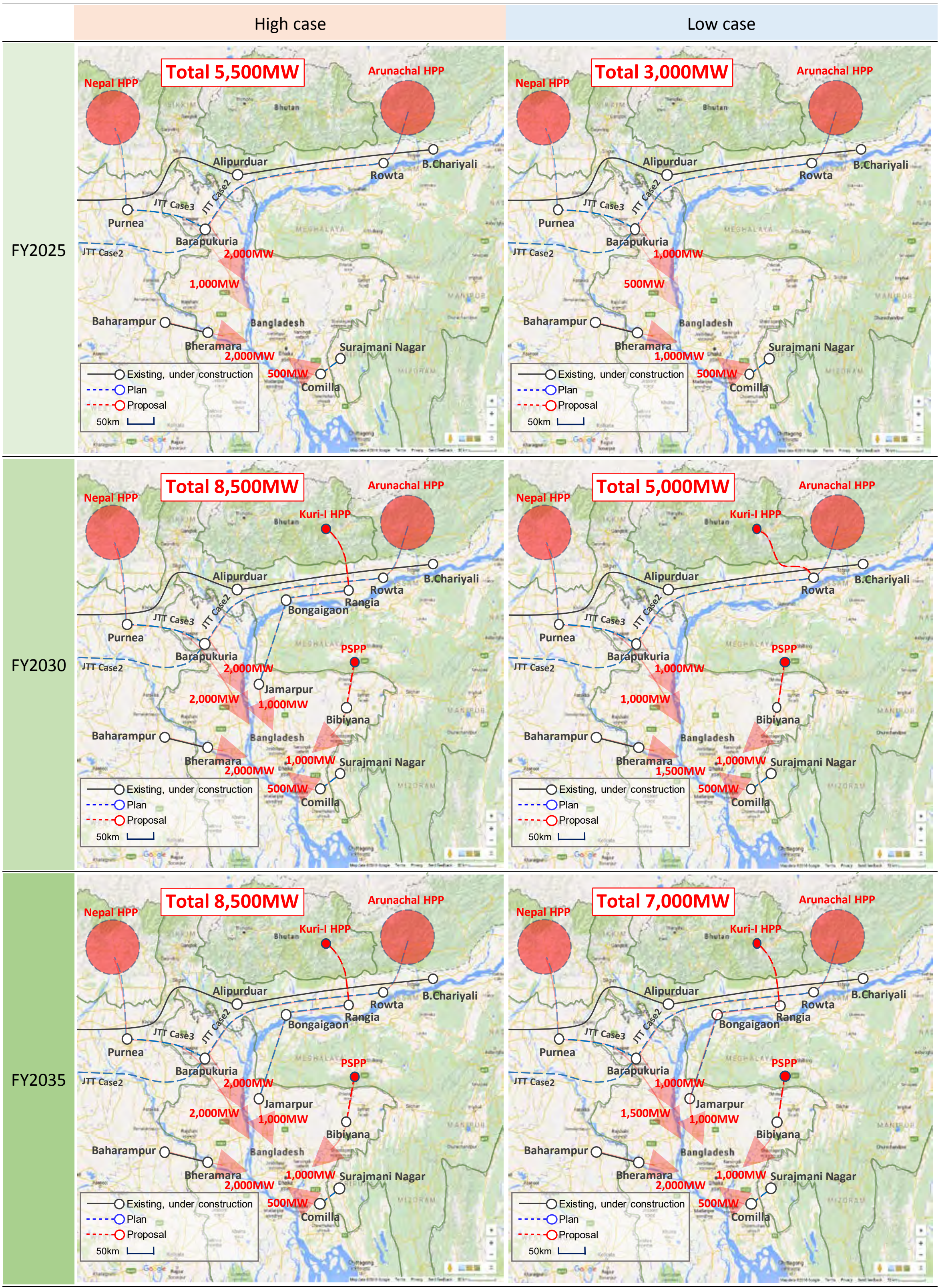
Source: JICA Survey Team

Figure 14-8 Future Power Import Volume and its Share (Low Case Scenario)

The share of power imports against the total supply capacity will be approximately 15% within the appropriate range after 2025.

(3) Power import situation

The power import from neighboring countries situation in 2025, 2030 and 2035 is shown below.



Source: JICA Survey Team

Figure 14-9 Power Import Situation

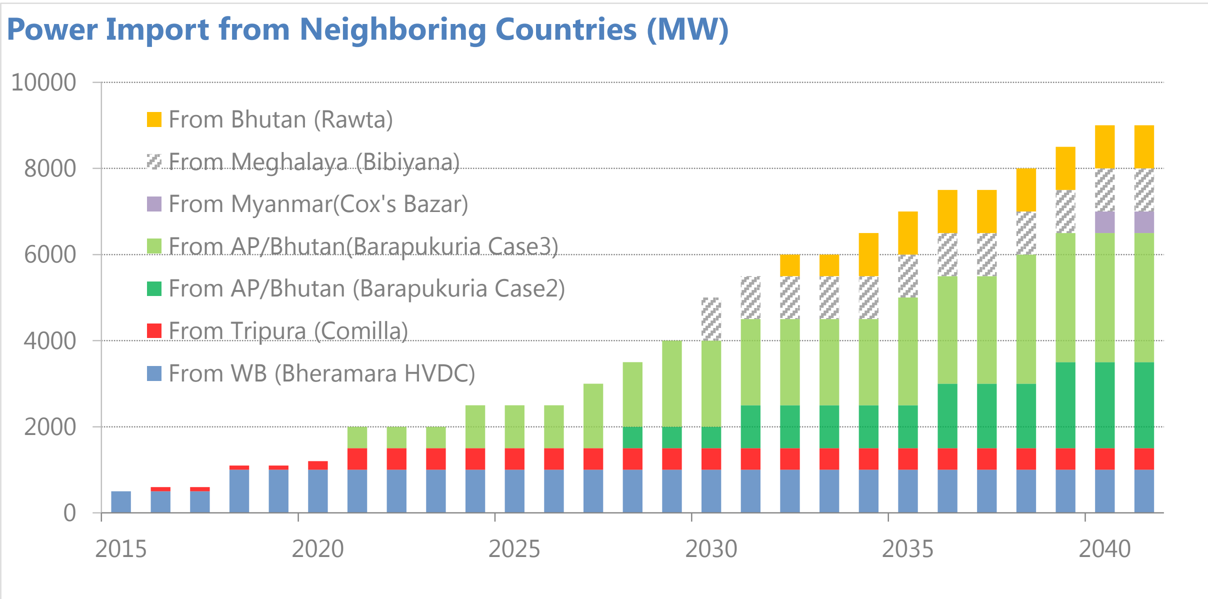
(4) PSMP2016 Scenario

The following table and figure show the PSMP2016 scenario based on the low case scenario, following discussions with the relevant institutions.

Table 14-11 PSMP2016 Scenario

Project Name	Location	Capacity (MW)	Company	COD (FY)
Bheramara-Bharampur HVDC		1000		
Bheramara-Bharampur HVDC Phase 1(from India)	India	500	BPDB	2013
Bheramara-Bharampur HVDC Phase 2 Bheramara - Baharampur (India)	India	500	BPDB	2018
Comilla - Tripura HVDC		500		
Comilla - Tripura HVDC Phase 1-1 (100MW) (India)	India	100	BPDB	2016
Comilla - Tripura HVDC Phase 1-2 (100MW) (India)	India	100	BPDB	2020
Comilla - Tripura HVDC Phase 2 (300MW) (India)	India	300	BPDB	2021
Case 2 HVDC (Barapkuria S/S)		2000		
Case 2 HVDC (Barapkuria S/S) Phase I-1 Bheramara - Baharampur Arunachal, India (East India)	Arunachal, India (East India)	500	BPDB	2028
Case 2 HVDC (Barapkuria S/S) Phase 1-2 Bheramara - Baharampur Arunachal, India (East India)	Arunachal, India	500		2031
Case 2 HVDC (Barapkuria S/S) Phase II	Arunachal, India	500	BPDB	2036
Case 2 HVDC (Barapkuria S/S) Phase III	Arunachal, India	500	BPDB	2039
Case 3 HVDC (Barapkuria S/S)		3000		
Case 3 HVDC (Barapkuria S/S) Phase I From India (Purnea - Barapukuria) (India)	India	500	BPDB	2021
Case 3 HVDC (Barapkuria S/S) Phase II Phase I From India (Purnea - Barapukuria) (India)	India	500	BPDB	2024
Case 3 HVDC (Barapkuria S/S) Phase III From Nepal (Purnea - Barapukuria) (Nepal)	Nepal	500	BPDB	2027
Case 3 HVDC (Barapkuria S/S) Phase IV From Nepal (Purnea - Barapukuria) (Nepal)	Nepal	500	BPDB	2029
Case 3 HVDC (Barapkuria S/S) Phase V From Nepal (Purnea - Barapukuria) (Nepal)	Nepal	500	BPDB	2035
Case 3 HVDC (Barapkuria S/S) Phase VI From Nepal (Purnea - Barapukuria) (Nepal)	Nepal	500	BPDB	2038
Bibiyana - Meghalaya (PSPP) (India)	Meg	1,000	BPDB	2030
Cox's Bazar - Myanmar	Myan	500	BPDB	2040
Rawta - Jamarpur HVDC		1,000	BPDB	
Rawta - Jamarpur HVDC PhaseI Bongaigaon/Rangia - Jamarpur (Bhutan)	Bhutan	500		2032
Rawta - Jamarpur HVDC PhaseII Bongaigaon/Rangia - Jamarpur (Bhutan)	Bhutan	500	BPDB	2034
Total		**9,000**		

Source: JICA Survey Team



Source: JICA Survey Team

Figure 14-10 PSMP2016 Scenario

14.5.3 Implementation Arrangement

Agreement acquisition with India is indispensable in order to achieve the plan for power imports from the neighboring countries that are mentioned above. In particular, it is important to negotiate tenaciously on the following items.

- Advanced development of the Case 3 line
  The Case 3 line is more flexible than the Case 2 line, and more effective for Bangladesh. Because Bangladesh can import electric power from various regions by using the Case 3 line it is important that it aims to advance development of this line.
- Securing power transmission capacity in India
  Bhutan and Nepal are positively in favor of electric power exports to Bangladesh. However, when Bangladesh imports electric power from the two countries, it must pass through the Indian system. It is especially important to match the system development plan in India and to advance the plan if necessary in order to secure the power transmission capacity in India.
- Direct connection of PSPP in Meghalaya state to Bangladesh system
  The PSPP is a very effective tool for stabilizing the system and improving the power quality. It is necessary to connect the generator directly to the Bangladesh system to enjoy such an effect. As for the PSPP in Meghalaya state, large-scale development of 1,000MW or more is possible at each site. Therefore, it is possible to secure economy even if the system is divided into two parts at the power plant and half of the generators connect with the Bangladesh system directly.

The existing communication channel suffices for discussions over bilateral power trades between Bangladesh and India. However, if power trades with Bhutan and Nepal are involved, the use of the Indian network is inevitable. Bilateral discussions between a seller (Bhutan or Nepal) and a buyer (Bangladesh) are not enough to facilitate such power trades. A multilateral framework that includes India is a prerequisite.

To provide a discussions platform of this kind, a group of countries comprising Bangladesh, Bhutan, India and Nepal (BBIN) has been formulated. BBIN holds Joint Working Groups (JWGs) twice a year. Therefore, it seems to be most effective to discuss regional power trades and interconnection in JWGs for the implementation of specific projects.

14.6 Nuclear Power Generation

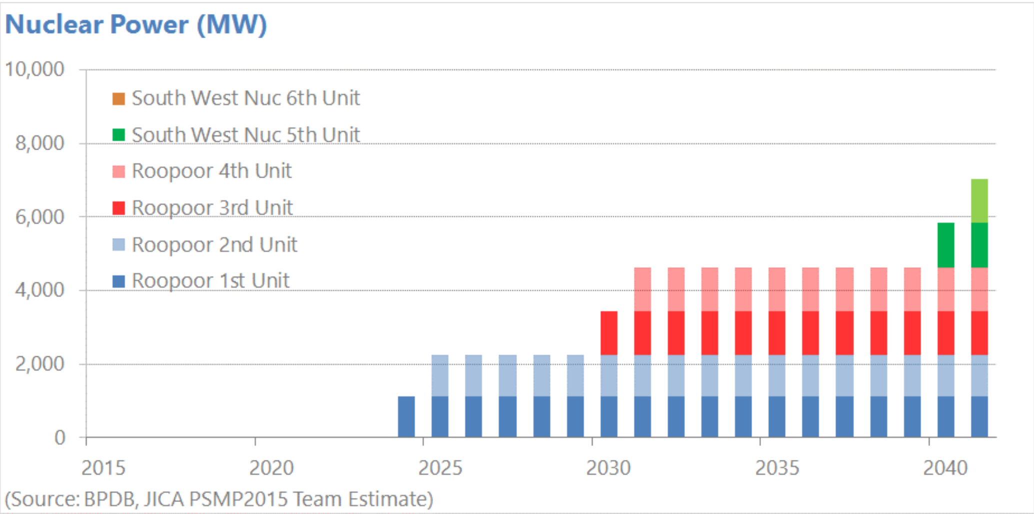
14.6.1 Nuclear Power Generation in PSMP2016

PSMP2016 aims to create a well-balanced power generation environment that maximizes the respective advantages of different types of power generation methods, including nuclear power, thermal power, hydropower generation, and power imports from neighboring countries, from the comprehensive perspective of stable supply, or energy security, environmental performance, and economic efficiency.

Daily power demand, or load curve varies according to season, temperature, and time of day. Since electricity cannot be stored, and must be used as it is produced. Gas and oil based thermal power generation, by virtue of its ability to respond quick flexibly to ever-changing power demand, supplies middle and peak load. Nuclear power, power import, hydropower, and coal-based thermal power generations are considered as a base load energy. This combination of different types of power sources is commonly referred to as the best mix of power sources. In this PSMP2016, nuclear power generation plays an important role in providing a stable base load.

The following figure shows the PSMP2016 scenario on nuclear power generation, following discussions with the relevant institutions. It is assumed the first unit 1200MW is to start operations by 2024 and the second 1200MW by 2025 on PSMP2016. These figures are preconditioned in the power development planning without alternative cases, which means nuclear power is assumed as one of the Fixed Factors in terms of generation capacity in the simulation, considering the government's nuclear power projects planning.

However, realization of these plans may face some challenges. In this sub-chaper, situation in Bangladesh will be put together, and those challenges be pointed.



Source: JICA Survey Team

Figure 14-11 Nuclear Power Development on PSMP2016

14.6.2 Development of Nuclear Power Generation in Bangladesh[1]

Peaceful uses of Nuclear Technology were initiated in Bangladesh in early 1960's under the framework of the then Pakistan Atomic Energy Commission (PAEC). After independence, Bangladesh became a Member State of the Agency in 1972. The Bangladesh Atomic Energy Commission (BAEC) was formed

[1] IAEA Country Nuclear Power Profiles, 2016 update

in 1973 by Presidential Order No. 15 with the goal of utilization of Nuclear Science & Technology for national development. The nuclear establishment in the country existed and carried out related activities even before its independence from Pakistan. The Commission was entrusted with the following charter of duties: "Promotion of the peaceful uses of atomic energy in Bangladesh, the discharge of International obligations connected therewith, the undertaking of research, the execution of development projects involving nuclear power stations and matters incidental thereto." Since then, the Commission pursued various R&D projects, established a number of research and service providing centres with necessary laboratory facilities and equipment, trained working scientists and developed supporting facilities that can be used to meet the fast changing trends of scientific and technological pursuits of the modern world.

The Law on Nuclear Safety and Radiation Control was enacted in 1993. Considering that BAEC was the only national institution that has expertise and trained human resources needed for the enforcement of the law, it was also given nuclear regulatory responsibility. On 12 February 2013, a separate regulatory organization was set in order to separate promotional responsibilities from the regulatory ones, in order to attain the required transparency in nuclear safety and radiation control especially in all stages of licensing and inspection of nuclear facilities and radiation sources.

Some of the key events milestones for Bangladesh national Nuclear Power program are as follows, and among those events, one of the most important milestones are also highlited.

- 1963: Rooppur site selected for implementation of NPP
- 1971-78: 1987-88: Feasibility studies for site and first NPP conducted. Further feasibility studies for site and first NPP conducted.
- 1996: National Energy Policy identifies nuclear power as an option
- 2000: Bangladesh Nuclear Power Action Plan (BANPAP) approved by the government
- 2010: National Parliament approves first NPP project and new structure for NP program development (equivalent NEPIO) were formed (National Committees, Technical Committee, Working Group).
- 2011: IGA with Russia signed for the first NPP with two VVER units, each of 1000 MW
- 2012: Bangladesh Atomic Energy Regulatory Act (BAER) was passed in the National Parliament on 19th June 2012.
- 2013: Bangladesh Atomic Energy Regulatory Authority was formed as a separate entity on 12th February 2013.
- 2015: General Contract for EPC was signed with Russian Enginnering Company for main stage construction of Rooppur NPP
- 2016: Inter-Governmental State Credit Agreement for financing the main stage construction of Rooppur NPP.

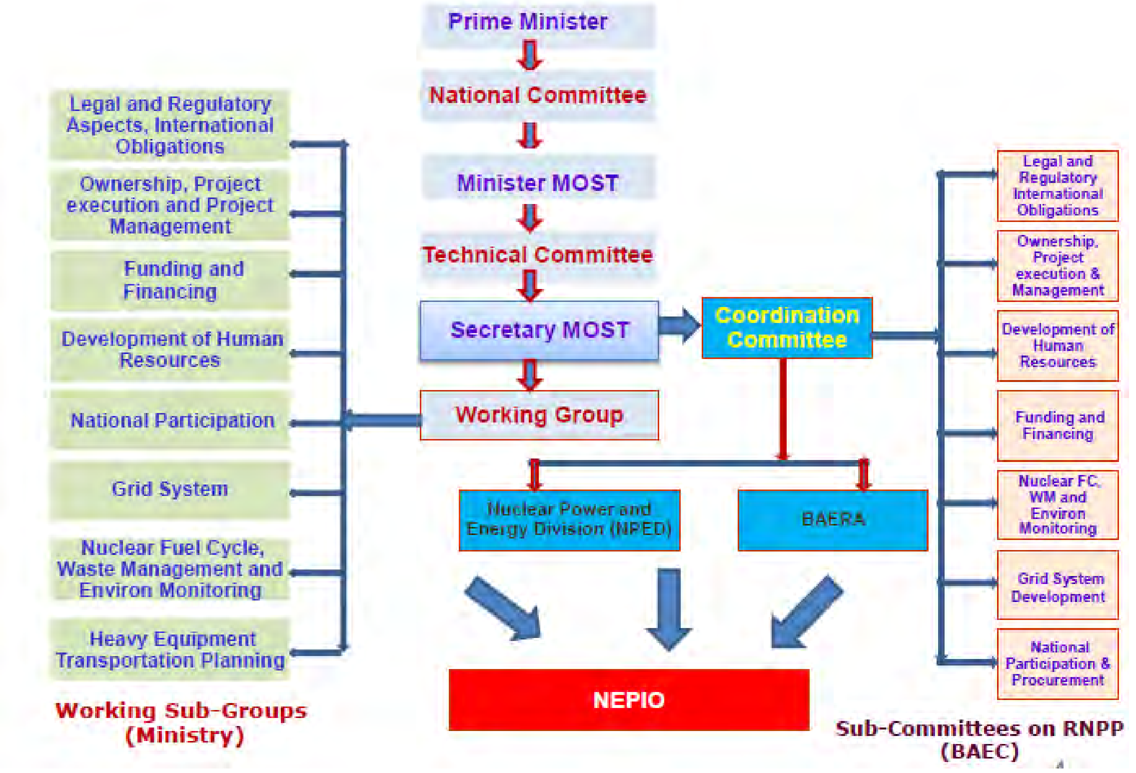
14.6.3 Implementation framework

The nation and the government have been showing their strong commitment; the National Parliament of Bangladesh passed a resolution in 2010: “In order to overcome the increasing power crisis in the country nuclear power plant shall be established immediately”. The government formed high-level committees in 2010, headed by the Prime Minister, to perform the tasks recommended in the IAEA Nuclear Energy Series Publications for the development of Policy Documents and Infrastructure Development – This set of committees, the Nuclear Energy Program and Implementation Organization (NEPIO), together with the government, have been performing the necessary actions towards realization of nuclear power plants.

According to the Nuclear Power Plant Act 2015, Bangladesh will set up the Nuclear Power Company of Bangladesh (NPCB) to run the plant, though ownership remains with the BAEC in accordance with the recommendation from NEPIO. In the NPCB, the Science and technology secretary will be the director and chairman of the company. The other directors will include BAEC chairman, an additional or joint secretary from the science and technology ministry, Finance Division and the Economic

Relations Division, a representative from FBCCI, Power Development Board chairman and Power Grid Company of Bangladesh Limited managing director.

Regarding nuclear power development, BAEC is strictly following IAEA guidelines. In NEPIO, there is a National Committee headed by prime minister. Secretary, Power Division is member of that Committee. Besides, representatives from Power Division participate in different phases of Rooppur NPP development. Grid system development is an important issue in nuclear project. There is a committee for Grid System development. BPDB and PGCB jointly prepared TOR for grid system study and one Russian company was engaged for that study. BPDB will purchase all power from RNPP as a single buyer. Power Purchase Agreement (PPA) will be signed between BPDB and BNPCL like Materbari coal power plant. Chief Engineer (P&D) is member of technical and financial negotiation committees.



Source: Ministry of Scenence &Technilogy, 2015

Figure 14-12 Nuclear Energy Program and Implementation Organization (NEPIO)

14.6.4 Ruppur Nuclear Power Plant Project

(1) Project outline and government Decision[2]

The nuclear power plant (Ruppur Nuclear Power Plant, RNPP) will be built at Ruppur, 200 km north-west of Dhaka, at Paksey union on the bank of the river Padma in the Ishwardi subdistrict of Pabna District, in the northwest of the country as shown in the following figure.

In February 2011, the Governments of Bangladesh and Russian Federation signed a Cooperation Agreement to build the approximately 2,400 MW with two reactors.

Due to limited resources and competencies, Bangladesh is considering building the Rooppur NPP through an Inter-Governmental arrangement (IGA). On 2 November 2011, Bangladesh signed an IGA with the Russian Federation for cooperation on construction of a NPP with two units, as well as in the

[2] IAEA Country Nuclear Power Profiles, 2016 update

establishment of necessary infrastructure to ensure the proper operation. BAEC is appointed as the customer for IGA on behalf of Bangladesh government. To implement the provisions of the IGA, a General Contract for construction of Rooppur NPP needs to be concluded.
As of Septermber 2016, RNPP obtained site clearance approval from Bangladesh Nuclear Regulatory Commission and site preparation work is going on.

Source: JICA Survey Team

Figure 14-13 Location of RNPP

(2) Finance
Russia agreed to build the Rooppur plant in an intergovernmental agreement signed in 2011, and agreed to provide $500 million to finance preparatory work including engineering surveys.
In July 26, 2016, Bangladesh and Russia signed a credit agreement of amount 11.38 billion US $ (90% of total project cost) for RNPP construction with an interest rate of Libor plus 1.75%. Bangladesh will pay off the loan within 28 years with a 10-year grace period[3].

(3) Technical assistance from Russia[4]
The contract signed in October 2013 by NIAEP-ASE and Bangladesh Atomic Energy Commission is a technical agreement covering the design stage of the project, which forms the basis for obtaining the necessary licences and starting construction of the plant. Rooppur's two reactors will be based on a modified version of the NPP-2006 VVER (pressurized water reactor) with a proven track record. Russia and Bangladesh will sign fuel supply agreement soon for fuel supply chain. Regarding O&M, there will another agreement to be signed later on.

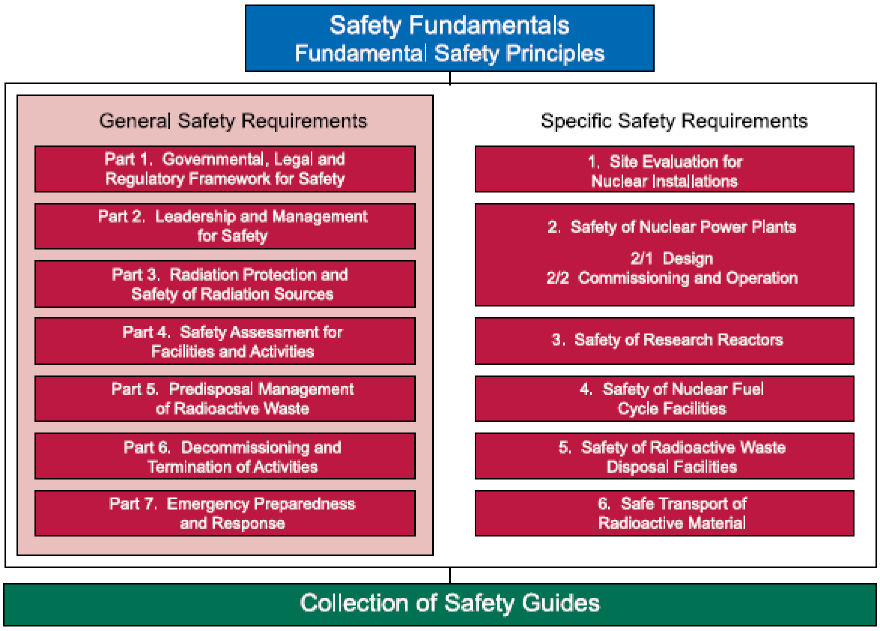
14.6.5 Challenges for Bangladesh

(1) Meeting IAEA safety standards5
Nuclear safety remains the highest priority for the nuclear sector. Regulators have a major role to play to ensure that all operations are carried out with the highest levels of safety. Safety culture must be promoted at all levels in the nuclear sector (operators and industry, including the supply chain, and regulators) and especially in newcomer countries (Nuclear energy roadmap actions and milestones, IEA, 2015) like Bangladesh. Followings are major frameworks to secure the nuclear safety to be followed and utilize for Bangladsh.

Nuclear safety is a global issue. There are many instruments for achieving high level of nuclear safety on a global basis, such as IAEA safety standards, safety review services provided by the IAEA. The

[3] World Nuclear News, World Nuclear Association, London, December, 2015
[4] Based on information from Secretary, Ministry of Science and Technology, 2015
[5] IAEA Safety Standards homepage

IAEA safety standards provide a system of safety fundamentals, Safety Requirements and Safety Guides for ensuring safety. They reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. The IAEA safety standards are applicable throughout the entire lifetime of facilities and activities existing and new utilized for peaceful purposes, and to protective actions to reduce existing radiation risks. For proceed nuclear power project, all shall follow the IAEA safety standards.



Source: IAEA Safety Standards homepage

Figure 14-14 Structure of IAEA Safety Standards

IAEA recommends some critical issue for strengthen nuclear safety

- The regulatory body should be strengthened. The draft Bangladesh Atomic Energy Regulations Act of 2011 should be promulgated as soon as possible to establish an independent regulatory body.
- Management of the nuclear infrastructure development should be strengthened. Bangladesh should commit to ensure appointment of leaders (especially in future owner and regulatory body) with appropriate training and experience for leadership and management of safety. Integrated management systems (including quality management) should be planned and implemented in both BAEC and the regulatory body that define the organizational goals and key processes in sufficient detail.

(2) Establishment of fuel cycle management[6]

Based upon the existing nature of the nuclear business worldwide, Bangladesh is considering a long-term contract and transparent suppliers' arrangements with supplier(s) through backing of the respective government in order to ensure availability of fuel for the nuclear power reactor of the country. Examples would be fuel leasing and fuel take-back offers, commercial offers to store and dispose of spent fuel, as well as commercial fuel banks. On the other hand, at present there is no international market for spent fuel disposal services except for the readiness of the Russian Federation to receive Russian supplied fuel. Storage facilities for spent fuel are in operation and are being built in several countries.

Bangladesh is considering accessing detailed technical descriptions of the nuclear fuel assemblies offered from the supplier side, including physical, thermo-hydraulic, thermodynamic and mechanical

[6] IAEA Country Nuclear Power Profiles, 2016 update

data as well as calculations for batch planning (short term and long term). The supplier shall provide the QA programme, Handling and inspection methods for new and spent fuel and Tools for fuel and control rod manipulation and the scope of supply and services. The first core as well as the first reload should be included in the scope of supply for the plant. The bidders should include the supply of further reloads as an option.

IEAE points out that the general concerns of Bangladesh about the nuclear fuel cycle are as follows.
- The owner/operator of the nuclear plant in Bangladesh needs to ensure availability of fuel for the NPP from supplier(s) covering its entire life cycle.
- The above life cycle supply assurance shall include all services related to the front end of the fuel cycle. “Fuel leasing-fuel take-back” model (full or partial) is conceivable for Bangladesh.
- Alternate sources of services and supply of the front end of fuel cycle should be identified to accommodate any unforeseen circumstances.
- Depending on the size of the nuclear power programme, efforts will be made to acquire the technology of fabrication of fuel elements based on imported raw materials and enrichment services in order to ensure security of fuel supply.
- Pending a final decision on the back-end of the fuel cycle, the NPPs will have provision for on/ off -site spent fuel storage, the size of which shall be sufficient to store the spent fuel generated over their respective life cycles.
- Sufficient security and physical protection and safety of the fuel storage on-site will be provided in accordance with the relevant provisions of the non-proliferation regime, as well as national law and regulations on nuclear safety and radiation control.

Bangladesh will consider any suitable model of nuclear fuel cycle under the responsibility of the IAEA as the guarantor of service and supplies, e.g. as administrator of a fuel bank.
Bangladesh opines that as far as assurances of supply are concerned, the proposed multilateral approaches to nuclear fuel cycle could provide the benefits of cost-effectiveness for developing countries with limited resources. Bangladesh is strongly supporting the Agency’s approach of developing and implementing international supply guarantees with IAEA participation.

(3) Proper knowledge about nuclear safety and Public Acceptance
Many kinds of programmes, such as meetings and seminaars with journalists, local people, have been arranged till now, and Bangladesh has established Nuclear Industry Information Center in 2013.[7] These kind of activities should be continued and enhanced for the public knowledge which will be the basis for public acceptance.
However, BAEC has conducted survey in 2015 on public acceptance / awareness for nuclear power project and it is found that still concrete public opinion for nuclear power generation has not yet formed in Bangladesh since accurate information of nuclear generation technology has not became widely and correctly known.
Therefore, the government has to do more supporting enlightenment activities to enhance accurate technical knowledge on nuclear generation with good point and bad point as well as safety issue.
It is also recommended to review other countries’ experience of interactive communication with public (citizen society) on nuclear technology and its safety, and ask for necessary cooperations.
As for emergency preparedness, several committees have been formed involving relevant stakeholders to formulate the emergency management system during the operation of Nuclear Power Plant in the territory of Bangladesh. These committees have already held several meeting with national and international experts. The Government is also very much eager to develop a standard emergency preparedness system for the densely populated country.

[7] Presentation by MoST, “NATIONAL NUCLEAR POWER PROGRAMME OF BANGLADESH”, https://www.iaea.org/NuclearPower/Downloadable/Meetings/2014/2015-02-03-02-06/D1_S2_Bangladesh_Akbar.pdf

Source: Ministry of Science and Technology, 2015

Figure 14-15 Nuclear Industry Information Center

In addition, the government is preparing the Multi purpose information center around Rooppur NPP site to strengthen public communication strategy with public and media. Expected PR-program is as follows;

- Scientific workshops & round tables, discussion clubs
- Information center
- Social networks/ Social activities
- Expert opinions
- Televisions (talks shows, documentaries)
- Book "100" Facts bout Nuclear Energy
- Communication of press releases & organization of interviews
- Interaction with neighboring countries…etc

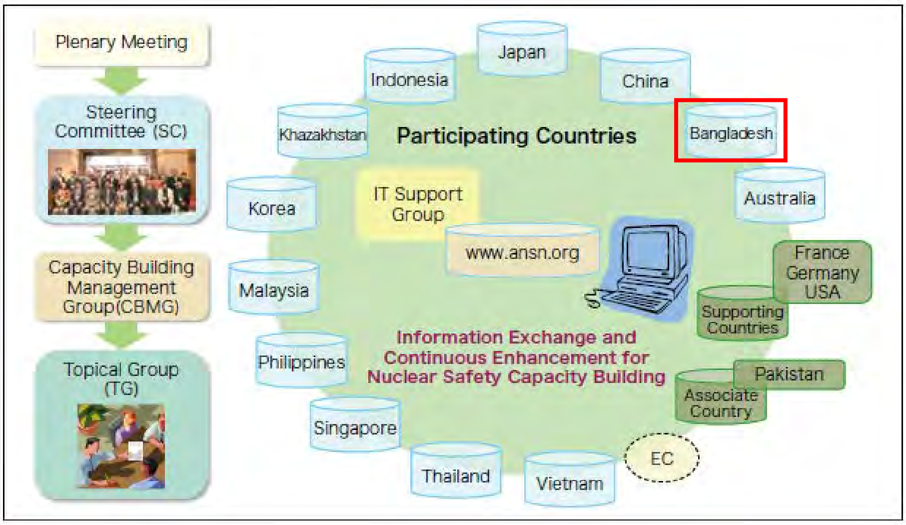
(4) Participating international framework[8]

The Asian Nuclear Safety Network (ANSN) was launched in 2002 to pool, analyze and share nuclear safety information, existing and new knowledge and practical experience among the countries. Moreover, the ANSN is expected to be a platform for facilitating sustainable regional cooperation and for creating human networks and cyber communities among the specialists of those countries. Development of a regional capacity building system composed of knowledge network, regional cooperation and human networks will serve for enhancement of nuclear safety infrastructures in the participating countries, and will serve eventually for ensuring and raising the safety levels of nuclear installations in the region. The ANSN has recently expanded to become a forum for broader safety strategy among countries in the region.

The current participating countries are **Bangladesh**, China, Indonesia, Japan, Kazakhstan, Republic of Korea, Malaysia, the Philippines, Singapore, Thailand and Vietnam. Australia, France, Germany and the USA are ANSN supporting countries. Pakistan is an associate country in activities related to the safety of nuclear power plants and/or strengthening their regulatory frameworks.

For proceed nuclear power project, all shall work with international framework.

[8] Asian Nuclear Safety Network homegage



Source: Japan Nuclear Energy Safety Organization

Figure 14-16 Asian Nuclear Safety Network (ANSN)

(5) Ratification to the international laws and standards

Bangladesh has not ratified the following critical international laws:

- Vienna Convention on Civil Liability for Nuclear Damage
- Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage
- Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, etc.[9]

For the implementation of RNPP, these international laws and standards should be followerd.

(6) Other issues

There are many issues such as;

- Nuclear power planning integrated into the part of power & energy planning, such as alternative generation capacity in case of outage of nuclear power plant, reliability of the power supply system
- Development of science technology experience within the country
- Emergency planning
- Protection of the power plant from natural disaster (e.g. cyclone, flood, earthquake, etc) or outside human disaster (e.g. terrorist activities, etc)

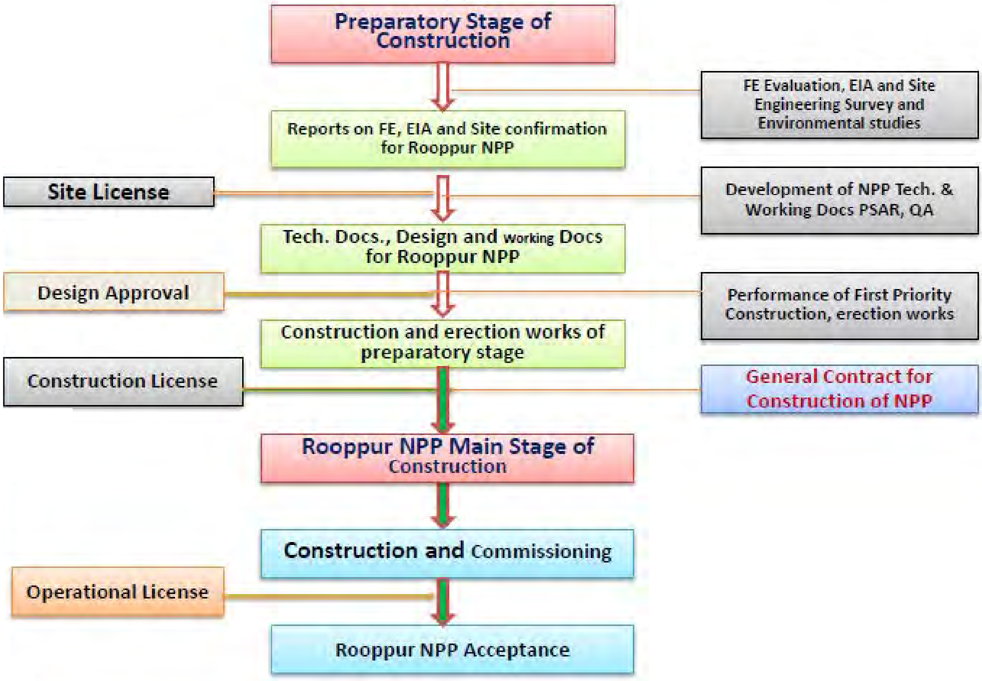
[9] IAEA factsheet: https://ola.iaea.org/ola/FactSheets/CountryDetails.asp?country=BD

14.6.6 Roadmap

(i) Construction

Consideration of the domestic legal and regulatory conditions to obtain;

- required licenses for building NPP,
- industrial base to support NPP construction,
- availability and competence of human resources for managing the NPP construction project,
- national resources as well as its social, economic and environmental condition to support NPP build.



Source: Ministry of Science and Technology, 2015

Figure 14-17 Roadmap for nuclear power development

(ii) Legal and implementation framework

All legal and implementation framework shall be established, and even be in an active before a commissioning of the first nucleare power generation as follows;

- Meeting IAEA safety standards
- Establishment of fuel cycle management
- Propoer knowledge about nuclear safety and public acceptance
- Participating international framework
- Ratification of the international law and standards

(iii) Comissioning of generation

- 2024/25: 1st and 2nd units
- 2030/31 3rd and 4th units
- 2040/41 5th and 6th units

Chapter 15 Power System Plan/ Rural Electrification (Distribution)

15.1 Power Network System Plan Tasks

The power network system planning will be examined by categorizing its phases into mid-term (2025) and long-term (2035) and reviewing PSMP2010. The required power system analysis will be carried out using PSS/E software. The Survey should take notice of the following issues.

Power Supply-Demand Imbalance among the Regions

The power interconnections with neighboring countries, the seaports for importing fuel and the mining points for domestic coal/gas will be scattered around the country, causing regional energy imbalance and requiring power trades among the regions. This trend appears to be growing and the transmission lines for regional connections will be further needed from the mid- and long-term points of view.

Power Imports and Exports via Interconnections

Power imports from the hydropower stations of neighboring countries such as India, Bhutan or Nepal are planned, in consideration of their potential for economical energy supply, due to the shortage of domestic gas supply and their role in broadening the energy sources for Bangladesh. The information regarding interconnections will be collected and the related detailed power system analysis will be carried out.

The Transmission Lines Crossing Rivers

There will be restrictions in power flow between the eastern and western sides of the country because Bangladesh has two large rivers in its center, Jamuna and Padma, with widths of 4.5km to 6km even at their narrowest points. It would entail much cost to construct power transmission lines across these large rivers.
A bridge across the Padma River was designed in detail in 2010 and the contractors that are currently under selection will also construct seven bases for towers for the 400kV transmission line connecting Khulna to Dhaka, located at its downstream side. This construction method may be applied for other river crossing transmission lines in Jamuna and Padma.

Optimal Operation Planning for Power System

Through the local power systems connecting to each other, improvement of power supply reliability and economic merit will be expected. On the other hand, new issues, such as concerns about accident impacts from weak points in the system upon the whole system and the necessity of different know-how to operate a large country-wide connection system, will be created. Countermeasures for the issues will be discussed and examined with the relevant counterparts.

15.2 Power System Plan Examination Criteria

15.2.1 Examination Methods

In this chapter, we examined a plan for a backbone power transmission and substation in Bangladesh up to 2035 based on the Bangladeshi power demand forecast, power development plan, and the power system plan for 2020 set out by PGCB.
Taking into account regional distribution of power stations and substations in the Bangladesh system, we confirmed through system analysis the validity of power flow, fault current and stability in 2025 and 2035. PSS/E software was used for system analysis.
System power demand was set based on the maximum expected demand on 132kV substations forecasted by PGCB, and on the aforementioned predicted value for system-wide maximum demand. Large-scale power stations are located in the Khulna region and in southern Chittagong, where development of seaports to expedite fuel imports is easy. Both locations are 200-300km from Dhaka, where power demand is highest. Therefore, to ensure supply reliability, we looked into consolidating power transmission routes. In addition, to reduce transmission routes and to cut costs, we looked into 765kV power transmission, alongside the 400kV system in the sections from Dhaka to Chittagong and from Dhaka to the Khulna region.
Finally, we estimated the scale of infrastructure investment for a 230kV-plus system, which will be necessary by 2035.

15.2.2 System Plan by PGCB for 2020

The system plan by PGCB for 2020 is shown in the figure on the next page. The black lines represent 400kV power lines, which are planned in a radial pattern from Dhaka toward Chittagong, Comilla, Bibiyana, Khulna, and Bogra. A ring of 400kV power lines will be constructed around the Dhaka metropolitan area, with 230kV power lines leading into the city, fed by the 400kV ring.
Table 15-1 shows a list of the on-going projects in March 2016, made by PGCB. The following are listed as projects for the installation of 400kV transmission lines and substations.

No. 1: Bibiyana-Kaliakoir 400kV transmission lines and substations and their related 230kV transmission lines
No. 4: Ghorasal-Tongi 400kV transmission lines and substations and the construction of their related 230kV and 132kV systems
No. 6: Ashuganj-Bhulta 400kV transmission lines and substations
No. 7: Aminbazar-Maowa-Mongla 400kV transmission lines and substations

The projects for expansion of the HVDC interconnection facilities to India are listed as follows.

No. 8: Expansion of Bheramara HVDC by 500MW and its related 230kV system

Nos. 2, 3, 5, 9-14 are projects for only 230kV and 132kV systems. No. 2 is the National Power System Network Development Project launched as a Yen-loan project.
Table 15-2 shows a list of the currently planned projects in April 2016, made by PGCB. The following are listed as projects for the installation of 400kV transmission lines and substations. No. 1 is the project for the installation of Matabari-Madunaghat-Meghnaghat 400kV with double circuits and Madunaghat and Meghnaghat 400kV substations.

No. 1: Matabari-Madunaghat-Meghnaghat 400kV transmission lines and substations
No. 3: Two 400kV substations in Dhaka, south of DPDC management area, and the construction of their related 230kV and 132kV systems
No. 4: One 400kV substation and 400kV transmission lines (their locations are unknown) and the construction of their related 230kV and 132kV systems

No. 5: Patuakhali-Gopalganj 400kV transmission lines and substations
No. 7: Madunaghat-Moheskhali 765kV transmission lines (initially operated at 400kV)
No. 8: Gopalgnj 400kV substation and 230kV and 132kV systems in the south regions
No. 9: Barapukuria-Bogra-Kaliakoir 400kV transmission lines
No. 11: 400kV transmission lines (including underground) and 230kV and 132kV system expansion in Chittagong
No. 12: Rooppur-Gopalganj 400kV transmission lines and substations and 230kV and 132kV system expansion
No. 13: Rooppur-Bogra 400kV transmission lines and 230kV and 132kV system expansion
No. 15: Banshkhali-Madunaghat 400kV transmission lines
No. 16: Kaliganj, Purbacha 400kV transmission lines (including underground) and substations in Dhaka, north of DESCO management area, and 230kV system.

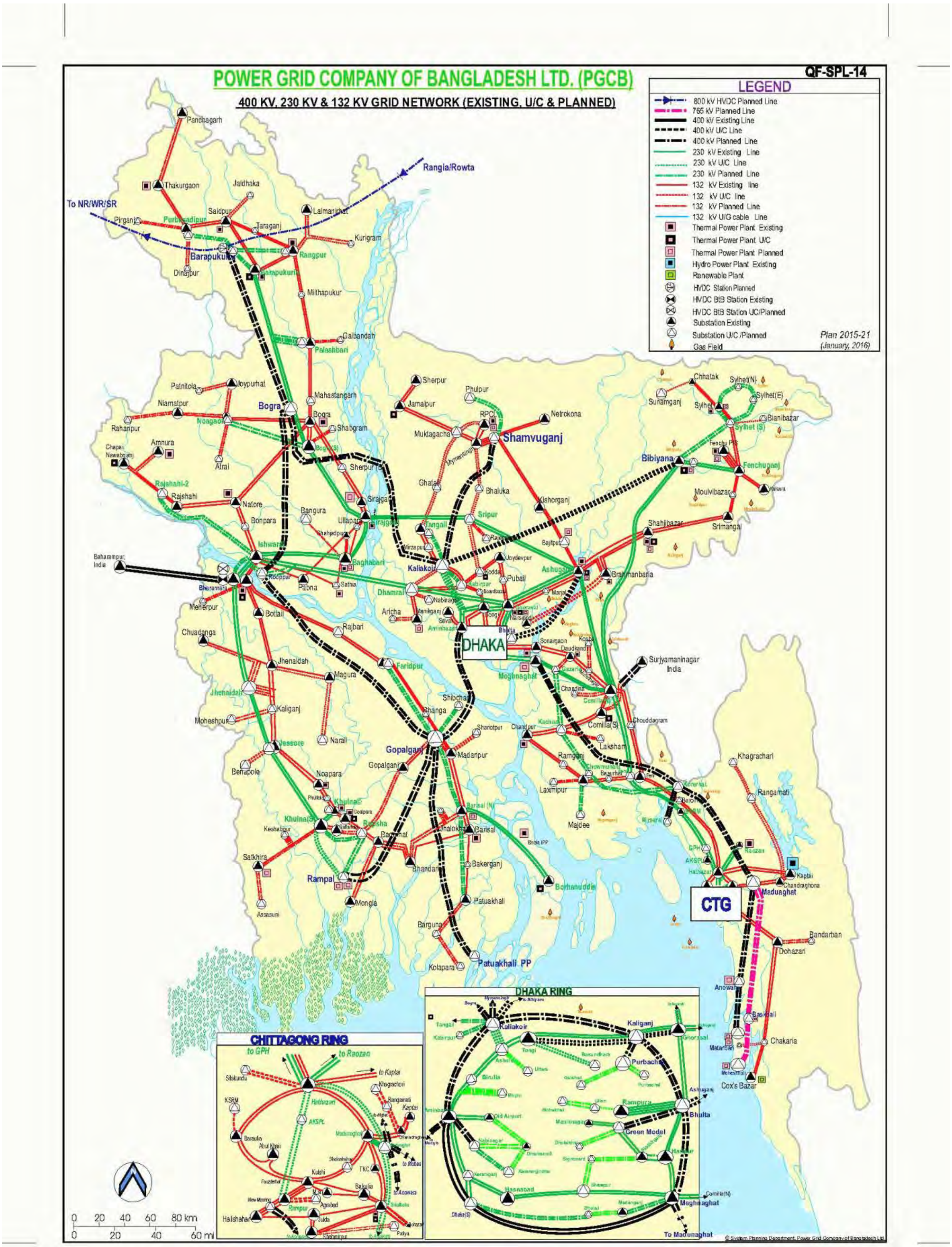
The project for the installation of the HVDC interconnection facilities to India is listed as follows.

No. 10: Barapukria 2000 MW HVDC Station

Nos. 2, 6, 5, 9 and 11-14 are projects for only 230kV and 132kV systems.
The 765kV transmission lines and substations and the 400kV underground lines included in the projects in Dhaka and Chittagong have been applied in other countries. However, they have only a shallow history of application. Thus, they should be designed with caution especially in consideration of the countermeasures for system overvoltage. Compact-scale substation facilities such as GIS or gas insulated transformers are expected to be applied in dense power demand areas such as Dhaka and Chittagong.

15.2.3 Examination of Power System Plan in this Study

The power system plan in this study is examined based on the reviews of the plan by PGCB and the discussions with them. The final results of the system plan are described in the latter half of this chapter.



Source: JICA Survey Team

Figure 15-1 Plan for Power Transmission System by PGCB

Table 15-1 On-going Projects by PGCB as of March 2016

SN	Projects Name	Scope of works	Main Objectives of the Project	Foreign Financing Status	Project Completion Year
1	**Bibiyana-Kaliakoir 400 kV and Fenchuganj-Bibiyana 230 kV Transmission Line (NG2)**	i) 168.64 km 400 kV Bibiyana-Kaliakoir Double ckt line. ii) 33.18 km Fenchuganj-Bibiyana 230 kV double ckt line iii) Installation of 400/230 kV 1x520 MVA transformer at Bibiyana. iv) 400/230 kV, 1x520 MVA & 400/132 kV, 2x325 MVA S/S at Kaliakoirv) 230/132 kV, 1x300 MVA S/S at Fenchuganj and renovation & extension of existing 132 kV substation at Fenchuganj vi) Construction of 36 km 230 kV line for turn-in and out of existing Aminbazar-Tongi230 kV line on four ckt tower at Kaliakoir. vii) Construction of 5 km 132 kV line for turn-in and out of existing Kabirpur-Tangail 132 kV line on four ckt tower at Kaliakoir. viii) Construction of16 km Kaliakoir-Dhamrai double circuit 132 kV line. ix) Construction of about 3.75 km 132 kV Four circuit transmission line on Four circuit tower from Fenchuganj SS to Fenchuganj PS	To build the power evacuation facilities for upcoming 2x450 MW CCPP at Bibiyana & to evacuate the surplus power of Sylhet area and also to supply adequate power to the northern part of Dhaka city.	**EDCF Korea & GOB**	July,2017 (Revised)
2	**National Power Transmission Network Development Project**	i) 230 kV Line: (a) 25 km Hathazari- Sikalbaha d/c TL (b) 25 km Hathazari- Rampur d/c TL (c) 5 km Hathazari- Rampur d/c u/g line ii) 132 kV Line: (a) 6 km d/c In Out u/g line of Khulshi-Halishaharline at new Rampur 132/33 kV GIS SS (b) 7 km d/c Rampur-Agrabad u/g (c) 132 kV interconnection line : 354 Ckt.km. iii) Two nos. 230/132 kV, 2×300 MVA Sub Stations at Rampur and Sikalbaha, Ctg. iv) 132/33 kV SS: 11 Sub Stations(1536 MVA) at Agrabad, Chowddagram, Benapole, Shariatpur, Ramganj, Baroirhat (Chg.), Bhaluka (Mymensingh), Barisal-(N), Mahastangarh (Bogra), Jaldhaka (Nilfamari), Rajshahi-2. v) Bay Extension:	i) To evacuate power from the proposed 225MWpower plant at Sikalbaha ii) Provide reliable power to Chittagong citythrough Rampur & Sikalbaha iii) Meet the growing load demand of the areas under the proposed new 132/33 kV substations atAgrabad (Ctg).; Chouddagram, Ramganj,Bhaluka (Myn), Baroirhat (Ctg), Benapol, Shariatpur, Barisal-(N), Mahastangarh (Bogra), Jaldhaka (Nilfamari) & Rajshahi-2	**JICA**	June, 2017
3	***132 kV Grid Network Development Project in Eastern Region***	i) 132 kV line: (a) 100 km RPCl-Tangail double circuitLine (b) 80 km Chandraghona-Rangamati-Khagrachari double circuit line (c) 55 km Brahmanbaria-Narsingdi double circuit line (d) 28 km Beanibazar-Sylhet(S) single circuit line on double circuit tower (e) 30 kmSunamganj-Chhatak single circuit line on double circuit tower ii) 132/33 kV SS: 4 nos. atRangamati, Khagrachari, Beanibazar, Sunamganj (each 82 MVA) iii) 132 kV Bay Extension : 17 nos. at Tangail (2), RPCL (2), Chandraghona (4), Brahmanbaria (2), Chhatak (1), Narsingdi (6). iv) 3 nos. of 132 kV Bay Modification at Narsingdi v) Conversion of Single Bus-bar configuration into Double Bus-bar at Narsingdi 132/33 kV S/S vi) Installation of one 132/33 kV 50/75 MVA transformer at Narsingdi S/S.	i) To increase the power supply reliability of Mymensingh area. ii) To reduce dependency on Ashuganj-Kishorganj 132kV line. iii) To evacuate the Power from the upcoming Power Plant in Mymensingh area. iv) To meet the growing demand of Rangamati, Khagrachari, Beanibazar & Sunamganj. v) To supply reliable power to Hill Tract area. vi) To minimize the accumulation of huge power at Ashuganj 132 kV bus bar. vii) To minimize the overloading of existing "Ashuganj-Ghorasal 132 kV transmission line". viii) To strengthen the power evacuation arrangement & increase power supply stability, reliability & transmission capability in Ashuganj & Ghorasal area.	**ADB**	June, 2016
4	***400/230/132 Network Development project***	(i)Construction of substations. a) 230 kV GIS Switching,Substation at Ghorasal b) 230/132 kV GIS, Substation at Ullon(2x225/300 MVA) , Basundhara (2x225/300MVA) & Shyampur(3x225/300 MVA) and 230/132 kV AIS Substation at Sripur(2x225/300MVA) c) 132/33 kV GIS, 2x80/120 MVASubstation at Ullon (d) 132/33kV SS at Rampur, Sholosahar,Sylhet(S), Kodda, Dhamrai, Kalurgaht, Kachua, Sitakunda, Rupshi, Sripur, Mirzapur. (ii) Construction of Lines. a) Construction of Ghorasal-Tongi 28 km 400 kV double circuit line. b) Construction of 132 kV line : 358 Ckt.km. c) Construction of 230 kV line : 62.6 Ckt.km. d) Re-conductoring 54 Ckt.km Ghorasal-Tongi 230kV line. e) 132/33 kV SS Renovation: Manikganj, Comilla(S), Madunaghat. f) 132 kV bay Extension : 4 g) 230 kV bay Extension : 6	i) To evacuate power from upcoming power plant at Ghorasal. (ii) To minimize the overloading of existing "Tongi-Ghorasal 230 kV transmission line". (iii) To meet up upcoming demand of Ullon and Dhanmondi area. (iv) To replace aged Ullon 132kV substation. (v) To strengthen the power supply stability, reliability & transmission capability in Ullon, Dhanmondi as well as inner of Dhaka city.(vi) To relieve the overloaded adjacent substations in different areas of the country(vii) To meet up upcoming demand of potential areas. (viii) To strengthen the power supply stability, reliability & transmission capability all over the country.	**ADB Tranche-2 Loan Package.**	June, 2017
5	***Enhancement of Capacity of Grid Substations and Transmission Line (Phase-I)***	i)Capacity Enhancement offive existing 132/33 kV S/S. ii)Construction of one new 230/132/33 kV S/S. iii) Construction of five new 132/33kV S/Ss. iv) Renovation / Upgradation of some existing transmission lines.	To meet the growing demand of respective area.	***WB***	June, 2017
6	***Ashuganj-Bhulta 400 kV Transmission line***	(i) **70 km** double ckt 400 kV line. (ii) **400/230 kV S/S at Bhulta**	To strengthing the power evacuation capability from Ashuganj to Dhaka.	***GOB & PGCB financing***	June, 2016
7	***Aminbazar-Maowa - Mongla 400 kV Transmission line***	i) 174 km 400 kV line ii) 400/230 kV 3x520 MVA at **Aminbazar**	To evacuate the Generated power of upcoming Rampal 1320 MW Coal Power Plant toDhaka & Khunla.	***ADB***	June, 2020
8	***Capacity Upgradation(500MW) of Existing Bheramara HVDC Station Project***	i.500MW BtB HVDC Station ii.Bheramara - Ishurdi 230 kV Double Circuit: 12km ii. Two 230 kV bay extension at Bheramara & Ishwardi	To import additional 500MW power from India.	***ADB***	June, 2018
9	***Western Grid Network Development Project***	i)Two no. of230/132 kV,2x225 MVA S/S at **Rajshahi & Jhenaidah** ii) 70 km Ishurdi-Rajshahi 230 kV Lines iii) 3 new 132/33 kVS/S at **Rajbaari, Mithapukur & Bangura(Pabna)** (iv) 60 km Khulna(S)-Gopalganj132 kV double ckt transmission line,	i)To meet the growing demand of Rajshahi area. ii) To enhance the power supply capacity & reliability of western Region.	***KfW***	June, 2018
10	***Barisal-Bhola-Borhanuddin 230 kV line project***	(i) 230KV Line (Double Circuit) : 61 km (ii) New 230/132 kV S/S:1 No (Barisal). 600 MVA (AIS)	To evacuate power to generated in upcomming Bhola power plant.	**PGCB Own Fund (HSBC)**	June, 2016
11	***Two New 132/33 kV Substations at Kulaura & Sherpur with***	(i)132 KV Line (Double Circuit) : 45 km (ii)New 132/33 kV S/S:2 Nos. (AIS) 1) Kulaura & 2) Sherpur (iii) 132 kV Bay Extension:4 Nos.	To meet the growing demand of the respective areas	**PGCB Own Fund**	June, 2016
12	***Goalpara-Bagerhat 132 kV Double Circuit Transmission***	(i) 45 km. 132 kV Double circuit lineand (ii) 4 nos. 132kV bay extension	To evaquite power from Goalpara Power Plant	**PGCB Own Fund**	June, 2016
13	***Mongla-Khulna (S) 230 kV Transmission Line Project***	i) 230 kV Mongla-Khulna d/c line :24km ii) Two 230kV bay extension at Khulna.	Power evacuation from coal based power plant at Mongla.	**PGCB Own Fund**	Dec, 2017
14	***Amnura 132/33 kV Grid Substation with Associated 132kV Transmission Line***	i) 132/33 kV AIS Substation, 1x35/50 MVA ii) 132kV line 15 km	To evacuate power to generated in upcomming 100MW power plant.	**Bidders Finance**	June, 2016

Source: PGCB

Table 15-2 Projects Planned by PGCB as of April 2016

SN	Projects Name	Scope of works	Main Objectives of the Project	Foreign Financing	Project Completio	Present Status
1	*Matarbari – Madunaghat – Meghnaghat 400 kV Transmission line (NG4)*	i) 314 km 400 kV line ii)400/230 kV, 3x520 MVA S/S at **Madunaghat & Meghnaghat** iii) 230/132 kV, 2x300 MVA S/S at **Madunaghat** iv) 230 kVLine: 16 km. v) 2 no. of 230 kV bay extension at Meghnaghat	To evacuate Generated power of upcoming CPP at Matarbari(1320MW), LNG PP at Anowara(1000MW) & transport the surplus power of Ctg area to Dhaka area.	*Expected from JICA*	2017-2021	DPP splitting into two part sent to Power Division on 14.01.2016. DPEC meeting held in Power Div on 07.02.2016. PGCB is now reviewing the DPP as per decision of DPEC meeting and will be submitted to Power Division.
2	*Energy Efficiency in Grid Based Power Supply Project*	i) Construction of 5 nos of 230/132 kV, 2x300 MVA s/s at **Purbasadipur, Naogaon, Feni, Bhulta & Biruli(Savar)**with interconnecting lines. ii) Construction of 8 nos of 132/33 kV s/s in rural areas (**Pubail, Gazaria, Ullapara, Bajitpur,Ghatail, Araihzar, Nabinagar & Rajendropur**) & interconnecting lines. iii) Renovation & upgragation of 9 nos of 132/33 kV s/s. vi) Upgradation & modification of 744 ckt-km 132 kV transmission line.	To meet the growing power demand & quality improvement of- -Dhaka City Adjacent -Greater Noakhali -Naogaon District -Saidpur District	*Expected from KfW*	June, 2019	Feasibility study report submitted. DPP under preperation
3	*Expansion and Strengthening of Power System Network Under DPDC Area*	i.400/230kV New Indoor GIS Substation :**2 nos. ,3000 MVA** ii.230/132kV New Indoor GIS Substation :**7 nos. ,7650 MVA** iii.New Transmission Line: - 400kV Line:**370 Ckt. km** - 230kV Line:**111 Ckt. Km** - 230kV Cable:96 Ckt. Km -132kV Line: **8.8 Ckt. km** iv.Bay Extension work at other Substations : **8 nos.**	To meet the growing power demand & quality improvement of- -Dhaka City & Adjacent	*Expected from EXIM Bank, China (G-G)*	December, 2020	Technical Feasibility Complete. Financial Negotiation in progress.
4	*Power Grid Network Strengthening Project under PGCB*	i.400/132kV New Substation :1 **no. ,650 MVA** ii.230/132kV New Substation :**13 nos. ,9200 MVA** iii.230/132kV Old Substation (Capacity Upgradation) :**7 nos. ,3075 MVA** iv.132/33kV New Substation :**28 nos. ,7240 MVA** v.132/33kV Old Substation (Capacity Upgradation) :**28 nos. ,3383 MVA** vi.Substation Renovation :**18 nos.** vii.New Transmission Line: - 400kV Line:**200 Ckt. km** - 230kV Line:**680 Ckt. km** - 132kV Line: **676 Ckt. km** viii.Old Transmission Line (All 132kV):6 nos. - Second Ckt. Stringing:**147 Ckt. km** - Conductor Upgradation :**312 Ckt. km**	· To meet nation-wide power demand & ensure quality improvement.	*Expected from EXIM Bank, China (G-G)*	December, 2020	Technical Feasibility Complete. Financial Negotiation in progress.
5	*Patuakhali – Gopalganj 400 kV Line & Gopalganj 400 kV Super Grid Sub-Station Project*	i) 400/230/132 kV SS: **Gopalganj** (1x520 MVA, 2x325MVA) ii) Patuakhali – Gopalganj 400 kV Double Circuit Line :165 km	· To ensure power evacuation from coal based power projects of Patuakhali area · To create a high capacity power evacuation node at Gopalganj.	**Proposed for IFC & GoB**	December, 2020	PDPP sent to planning commission 11-01-2015
6	*Enhancement & Strengthening of Power Network in Eastern Region*	i. 230/132kV GIS Substation: **2 nos (Chowmohoni, Kachua, 1750 MVA)** ii. 132/33kV Substation: **9no.(Muradnagar, Laksham, Maijdee, Paitya, Chandina, New Mooring, Basurhat, Laxmipur, Kosba, 1920 MVA)** iii. 230kV Line: **246 Ckt. km** iv. 132kV Line: **304 Ckt. km** v. 132/33kV SS Renovation: **01 no. (360 MVA)**	i. To enhance & strengthen existing grid network of Eastern Region. ii. To meet up the growing demand of Eastern Region. iii. To ensure reliable power supply to Industrial/ Commercial /Residence points of Greater Comilla, Chittagong, Greater Noakhali area.	**Expected from WB**	December, 2020	PDPP sent to Power Division on 19-08-2015 Consultant appointment for Feasibility Study in progress
7	*Madunaghat – Moheskhali 765kV Transmission line*	i) 765 kV Line: **200 Ckt. km** ii) Two 400 kV bay at Madunaghat	* To establish transmission infrastructure for evacuation of power to be generated from proposed power plants at Maheshkhali. * To provide reliable power to all over the country.	*Proposed for EDCF, Korea*	June, 2020	PDPP sent to Power Division on 30-08-2015

SN	Projects Name	Scope of works	Main Objectives of the Project	Foreign Financing	Project Completio	Present Status
8	*Grid Network Development Project at Southern Area*	i) 230kV Switching Station: **Korerhat, Gogalganj (400/230kV, 2x350/450 MVA)** ii) 230/132KV SS: **Mirsarai (4x350/450), Faridpur (2x350/450 MVA),** iii) 132/33 kV SS: **Phultola (2x80/120MVA) Jhalokhati, Kolapara, Barguna** (2x50/75 MVA Each) , **Kaliganj / Assasuni** (2x25/41 MVA) iv) 400 kV Line: 58 Ckt. km v) 230 kV Line: 270 Ckt. km. vi) 132 kV Line: 154 Ckt. Km.	To improve Southern Area power supply relaibility To ensure adequate and relaible power supply for Mirsarai Economic Zone	*Proposed for ADB*	June, 2020	PDPP sent to Power Division on 06-12-2015
9	*Baropukuria-Bogra-Kaliakoir 400 kV Transmission Line Project (NG-5)*	i.400 kV Line: 520 Ckt. km. ii. 400kV bay extension: 6 no's	· To ensure power evacuation from proposed Bangladesh-India eastern grid interconnection from Barapukuria.	*Proposed for Credit Loan (India)*	December, 2019	PDPP sent to planning commission on 22-01-2015
10	*North- Eastern Interconnection*	i.2000MW HVDC Station at **Barapukuria** ii.198km 800kV Bipole HVDC Line	* To connect the huge hydroelectric potential of Bhutan and Arunachal Province to India through Bangladesh territory * To draw 1000-2000MW power at Barapukuria from Cross Boarder Interconnection	**Yet to be Funded**	June, 2021	PDPP Under Preparation
11	*Expansion and Strengthening of Power System Network Under Chittagong Area*	i) 230/132/33 kV GIS SS: **Anowara, Khulshi** (2x350/450 MVA, 3x80/120 MVA) ii) 230/132kV GIS Swithing: **New Mooring** ii) 400 kV Line: 54 Ckt. km. (OH & UG) iv) 230kV U/G line: 44 Ckt. km v) 230kV bay extension: 2 no's	To improve CTG city power supply relaibility To meet growing demand of CTG City Adjacent Area	*Proposed for ADB*	June, 2020	PDPP sent to Power Division on 31.01.16
12	*Rooppur-Gopalganj 400 kV Transmission Line (NG-7)*	i) 400 kV Line: 330 Ckt. km. ii) 230 kV Line: 120 Ckt. km. iii) 132 kV Line: 40 Ckt. Km. iv) 400kV Bay extension at Rooppur S/S	· To ensure power evacuation from Rooppur NPP · To create power evacuation facilities for future NPPs at Rooppur.	*Yet to be Funded*	December, 2021	PDPP sent to planning commission 11-01-2015.
13	*Rooppur-Bogra 400kV Transmission Line Project (NG-6)*	i) 400/230 kV SS: **Bogra GIS (2x750 MVA)** ii) 400 kV Line: 200 Ckt. km. iii) 230 kV Line: 24 Ckt. km.	· To ensure power evacuation from Rooppur NPP · To create power evacuation facilities for future NPPs at Rooppur.	*Yet to be Funded*	December, 2021	PDPP sent to planning commission on 22-01-2015
14	*230 & 132 kV Transmission Network Development Project in Western Zone*	i) 230/132/33 KV SS: **Rupsha** (3x350/450, 2x80/120 MVA) ii) 132/33 kV SS: **Bhanga, Meherpur,Kesabpur, Mahespur** (2x50/75 MVA Each) iii) 230 kV Line: 92 Ckt. km. iv) 132 kV Line: 238 Ckt. Km. v) 132 kV Line Stringing: 82 Ckt. km. vi) 230 kV bay extension: 4 no's vii) 132 kV Bay extension : 8 No's	i)To meet the growing demand of Khulna & Barisal area. ii) To enhance the power supply capacity & reliability of Khulna & Barisal Region.	*Proposed for ADB*	June, 2020	PDPP sent to Power Division on 18.02.16
15	*Banshkhali-Madunaghat 400kV Transmission Line Project*	i) 400 kV line: 130 Ckt. km. ii) 400 kV GIS Bay Extension: 2 no's	(i) To ensure reliable transmission facilities to evacuate power from proposed coal based thermal PP project at Banshkhali (1320 MW). (ii) To meet the growing demand of the Chittagong	*Yet to be Funded*	June, 2019	PDPP sent to Power Division on 27.04.16
16	*Expansion and Strengthening of Power System Network in DESCO & its Adjacent Area (Phase-1)*	i) 400/230 kV GIS SS: **Kaliganj, Purbachal** ii) 230/132 kV GIS/GIT SS: **Gulshan, Uttara, Mirpur, Ashulia, Mohakhali, Purbachal-2** iii) 400 kV (O/H+U/G) line: 33 km iv) 230 kV (O/H+U/G) line: 74 km	To meet the growing power demand & quality improvement of- -DESCO & Adjacent area	*Yet to be Funded*	December, 2021	PDPP Under Preparation

Source: PGCB

15.2.4 Maximum Power Demand Forecast

(1) Load Borne by 132kV Transformer Substations

PGCB set a plan for 132kV transformer substations up to 2040 based on data from each power distribution company and forecast the maximum power demand for each substation. The list of planned 132kV substations prepared by PGCB and the maximum power demand forecast are shown on the following pages. A whole-system model was established during this survey's examination of the system plan, based on this list of planned 132kV substations.

(2) System-Wide Demand

The maximum system-wide power demand is shown below.

Table 15-3 Maximum Power Demand used for Power System Plan

Year	2015	2025	2035
Maximum Power Demand	8,920MW	19,874MW	37,221MW

Source: JICA Survey Team

Table 15-4 List of Planned 132kV Substations and Maximum Power Demand (Bogra)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Barapukuria	46	72	104	94	104	104	Hatibandha	0	0	0	0	43	43
Bogra	186	83	76	79	91	91	Kurigram	0	49	71	93	83	83
Matidali	0	0	0	60	69	69	Kurigram-2	0	0	0	0	39	39
Sultanganj	0	0	0	88	102	102	Mahastanghar	0	58	87	84	102	102
Joypurhat	38	60	87	79	92	92	Mithapukur	0	70	82	107	108	108
Hakimpur	0	0	0	78	100	100	Palashbari	74	65	88	114	103	103
Lalmonirhat	60	46	67	88	66	66	Gobindaganj	0	0	0	0	52	52
Naogaon	105	115	121	132	153	153	Panchagarh	21	40	67	97	66	66
Dupchachia	0	0	52	68	64	64	Panchagarh-2	0	0	0	0	43	43
Natore	84	57	72	94	109	109	Purbasadipur	77	73	113	109	126	126
Atrai	0	0	55	74	85	85	Birganj	0	0	0	48	55	55
Niyamatpur	62	78	112	122	142	142	Rajshahi (N)	0	87	72	94	84	84
Chowdala	0	45	65	85	99	99	Shahjadpur	71	44	61	78	90	90
Pabna	81	70	101	89	114	114	Sherpur (Bogra)	0	64	93	98	77	77
Ataikula	0	0	0	63	73	73	Bangura	0	43	62	82	95	95
Rajshahi	108	106	96	127	113	113	Bonpara	0	40	58	74	86	86
Rajshahi-3	0	0	0	0	85	85	Bogra (New)	0	82	133	124	100	100
Rangpur	104	85	73	96	88	88	Gabtoli	0	0	0	0	62	62
Pirgacha	0	0	70	92	94	94	Dinajpur	0	58	85	103	77	77
Rangpur-2	0	0	0	0	61	61	Dinajpur-2	0	0	0	0	55	55
Saidpur	90	70	105	100	115	115	Gaibandah	0	39	56	74	84	84
Parbatipur	0	0	0	61	70	70	Paglapir	0	64	92	99	114	114
Sirajganj	69	88	82	108	125	125	Patnitola	0	77	114	112	130	130
Thakurgaon	75	66	94	86	95	95	Mahadevpur	0	0	0	85	99	99
Thakurgaon-2	0	0	0	60	66	66	Pirganj	0	61	96	87	101	101
Amnura	0	45	64	82	95	95	Puthia	0	44	64	82	95	95
Bera	0	60	87	85	100	100	Bagha	0	0	69	90	105	105
Chapai Nawabganj	82	42	61	80	93	93	Ullapara	0	40	58	74	86	86
Tanore	0	0	69	90	105	105	Belkuchi	0	0	45	58	67	67
Jaldhaka	0	54	73	90	102	102							

Source: JICA Survey Team

Table 15-5 List of Planned 132kV Substations and Maximum Power Demand (Chittagong)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Bakulia	108	97	84	110	133	133	Fatikchari	0	0	52	55	61	61
Bakulia-2	0	0	70	94	114	114	Mirsharai	0	0	0	67	90	90
Cox's Bazar	65	94	110	115	75	75	Chandraghona	33	39	58	50	55	55
Teknaf	0	0	0	47	52	52	Kalurghat	0	70	78	104	127	127
Cox's Bazar-2	0	0	0	0	70	70	Khagrachari	0	45	64	82	104	104
Dohazari	74	92	68	100	70	70	Modern Steel	18	18	30	30	30	30
Bandarban	0	0	40	59	83	83	Matarbari	0	54	51	71	78	78
Chakaria	0	0	47	69	76	76	Baskhali	0	0	49	70	77	77
Lohagara	0	0	0	0	56	56	Moheskhali	0	0	47	63	69	69
Halishahar	159	72	50	67	90	90	Rampur	0	70	79	107	92	92
Patenga	0	0	79	105	127	127	Rampur-2	0	0	0	0	126	126
Hathazari	98	97	93	85	103	103	Rangamati	0	45	64	85	94	94
Raozan	0	0	0	80	88	88	Sholoshahar	0	67	56	75	92	92
Juldah	32	38	61	69	84	84	TKC	13	13	30	30	30	30
Kaptai	9	17	27	43	48	48	Bhoalkhali	0	0	53	59	72	72
Khulshi	186	140	149	199	178	178	F.hat	0	59	86	74	98	98
Nasirabad	0	0	86	120	168	168	Batiari	0	0	0	88	108	108
Khulshi-2	0	0	0	0	88	88	Newmooring	0	68	76	101	122	122
Madunaghat	57	57	77	83	112	112	Patiya	0	53	67	91	100	100
Shahmirpur	20	37	60	56	68	68	Sikalbaha-2	0	0	0	75	91	91
Sikalbaha	40	64	44	48	58	58	KSRM	0	30	50	50	50	50
Agrabad	0	79	70	98	95	95	KYCR	0	20	20	40	40	40
Agrabad-2	0	0	68	95	91	91	Kumira	0	0	77	80	120	120
Baroaulia	106	74	76	79	106	106	Sitakundu	0	69	71	84	112	112
Baroirhat	0	68	102	82	110	110							

Source: JICA Survey Team

Table 15-6 List of Planned 132kV Substations and Maximum Power Demand (Comilla)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Ashuganj	70	43	51	75	55	55	Barlekha	0	0	0	0	67	67
Chandpur	100	93	87	107	124	124	Kachua	0	63	95	111	79	79
Chandpur-2	0	0	70	74	86	86	Kulaura	39	53	83	117	103	103
Matlob	0	0	0	52	60	60	Ramganj	0	63	100	118	112	112
Chhatak	46	39	58	78	86	86	Raipur	0	0	0	0	54	54
Chowmuhani	155	90	142	105	123	123	Srimangal	43	54	86	121	88	88
Laxmipur	0	50	80	115	98	98	Srimangal-2	0	0	0	0	70	70
Sonaimuri	0	0	0	121	133	133	Sunamganj	0	50	80	69	80	80
Senbag	0	0	0	0	68	68	Sylhet	138	88	81	111	103	103
Comilla (N)	54	73	80	110	135	135	Sylhet©	0	0	92	128	126	126
Amratali	0	0	93	112	130	130	Biswnath	0	0	67	98	113	113
Maynamoti	0	0	80	110	97	97	Tuker Bazar	0	0	0	0	70	70
Comilla (S)	165	145	78	73	98	98	Sylhet (S)	0	73	75	114	118	118
Lalmai	0	0	84	105	122	122	Chandina	0	45	56	80	70	70
Daudkandi	71	84	108	126	146	146	Nimsar	0	0	0	0	87	87
Sachar	0	0	0	0	53	53	Gazaria	0	57	98	68	79	79
Feni	100	109	67	90	105	105	Baluakandi	0	0	0	72	84	84
Shahjibazar	66	54	86	81	97	97	Laksham	0	50	51	51	59	59
Nabiganj	0	39	60	60	72	72	Muradnagar	0	66	66	88	102	102
Derai	0	0	0	53	62	62	Homna	0	0	52	60	69	69
Madovpur	0	0	0	60	71	71	Maijdee	0	57	101	156	122	122
Brahmanbaria	89	85	97	132	87	87	Subarnachar	0	0	0	0	53	53
Kosba	0	56	54	73	84	84	Sylhet (N)	0	78	81	114	91	91
Beanibazar	0	55	57	76	90	90	Sylhet (N)-2	0	0	0	0	93	93
Darbosto	0	0	50	68	80	80	Basurhat	0	62	94	104	54	54
Chauddagram	0	83	131	125	145	145	Companiganj	0	0	0	62	72	72
Miarbazar	0	0	0	90	104	104	Feni-2	0	0	51	67	78	78
Fenchuganj	36	45	70	97	100	100	Feni-3	0	0	76	102	118	118
Moulvibazar	0	45	76	105	116	116							

Source: JICA Survey Team

Table 15-7 List of Planned 132kV Substations and Maximum Power Demand (DESCO and DPDC)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Cantonment	106	141	96	91	111	111	English Road	0	93	130	133	147	147
Gulshan	138	86	145	131	171	171	Goran	0	73	92	142	164	164
Gulshan-2	0	70	129	156	141	141	Green Model	0	56	99	171	130	130
Mirpur	106	125	139	133	162	162	Shyampur	161	161	160	214	163	163
Pallabi	0	0	0	108	133	133	Pagla	0	0	111	149	122	122
Aftabnagar	0	84	130	150	138	138	Farashganj	0	0	0	154	170	170
Banani	0	148	150	120	154	154	Ullon	79	88	94	125	145	145
Mohakhali	0	0	0	130	166	166	Niketon	0	0	136	151	192	192
Sainik Club	0	0	0	0	90	90	Old Airport	79	109	139	95	115	115
Bashundhara	174	81	100	152	179	179	Old Airport-2	0	0	0	93	114	114
Basundhara-2	0	0	75	114	126	126	Fatullah	0	130	168	209	213	213
Kalachandpur	0	0	0	104	132	132	Chasara	0	0	145	158	175	175
Badda	0	0	0	98	90	90	Kazla	0	82	144	113	103	103
Dumni	0	76	88	141	163	163	Lalbagh	86	72	106	149	165	165
Basundhara-3	0	0	0	0	137	137	BUET	0	0	0	0	119	119
Purbachal	0	52	73	152	145	145	Madertek	60	71	94	149	173	173
Purbachal-2	0	0	52	107	133	133	Motijheel	0	100	99	148	189	189
Purbachal-3	0	0	0	0	109	109	Panthapath	0	0	109	154	150	150
New Tongi	112	128	171	120	145	145	Postagola	0	114	155	217	165	165
Uttara	117	57	80	92	117	117	Shyampur-2	0	0	0	0	110	110
Uttara-3rd	0	89	179	115	161	161	Muradpur	0	0	0	0	194	194
Uttara-3rd-2	0	0	0	100	141	141	Satmasjid	72	53	94	143	158	158
Uttara-VI	0	0	0	126	179	179	Mohammadpur	0	0	48	73	113	113
Airport	0	75	127	97	124	124	Siddhirganj	142	67	78	91	141	141
Baunia	0	0	95	121	147	147	Sign Board	0	89	159	147	147	147
Mirpur-II	0	79	101	96	117	117	Adamjee	0	0	55	70	89	89
United City	0	58	89	143	166	166	Konapra	0	0	0	129	97	97
Satarkul	0	0	0	0	118	118	Rayerbagh	0	0	0	0	99	99
Uttarkhan	0	61	103	104	133	133	Sitalakhya	112	105	132	170	172	172
Dakshinkhan	0	0	0	89	113	113	Sitalakhya-2	0	0	0	172	204	204
Ashian City	0	0	0	85	113	113	Zigatola	0	98	104	154	171	171
Bangabhaban	51	42	56	69	76	76	Charsaidpur	0	96	146	118	150	150
Dhanmondi	157	125	118	159	136	136	Charsaidpur-2	0	0	0	126	161	161
Kakrail	0	0	94	151	199	199	New Ramna	0	120	113	158	169	169
DU	0	0	0	0	125	125	Bandar	0	44	66	79	101	101
Kallayanpur	124	127	103	131	159	159	Basila	0	46	62	113	158	158
Kallayanpur-2	0	0	80	102	124	124	Hazaribagh	0	0	120	129	175	175
Kamrangirchar	65	69	106	150	166	166	Rayerbazar	0	0	0	130	144	144
Azimpur	0	0	102	151	133	133	Ctg Road	0	0	0	80	74	74
Madanganj	89	59	99	95	127	127	Demra	0	0	0	0	112	112
Maniknagar	102	67	112	140	179	179	Near Balu River	0	0	0	0	91	91
Matuail	72	50	55	76	102	102	Amulia	0	0	0	0	106	106
Matuail Ext.	0	50	101	172	230	230	Khanpur	0	0	0	0	185	185
Godnail	0	0	0	86	115	115	Khilgaon Taltola	0	0	88	124	144	144
Moghbazar	160	125	124	182	153	153	Tejgaon	0	125	140	206	141	141
Railway Colony	0	0	0	0	138	138	Tejgaon-2	0	0	0	0	164	164
Narinda	103	116	139	150	191	191	Sarulia	0	0	0	0	90	90

Source: JICA Survey Team

Table 15-8 List of Planned 132kV Substations and Maximum Power Demand (Dhaka)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Nabinagar	0	0	74	89	99	99	Kishoreganj-2	0	0	0	0	76	76
Ghorasal	91	92	78	104	134	134	Madan	0	0	0	0	49	49
Shibpur	0	0	48	66	61	61	Kodda	0	136	121	159	194	194
Haripur	68	63	84	103	123	123	Mirjapur	0	88	80	107	130	130
Rahim Steel	18	35	35	35	50	50	Narsingdi	77	67	65	90	92	92
Hasnabad	183	85	126	107	141	141	Pachdona	0	0	75	103	108	108
Hasnabad-2	0	0	0	101	134	134	Rupshi	0	122	86	117	149	149
Ishwardi	38	57	56	73	85	85	Rupshi-2	0	0	101	136	173	173
Jamalpur	81	109	126	126	90	90	Nabinagar Housing	0	40	95	152	167	167
Bakshiganj	0	0	64	88	95	95	Sherpur	45	73	75	103	81	81
Jamalpur-2	0	0	0	0	79	79	Nandigram	0	0	0	0	56	56
Sherpur-2	0	0	0	0	64	64	Sonargaon	50	59	97	74	95	95
Kabirpur	189	81	73	101	84	84	Sonargaon-2	0	0	0	84	108	108
Shafipur	0	0	100	138	147	147	Sreenagar	0	68	80	110	134	134
Keraniganj	0	79	118	117	105	105	Sreepur	0	108	94	91	111	111
Ruhitpur	0	0	0	0	100	100	Sreepur-2	0	0	110	112	136	136
Manikganj	88	65	97	95	76	76	Shakhipur	0	0	79	106	134	134
Manikganj-2	0	0	0	0	90	90	Barmibazar	0	0	0	74	99	99
Munshiganj	101	108	117	161	125	125	New Tongi-2	0	0	0	105	128	128
Tongibari	0	0	66	91	98	98	Akrain	0	0	0	103	108	108
Munshiganj-2	0	0	0	0	90	90	Araihazar	0	57	63	85	109	109
Mymensingh	161	116	109	146	123	123	Aricha	0	45	69	82	83	83
Ishwarganj	0	0	77	104	119	119	Ashulia	0	66	99	72	46	46
Trishal	0	0	75	100	99	99	Ashulia-2	0	0	0	0	79	79
Mymensingh-2	0	0	0	0	107	107	Bajitpur	0	57	82	110	83	83
Nawabganj	0	68	101	135	141	141	Monohordi	0	0	0	0	97	97
Netrokona	60	90	76	102	79	79	Shibchar	0	0	0	51	62	62
Purbadhala	0	0	45	60	69	69	Boardbazar	0	62	72	99	132	132
Savar	92	53	79	70	88	88	Sataish	0	0	74	99	115	115
Singair	0	0	0	84	86	86	Dhaka EPZ	0	68	101	75	66	66
Tangail	128	92	60	82	105	105	Dendabor	0	0	0	103	106	106
Deldwar	0	0	52	70	81	81	Ghatail	0	45	69	94	120	120
Tongi	84	59	50	68	90	90	Dhanbari	0	0	0	74	77	77
Bhaluka	0	97	100	133	109	109	Hemayetpur	0	45	72	100	73	73
Gaforgaon	0	0	0	0	60	60	Hemayetpur-2	0	0	0	0	54	54
Bhulta	149	78	70	94	121	121	Madobdi	0	65	97	131	168	168
Kanchan	0	0	80	108	138	138	Marjal	0	62	67	92	94	94
Dhamrai	0	83	126	128	83	83	Mukhtagacha	0	64	99	105	121	121
Dhamrai-2	0	0	0	0	79	79	Nabinagar	0	57	85	49	63	63
Joydevpur	143	88	44	61	33	33	Sarail	0	0	0	0	97	97
BRRI	0	0	79	111	113	113	Phulpur	0	37	55	74	85	85
Shimulia	0	0	0	0	105	105	Pubail	0	61	68	94	126	126
Gazipur	0	0	0	0	81	81	Rajendrapur	0	70	95	68	91	91
Abdullahpur	0	48	72	99	119	119	Kapasia	0	0	0	62	83	83
Kishoreganj	61	74	77	103	86	86							

Source: JICA Survey Team

15.2.5 Power Generation Plan

Based on the power system plan noted in the previous chapters, generators were modeled using systems analysis data. The capacities of the generators as modeled by the systems analysis data are shown in the table below.

Table 15-9 Capacities of Generators as Modeled by Systems Analysis Data

Unit: MW

Bus Name	2025	2030	Bus Name	2025	2030	Bus Name	2025	2030
JMLPR DC	0	500	KAPTAI	230	230	DCBERM	1000	1000
JMLPR DC	0	500	ANOWARA	0	250	DCBERM	1000	1000
HARIPUR	400	400	ANOWARA	0	250	BHOLA	220	220
MUNSIGANJ	522	522	ANOWARA	300	300	KHULNA (S)	630	630
LALBAG	163	163	MATABARI	1104	1104	KHULNA (S)	1214	1214
ASHUGANJ	361	361	MATABARI	0	1200	ROOPPUR	1200	1200
SIDDHIRGANJ	328	328	MATABARI	0	1200	ROOPPUR	1200	1200
DHAKAG	635	635	PYRA	0	600	ROOPPUR	0	1200
GHORASAL	168	0	PYRA	0	600	ROOPPUR	0	1200
SIDDHIRGANJ	138	0	MOHESIKHALI	0	1200	PAYRA	1214	1214
SIDDHIRGANJ)	206	0	MOHESIKHALI	0	800	FARIDPUR	52	0
MYMENSHING	202	0	MOHESIKHALI	0	800	GOPALGONJ	107	0
HARIPUR	360	0	MOHESIKHALI	0	800	KATAKHALI	49	0
MEGHNAGHAT	450	0	MOHESIKHALI	0	800	NOAPARA	40	0
GHORASAL	108	0	MOHESIKHALI	0	500	SATKHIRA	50	0
ASHUGANJ	195	0	SHIKALBAHA	147	0	BHERAMARA	402	402
GAZIPUR	51	0	HATHAZARI	96	0	KHULNA (S)	221	221
SANTAHAR	49	0	DOHAZARI	99	0	KHULNA (S)	196	196
GOGNAGAR	102	0	RAOJAN	25	0	PYRA	0	800
BARAKA	50	0	POTIYA	108	0	PYRA	0	800
JANGALIA	52	0	PATIYA	100	0	PYRA	0	800
MUNSHIGONJ	51	0	JULDA	100	0	PYRA	0	250
KODDA	147	0	KAPTAIPSPP	0	100	PYRA	0	250
KERANIGONJ	100	0	SIKALBAHA	218	218	PYRA	0	500
KERANIGONJ	108	0	SALAM	612	612	BHOLA	189	189
JAMALPUR	95	0	SALAM	612	612	Khulna	8984	14486
MADANGONJ	55	0	Chittagong	3751	12176			
MANIKGONJ	50	0				DC BRPK	1000	1000
KAMALAGHAT	55	0	CHANDPUR	158	158	DC BRPK	0	500
NABABGONJ	55	0	SYLHET	221	221	DC BRPK	0	500
BHAIRAB	50	0	PSPP	0	1000	DC BRPK	0	500
ASHUGANJ	51	0	COM_INDA	500	500	BAGHABARI	102	102
ASHUGANJ	44	0	FENCHUGONJ	50	0	SIRAJGANJ	204	204
GHORASAL	352	352	DOUDKANDI	51	0	BARAPUKURIA	182	182
ASHUGANJ	218	218	BIBIYANA	341	341	BARAPUKURIA	252	252
ASHUGANJ	370	370	BIBIYANA	388	388	BAGHABARI	51	0
MEGHNAGHAT	305	305	SHAHJIBAZAR	98	98	BERA	70	0
GHORASAL	776	776	BIBIYANA	372	372	NATORE	52	0
Dhaka	7422	5430	SHAHJIBAZAR	322	322	CHAPAI	102	0
			Comilla	2501	3400	BARISAL	110	0
						SIRAJGANJ	414	414
						SIRAJGANJ	216	216
						SIRAJGANJ	216	216
						Bogra	2971	4086

Source: JICA Survey Team

15.2.6 Power Supply and Demand Balance by Region

Power supply and demand balances by region were calculated through system analysis, and the results are shown in the next table.

In 2025, at time of maximum demand, power supply in the Dhaka region will be 7,422MW, but demand will be 12,564MW, and because system loss will be 127MW there will be a total power shortage of 5,269MW. Furthermore, there will also be a shortage in the Comilla region of 696MW, and a shortage in the Bogra region of 171MW. However, the Khulna region has many large-scale power resources, including DC interconnection from Bheramara, 2,400MW from nuclear power, 1,214MW from Pyra, and others, with 4,905MW of excess power. In addition, the Chittagong region has large-scale power resources, including 1,104MW from Matarbari and 1,224MW from S. Alam, with 1,232MW of excess power. This excess power will be sent to Dhaka, Comilla, and Bogra to make up for the deficits in those areas.

Table 15-10 Power Supply and Demand Balance by Region in 2025 at Maximum Power Demand

Unit: MW

Area	Generation	Load	Loss	Interchange
Dhaka	7,422	12,564	127	-5,269
Chittagong	3,751	2,478	41	1,232
Comilla	2,273	2,929	40	-696
Khulna	7,984	3,007	73	4,905
Bogra	2,971	3,040	103	-171
Total	24,401	24,017	384	0

Source: JICA Survey Team

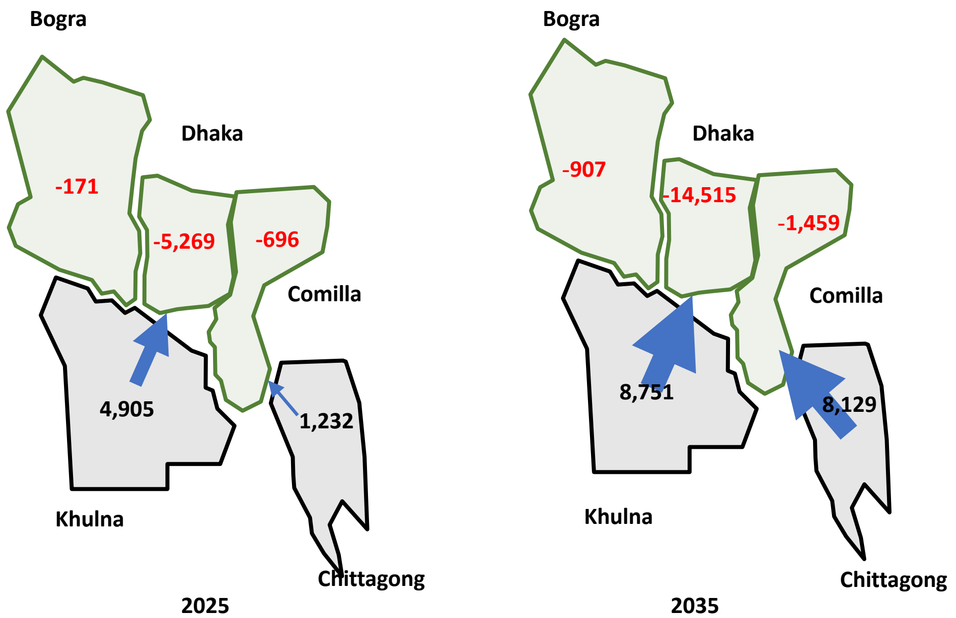
Table 15-11 Power Supply and Demand Balance by Region in 2035 at Maximum Power Demand

Unit: MW

Area	Generation	Load	Loss	Interchange
Dhaka	5,430	19,608	336	-14,515
Chittagong	12,176	3,867	180	8,129
Comilla	3,233	4,571	121	-1,459
Khulna	13,486	4,599	136	8,751
Bogra	4,086	4,744	249	-907
Total	38,411	37,389	1,022	0

Source: JICA Survey Team

The regional excesses and deficits listed in the table above are shown in the schematic maps below. Major power plants are clustered in Khulna and Chittagong, where development of seaports for fuel import is easy. However, the Bogra, Dhaka, and Comilla regions have power deficits, and will receive power supplies from Khulna and Chittagong.
In 2025, at time of maximum demand, 4,905MW will be sent from Khulna, and 1,232MW will be sent from Chittagong to make up for the power deficits in other areas. In 2035, at time of maximum demand, 8,751MW will be sent from Khulna, and 8,129MW will be sent from Chittagong to make up for the power deficits in other areas.



Source: JICA Survey Team

Figure 15-2 Power Supply and Demand Balance by Region

15.3 Setting Plans for 2025 and 2035

Based on the previously mentioned plan, expected power flow and the results of discussions with PGCB, the power network system plans for 2025 and 2035 have been set as shown below.

15.3.1 The Plan for 2025

Figure 15-3 and Figure 15-4 show the nation-wide 400kV system in 2025 and its expected power flow. The required facilities in the 400kV system up to 2025 are by the main regions described as follows. Some circuit breakers in a portion of the 230kV system in Dhaka and Chittagong are assumed to be operated in an open position in order to suppress the fault current levels.

(1) Dhaka area (Figure 15-5)

The 400kV substations of Meghnaghat, Bhulta, Green Model, Bashundara, Kaliakoir, Aminbazar, Gabtoli and Dhaka South are constructed. The 400kV transmission lines are constructed surrounding Dhaka city.

(2) Chittagong area (Figure 15-6)

The construction of 400kV Matabari-Madunaghat-Meghnaghat transmission lines with double circuits and 400kV Madunaghat and Meghnaghat substations will be launched as a yen-loan project. In addition, 400kV S. Alam-Matabari and S. Alam-Madunaghat transmission lines with double circuits will be constructed in accordance with the start of operations of S. Alam thermal power plant. The 400kV Mirsharai substation will also be constructed.

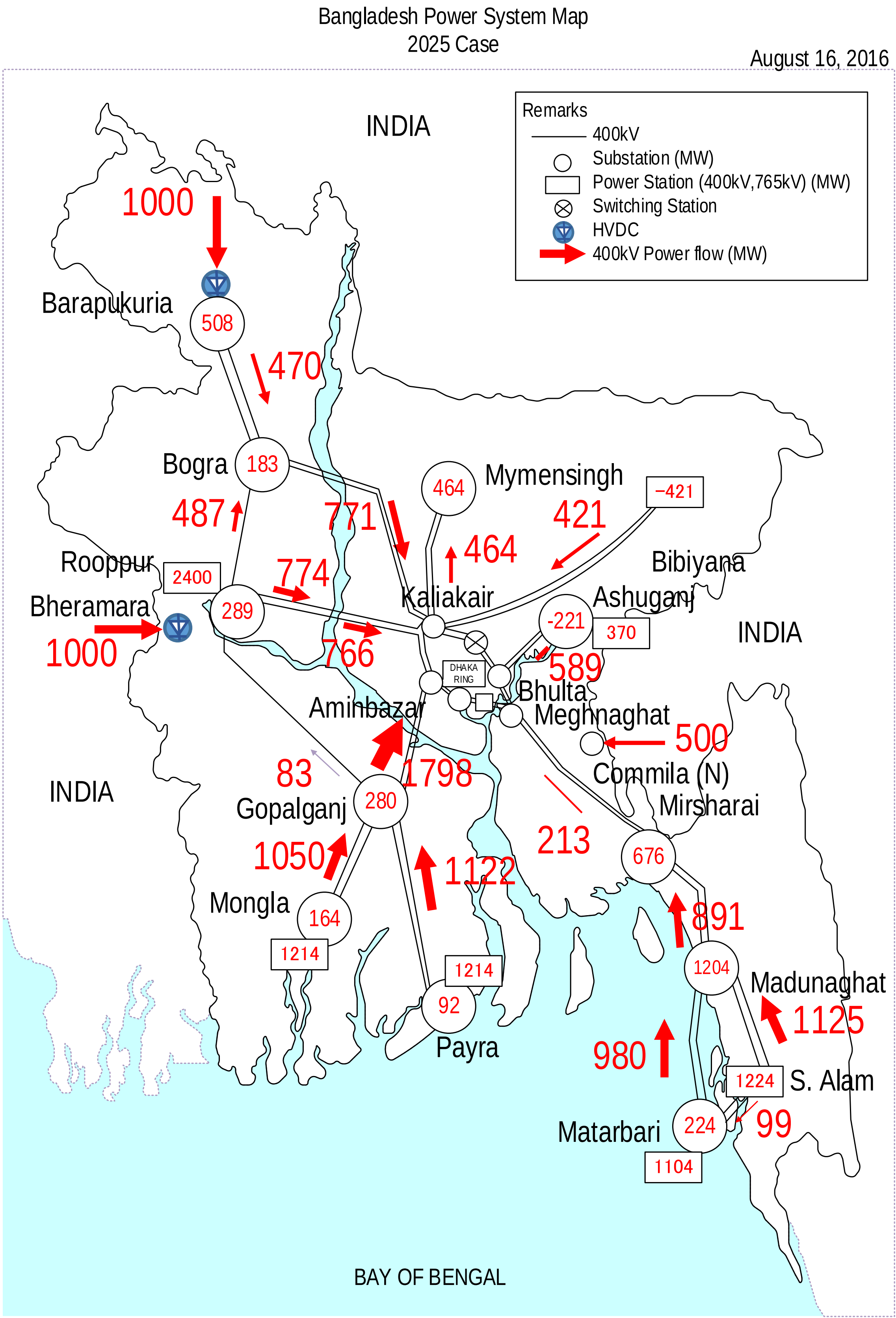
(3) Khulna area (Figure 15-7)

- Power Transmission for Rooppur Nuclear Power Station

400kV Rooppur-Kaliakoir and Rooppur-Aminbazar transmission lines with a single circuit will be constructed in accordance with the start of operations of Rooppur Nuclear Power Station. Single circuits of both Rooppur-Kaliakoir and Rooppur-Aminbazar are co-mounted on the same towers from Rooppur to a point near Dhaka city. The four circuits of the transmission lines will be derived from Rooppur to enhance the system reliability for power transmission from the nuclear power plant even if the Rooppur-Kaliakoir and Rooppur-Aminbazar towers collapse.

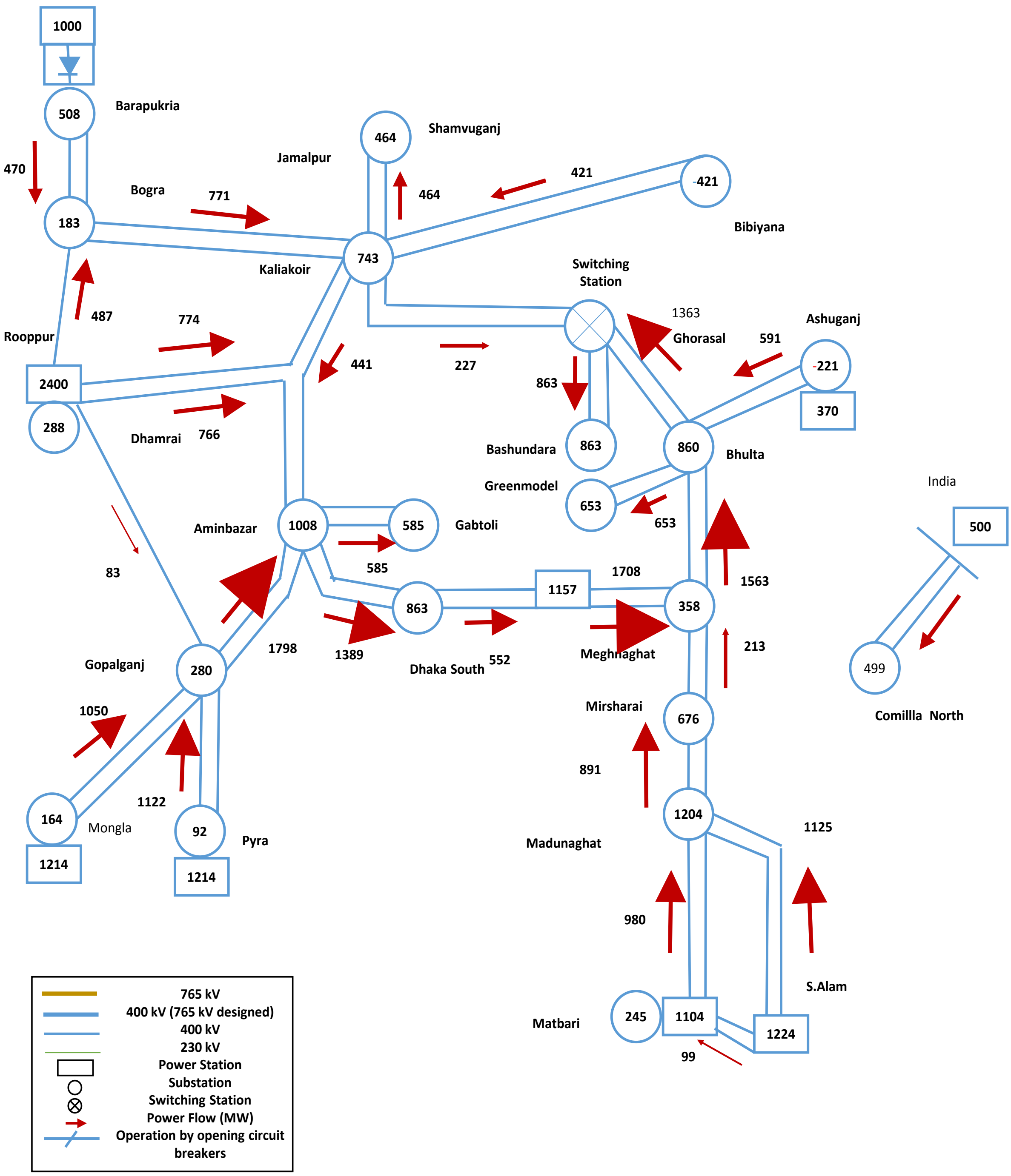
- Power Transmission for Mongla and Pyra (Patuakhali) Thermal Power Plants

400kV Mongla-Gopalganj, Pyra-Gopalganj and Gopalganj-Aminbazar with double circuits will be constructed in accordance with the installation of Mongla and Pyra (Patuakhali) thermal power plants.



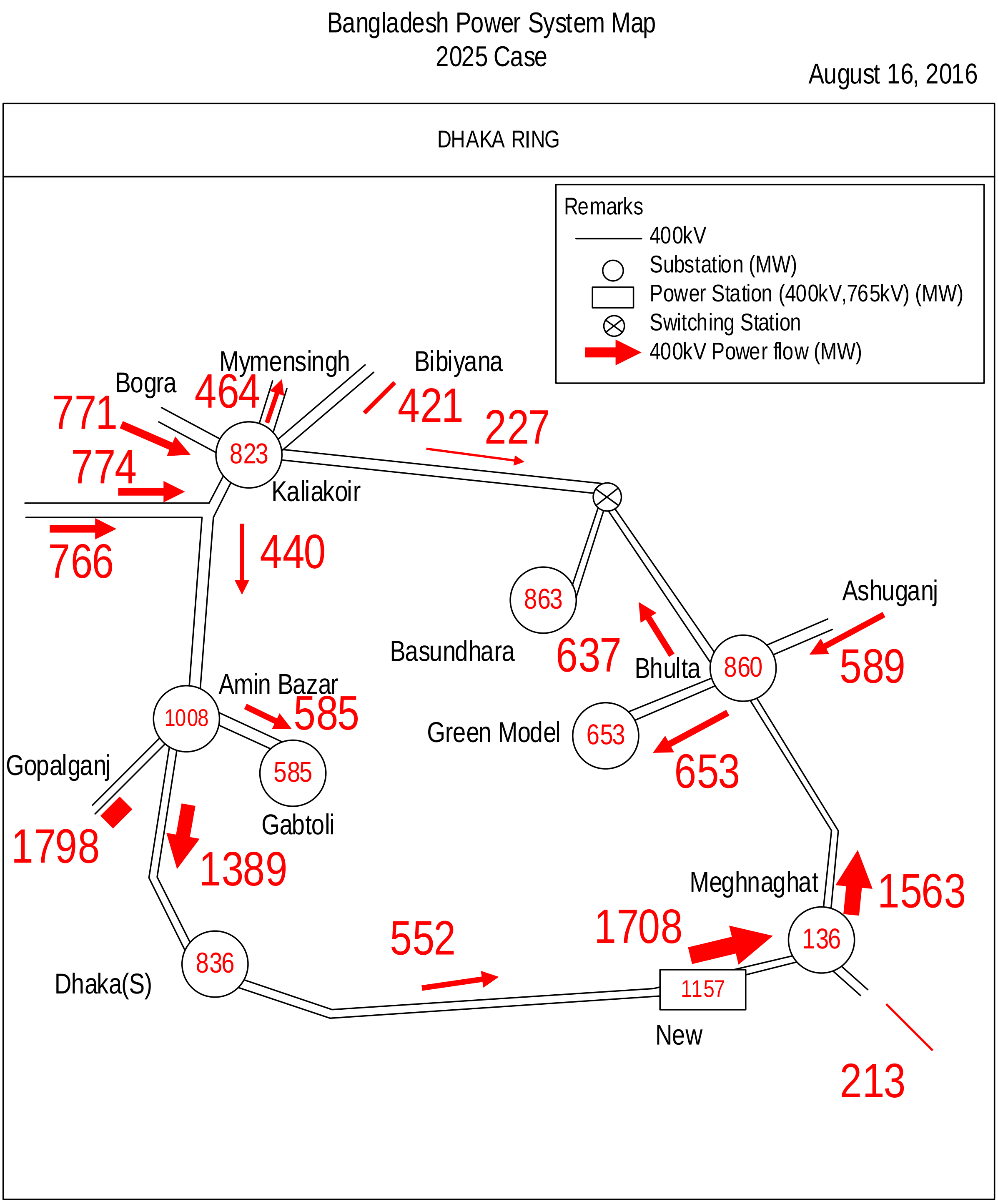
Source: JICA Survey Team

Figure 15-3 Map of Bangladesh System with Expected Power Flow in 2025 (Nation-wide)



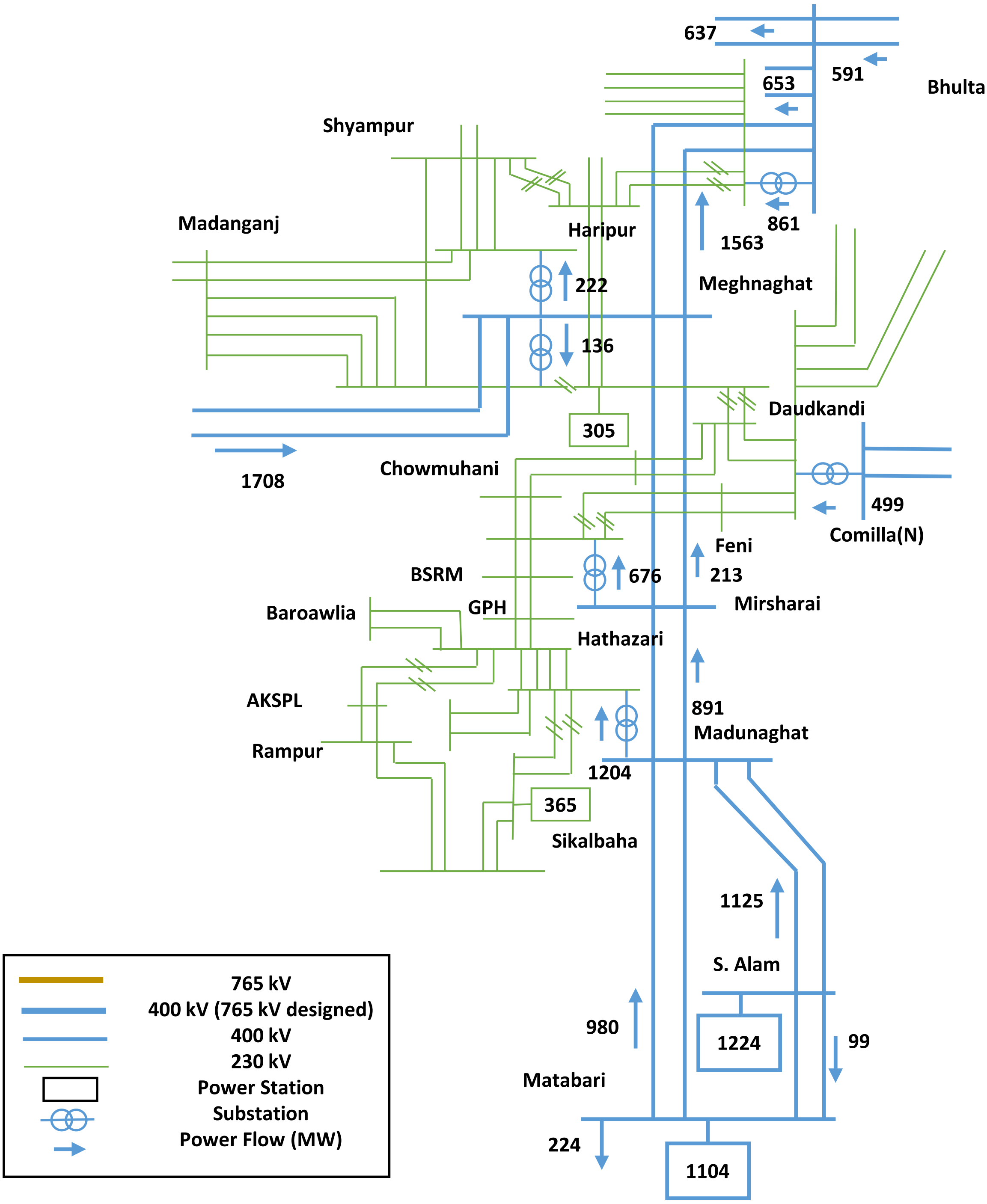
Source: JICA Survey Team

Figure 15-4 400kV System Diagram for Bangladesh with Expected Power Flow in 2025



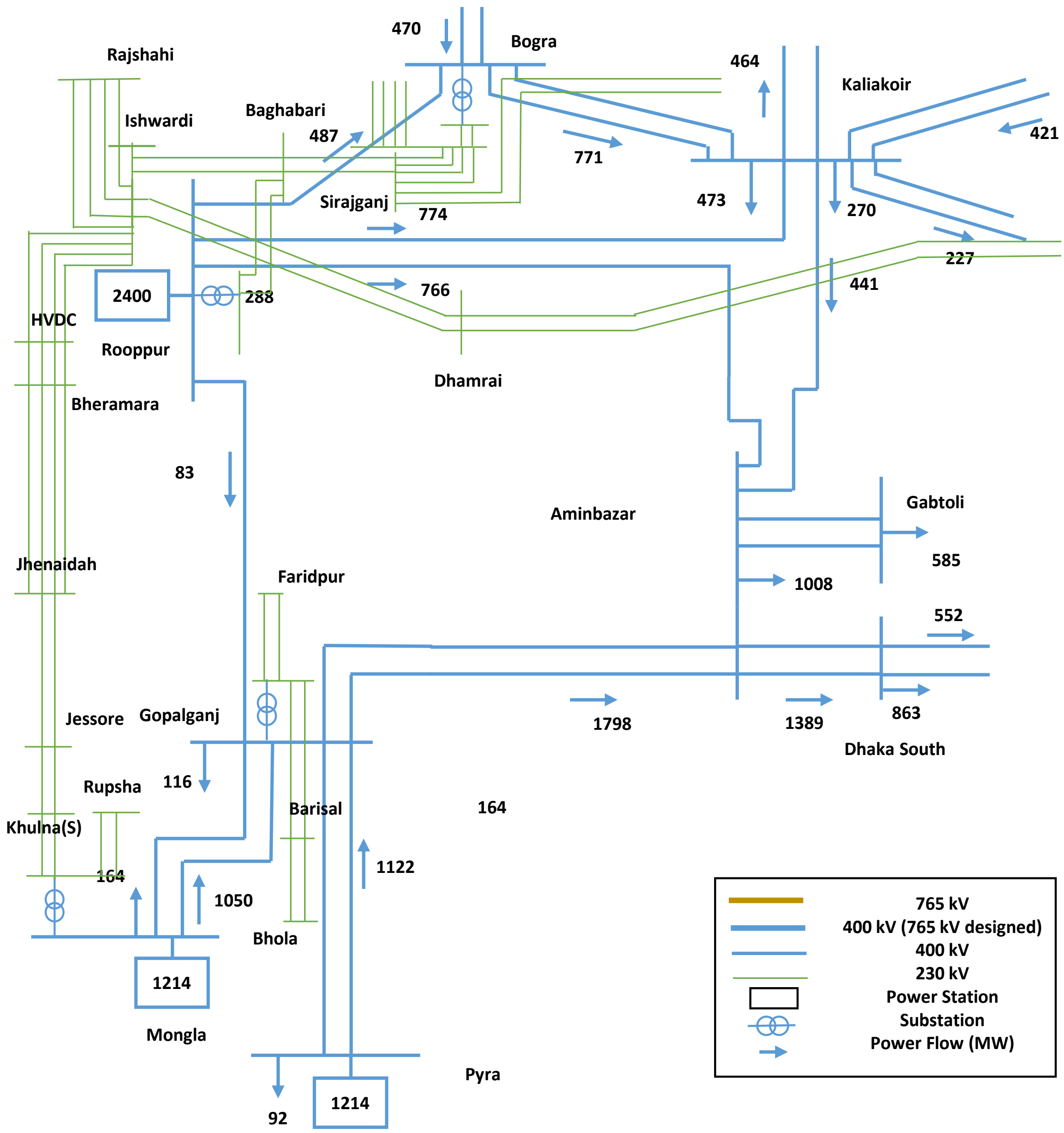
Source: JICA Survey Team

Figure 15-5 Map of Bangladesh System with Expected Power Flow in 2035 (Dhaka Area)



Source: JICA Survey Team

Figure 15-6 400kV System Diagram for Chittagong with Expected Power Flow in 2025



Source: JICA Survey Team

Figure 15-7 400kV System Diagram for Khulna with Expected Power Flow in 2025

15.3.2 The Plan for 2035

Figure 15-8 and Figure 15-9 show the nation-wide 400kV system in 2035 and its expected power flow. The required facilities in the 400kV system up to 2035 are described by the main regions as follows. Some circuit breakers in a portion of the 400kV and 230kV systems in Dhaka and Chittagong are assumed to be operated with opening in order to suppress the fault current levels.

(1) Dhaka area (Figure 15-10)

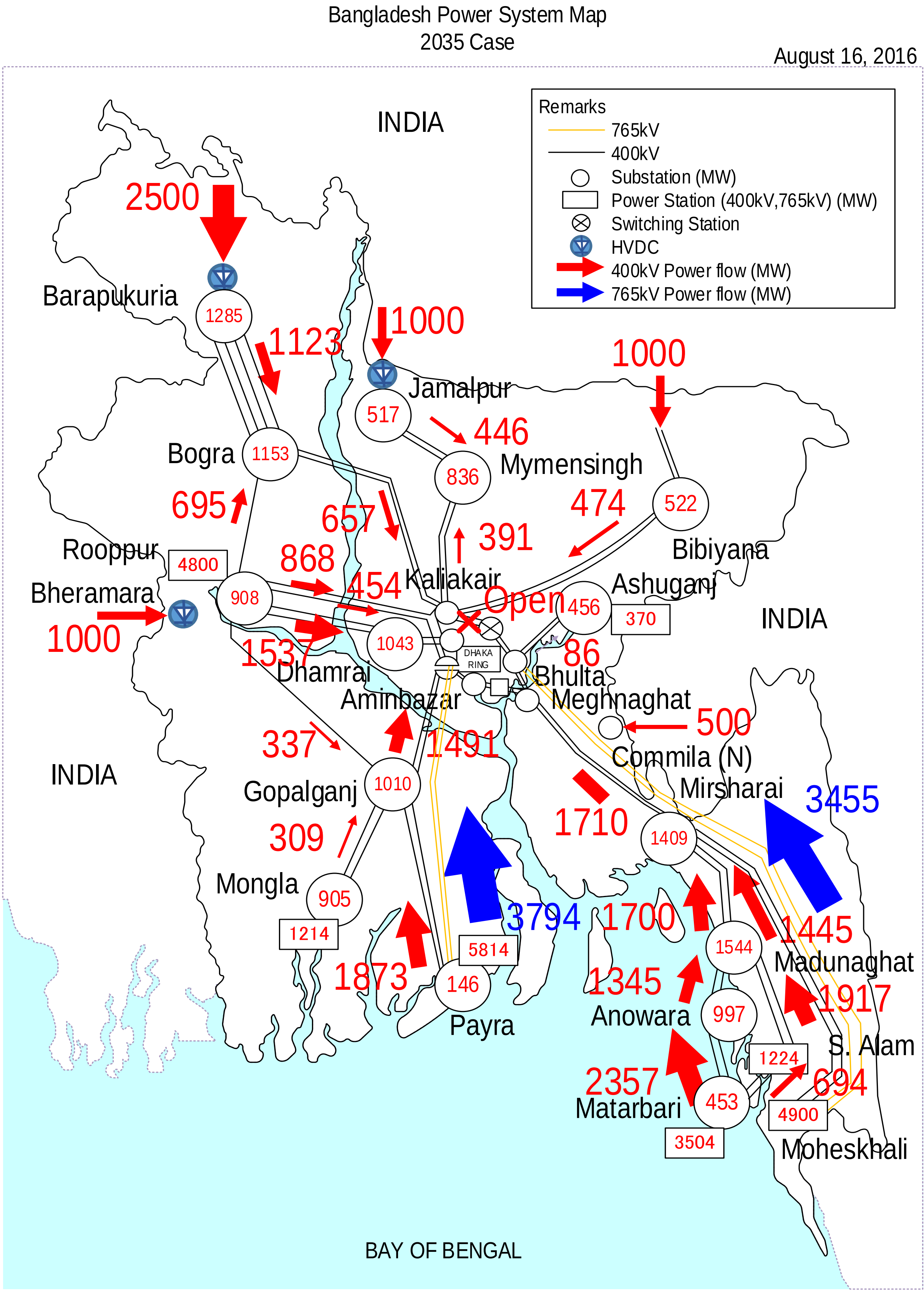
400kV Ghorsal, Tongi and Birlia substations will be constructed between 2025 and 2035.

(2) Chittagong area (Figure 15-11)

A 765kV Mohesikali-Bhulta transmission line with double circuits will be constructed between 2025 and 2035 in accordance with the start of operations of Mohesikali thermal power plant. The 765kV-designed Mohesikali-Mirsharai transmission line, operated at 400kV with double circuits, will be constructed. Some units of Mohesikali power plant will be connected directly to 765kV through their step-up transformers.

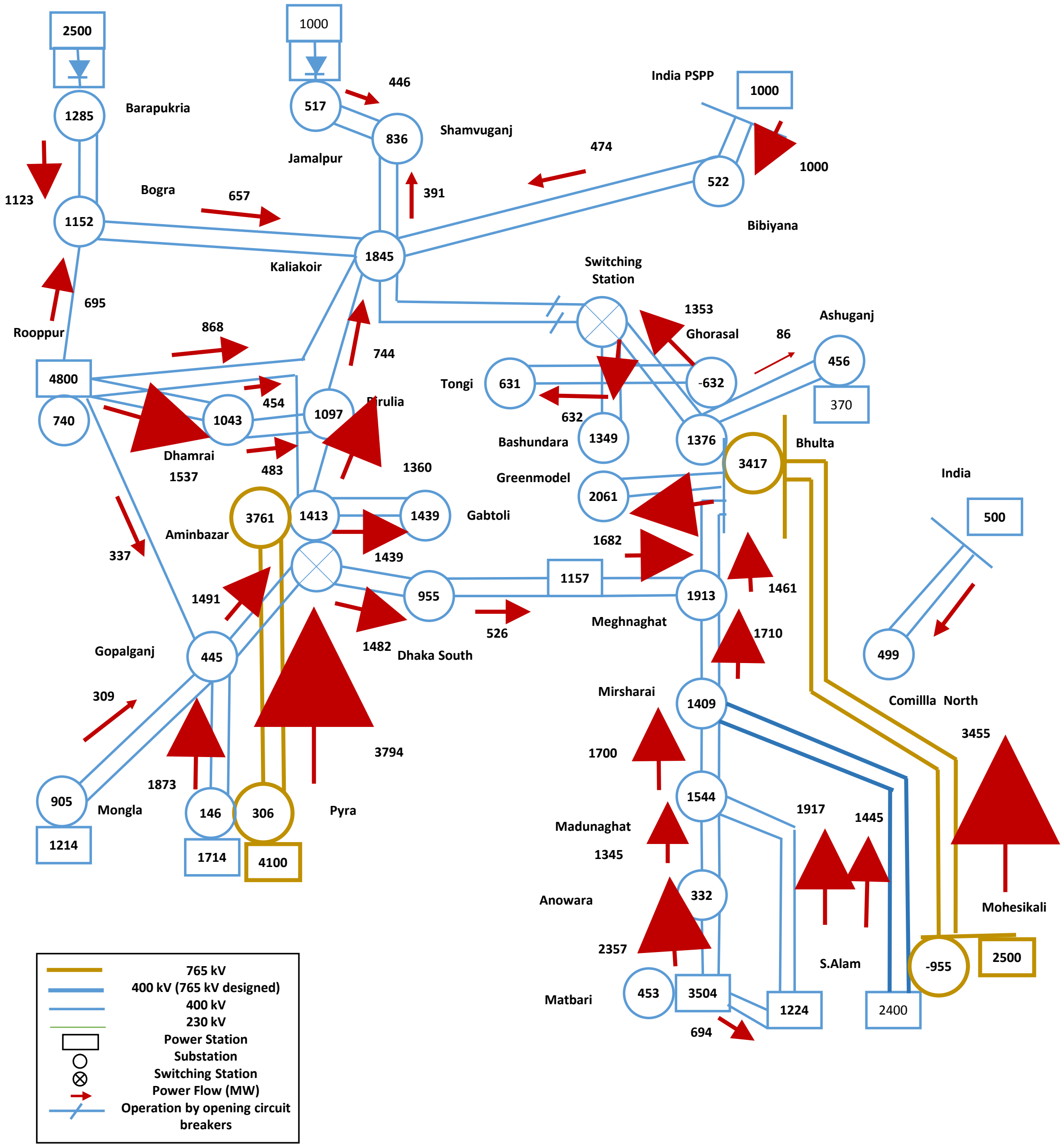
(3) Khulna area (Figure 15-12)

The 400kV Rooppur-Dhamrai-Birulia with double circuits will be constructed between 2025 and 2035.
A 765kV Pyra-Aminbazar transmission line with double circuits will be constructed in accordance with the additional installation of the Pyra (Patuakhali) units.



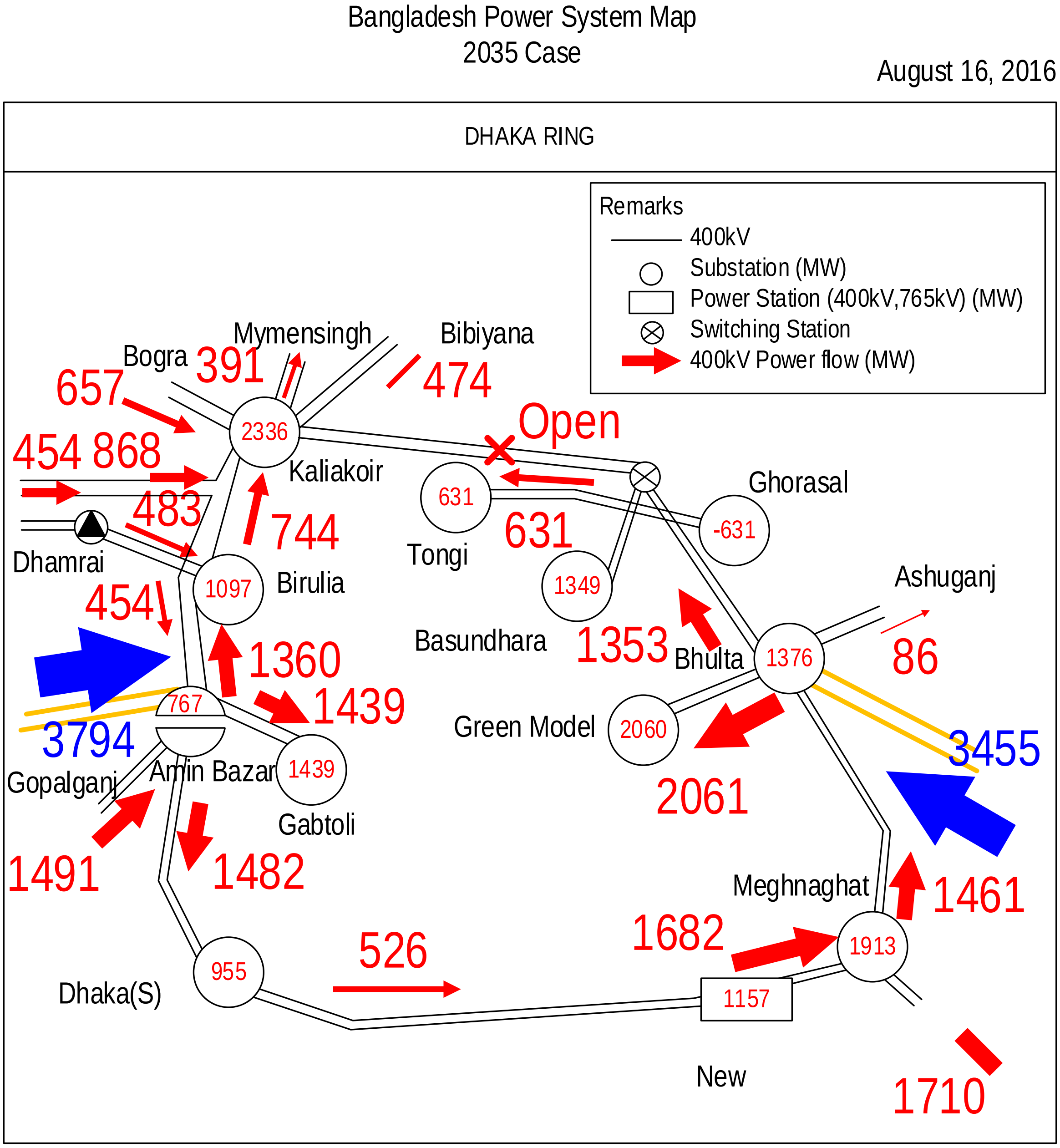
Source: JICA Survey Team

Figure 15-8 Map of Bangladesh System with Expected Power Flow in 2035 (Nation-wide)



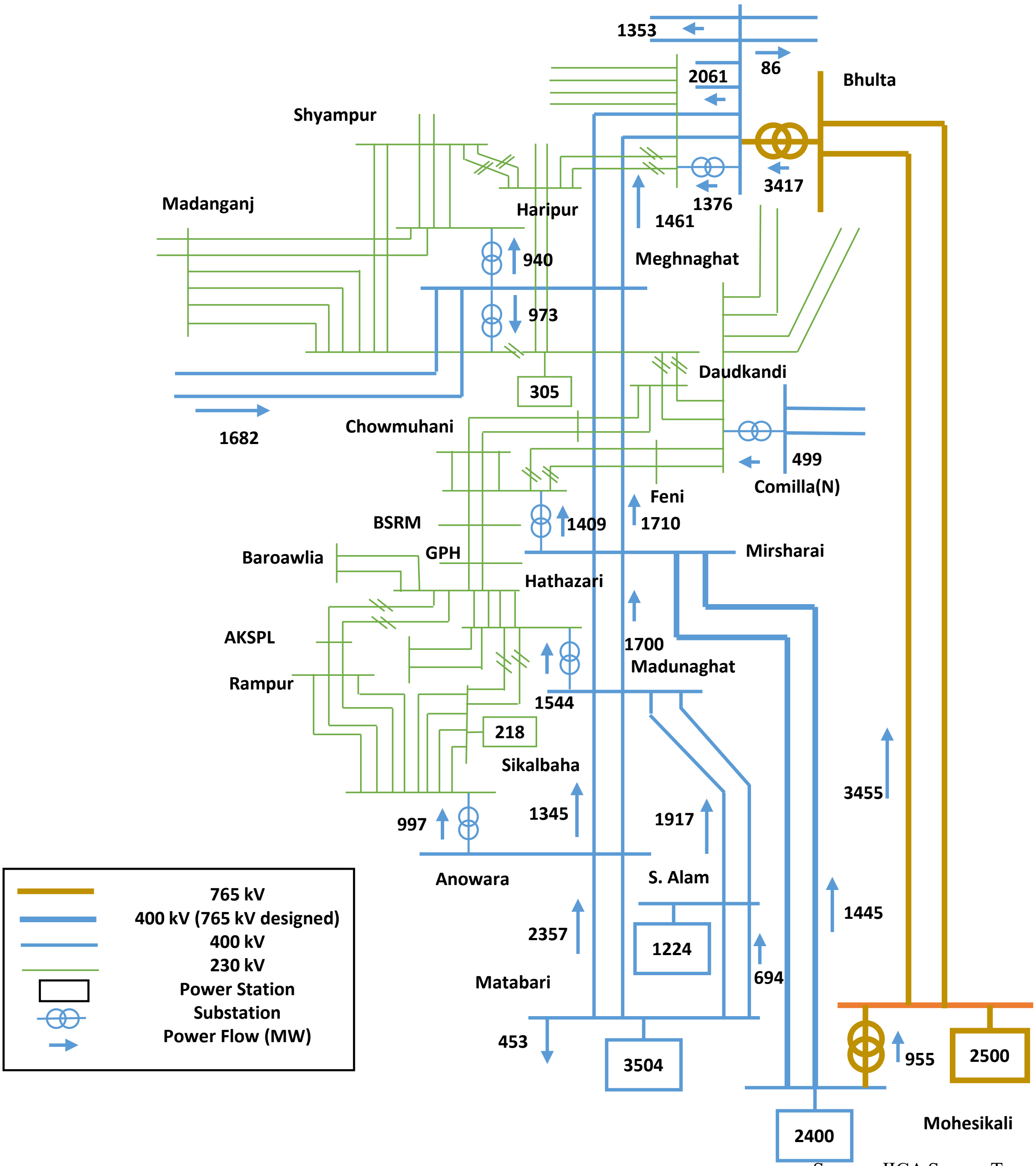
Source: JICA Survey Team

Figure 15-9 400kV System Diagram for Bangladesh with Expected Power Flow in 2035



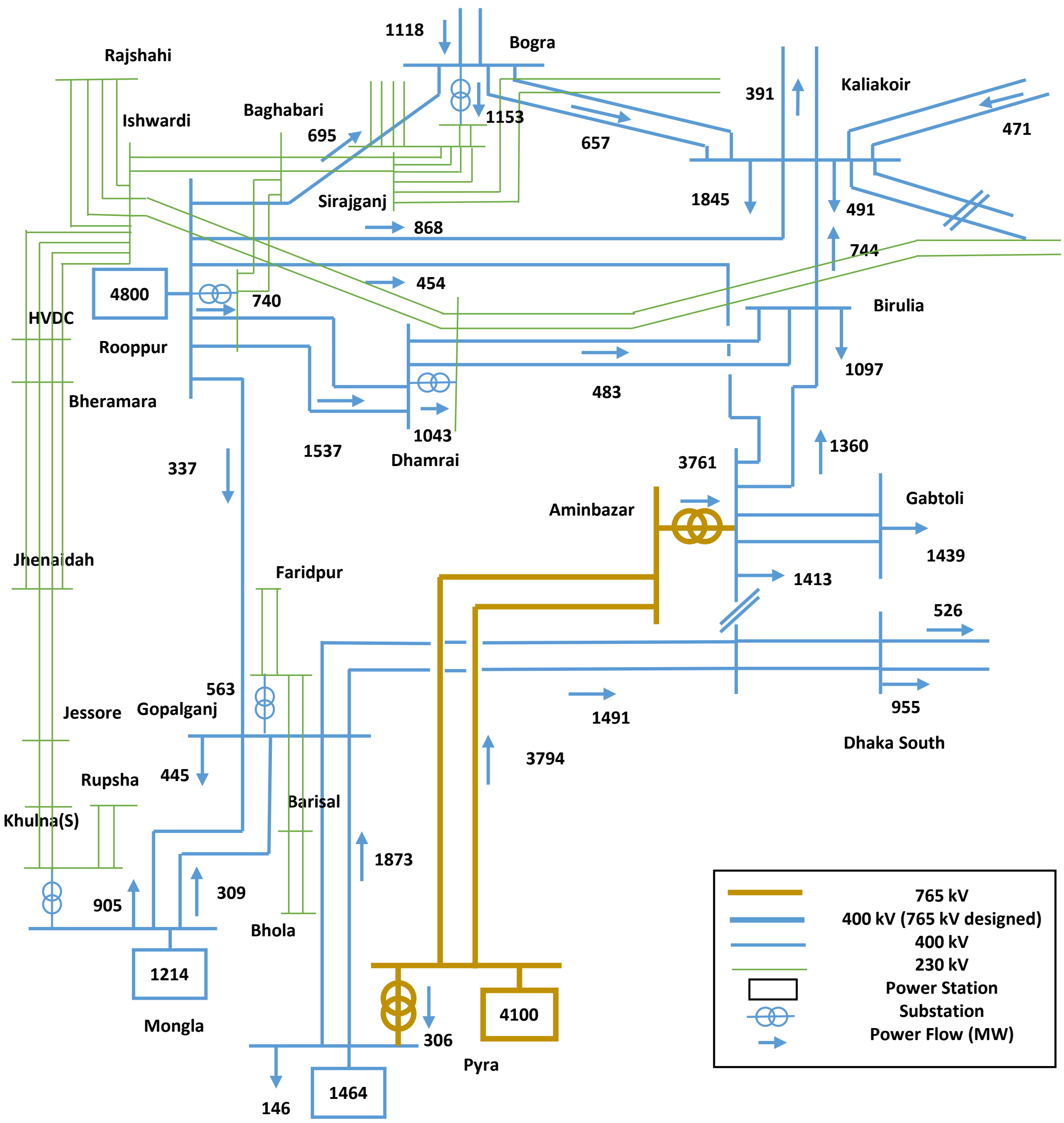
Source: JICA Survey Team

Figure 15-10 Map of Bangladesh System with Expected Power Flow in 2035 (Dhaka Area)



Source: JICA Survey Team

Figure 15-11 400kV System Diagram for Chittagong with Expected Power Flow in 2035



Source: JICA Survey Team

Figure 15-12 400kV System Diagram for Khulna with Expected Power Flow in 2035

15.4 Power System Analysis for 2025 and 2035

15.4.1 System Analysis Criteria

Based on the power demand forecast and power system plan detailed in the previous section, the following criteria were used to analyze power flow, fault current, and stability for the entire Bangladesh power system for 2025 and 2035.

(1) Generator Model

A model with fixed terminal voltage and active current output was used to calculate power flow.
Stability is calculated by applying the salient-pole model (hydropower generators), round-rotor model (thermal power generators), and exciter model, as listed below. A portion of the generators was assumed to be equipped with a power system stabilizer (PSS). A direct current model was considered for grid connections with India.

Thermal Generator (Round-rotor model)

T'do	T"do	T'qo	T"qo	H	D	Xd	Xq	X'd	X'q	X"d = X"q	Xl	S(1.0)	S(1.2)
8.73	0.045	0.97	0.068	2.607	0	2.26	2.2	0.275	0.405	0.214	0.1	0.12	0.6

Hydropower Generator (salient-pole model)

T'do	T"do	T"qo	H	D	Xd	Xq	X'd	X"d = X"q	X1	S(1.0)	S(1.2)
5	0.05	0.06	5.084	1	1.5	1.2	0.4	0.2	0.12	0.03	0.25

Exciter Model

TA/TB	TB	K	TE	EMIN	EMAX
0.1	10	100	0.1	0	5

Power System Stabilizer

T1	T2	T3	T4	T5	T6	KS	LSMAX	LSMIN
0.06	0.18	0.06	0.18	5	1.5	-0.75	0.1	-0.1

(2) Load Model

A constant power model was used as the load model for calculating power flow.
A model with constant current for active current and constant impedance for reactive power was used to calculate stability.
In addition, the loads of 132kV substations to be newly installed in the future were modeled at the 132kV substations that would be expected in the vicinity up to 2020. As necessary, the 132kV transmission lines were assumed and incorporated into the completed model.
Load factors at 132kV buses are assumed as 0.9.

(3) Power Transmission Line Model

The values listed below were used for the line constants for power lines to be newly installed in the near future.

Line Impedance for New Power Transmission Lines (Unit: p.u./km (100 MVA base))

	R	X	Y
765kV (6 x ACSR 480)	0.0000018095	0.0000471520	0.0243821390
400kV (4 x Finch)	0.000008554	0.000151229	0.007651757
230kV (Mallard)	0.00015	0.00077	0.001488

(4) Substation Model

The values listed below were used for the main specifications of substations to be newly installed in the near future.

Transformers	Unit Capacity	Primary-Secondary Impedance
765/4000kV	2,250 MVA	13.5%
400/230kV	750 MVA	12.5%
230/132kV	300 MVA	12.5%
Generator Step-up Transformer (Thermal, Hydro)		12.5%
Generator Step-up Transformer (Nuclear) *)		15%

*) Because fault currents around Nuclear Power Stations in the Bangladesh system are high, high-impedance transformers were assumed.

(5) HVDC Model

HVDC model is used for the HVDC interconnection to India.

(6) Capacitor and Reactor Model

Shunt reactors to compensate for the line charge of the 765kV transmission lines and the long distance 400kV lines are installed at some intervals.
The shunt capacitors are assumed to be installed at the areas of the system where voltage drops are observed.

(7) Planning Criteria

- Power Flow

Even when a unit of transformers or a single circuit breaks down, the power flow should be below the capacity of the remaining facilities.
However, for the double circuit lines leading from a nuclear power plant, when the double circuits break down the power flow should be below the capacity of the remaining circuits.

- Fault Current

Fault current was calculated using the IEC60909 method. The fault current levels for the 400kV and 230kV systems were evaluated as symmetric components of the fault current 100ms after fault occurrence.
The allowable fault current levels should be less than 50kA at buses of 765kV, 400kV and 230kV.

- Stability

A three-phase short circuit fault at the near end of the bus was assumed. After fault clearance, convergence of fluctuations in the generator angles was checked and stability was determined.

15.4.2 Power Flow Calculation

It is confirmed that the power flow in the 765kV, 400kV and 230kV systems meets the criteria for every case in 2025 and 2035.

15.4.3 Fault Current Calculation

Three phase short circuit currents are analyzed at the buses of substations with nominal voltages of 400kV and 230kV on the condition that operating generators and power network configuration are set as shown in the previous sections.
Although a fault current due to a single phase grounding near the generators might sometimes be larger than a three phase short circuit current, single phase grounding fault currents are not calculated in this study because of a lack of data about zero sequence impedances. Single phase grounding currents should be analyzed in future.
The three phase short circuit currents at all the busses of 400kV and 230kV are below 50kV in 2025.
The following table shows the buses with their three phase short circuit currents over 40kA in 2025.

Table 15-12 Three Phase Short Circuit Currents of 400kV and 230kV Buses in 2025 (Over 40kA)

Name of Bus	Voltage (kV)	Three Phase Short Circuit Current (kA)	Name of Bus	Voltage (kV)	Three Phase Short Circuit Current (kA)
MEGHNAGHAT	400	47.0	MEGHNAGHAT	230	41.0
ORION	400	47.0	KALIAKOIR	230	41.0
BHULTA	400	45.1	MADANGANJ	230	40.7
KALIAKOIR	400	41.5			

Source: JICA Survey Team

The following table shows the buses with their three phase short circuit currents over 40kA in 2035.
The 400kV bus of Rooppur nuclear power plant has its three phase short circuit at over 50kA.

Table 15-13 Three Phase Short Circuit Currents of 400kV and 230kV Buses in 2035 (Over 40kA)

Name of Bus	Voltage (kV)	Three Phase Short Circuit Current (kA)	Name of Bus	Voltage (kV)	Three Phase Short Circuit Current (kA)
ROOPPUR	400	52.6	GABTOLI	230	45.0
MEGHNAGHAT	400	47.3	DHANMONDI	230	44.7
ORION	400	47.3	AMINBAZAR	230	44.0
BHULTA	400	44.4	KCHAR	230	44.0
BIRULIA	400	43.0	KALIAKOIR	230	43.6
AMINBAZAR	400	42.1	OLDAIRPORT	230	43.3
PYRA	400	40.4	ANOWARA	230	42.6
			BSRM	230	41.7
			ROOPPUR	230	40.4
			DHAMRAI	230	40.4

Source: JICA Survey Team

Many circuits of the transmission lines will be derived from the nuclear power station in order to maintain the power system reliability. Four units of generators will start to be operated up to 2035. Thus, a huge fault current would be observed at the 400kV buses of Rooppur nuclear power station and this may become larger than 50kA in 2035 if no change to the system configuration is made.
The three phase short circuit currents at some buses in Dhaka city are close to 50kA and the fault currents of those buses may become greater than 50kA because the single circuit grounding fault current may be larger than the three phase short circuit current near generators.
Countermeasures for large fault current would be required for the places where the fault current is expected to exceed 50kA. General countermeasures are considered as follows.

- Countermeasures against large fault current

① Split of buses or network connection
② Application of high impedance transformers
③ Application of 63kA circuit breakers fulfilling the necessary conditions (securing mechanical strength of facilities at power transmission lines and substations or electro-magnetic induced current)

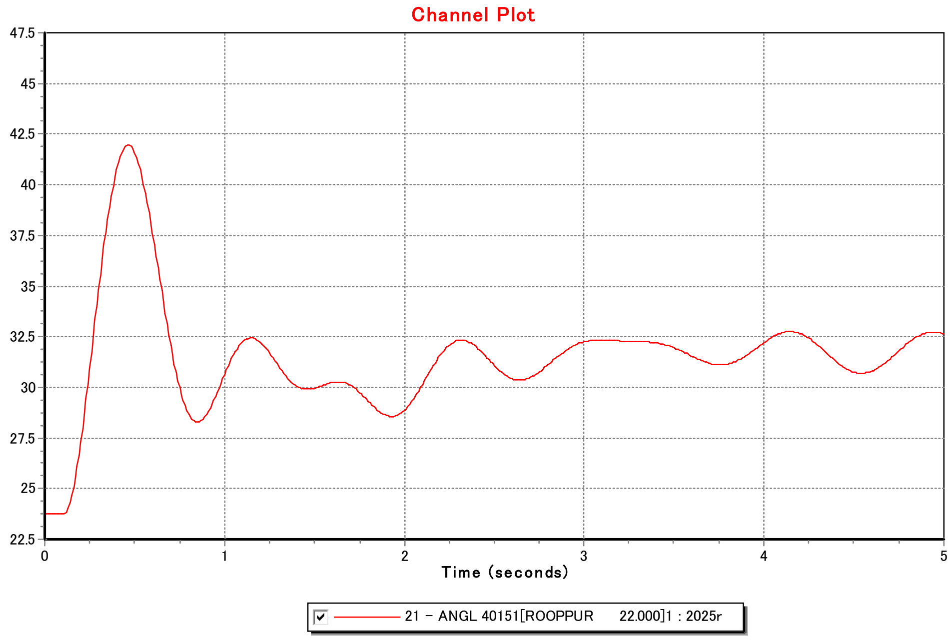
Countermeasure ③ “Application of 63kA circuit breakers fulfilling the necessary conditions” should be considered as the countermeasure for the 400kV bus of Rooppur nuclear power station because ① “Split of buses or network connection” and ② “Application of high impedance transformers” tend to weaken stability of the generators with long distance power transmission.
On the other hand, for the Dhaka system, ① “Split of buses or network connection” or ② “Application of high impedance transformers” can be recommended as the countermeasure against large fault current because the areas to be improved against increase in their fault current levels are widely spread out and the countermeasure seems inefficient.
The system models for 2025 and 2035 set in this study assume that some circuit breakers of the transmission lines and substation buses in the system around Dhaka are operated in an open position to reduce the fault current.

15.4.4 System Stability Calculation

System stability is calculated for cases of faults at the transmission lines from the main power stations located in Chittagong and Khulna. The power outputs of the targeted power generators are set to be operated at their maximum values for each case. It is found that the system can be kept stable for each case.

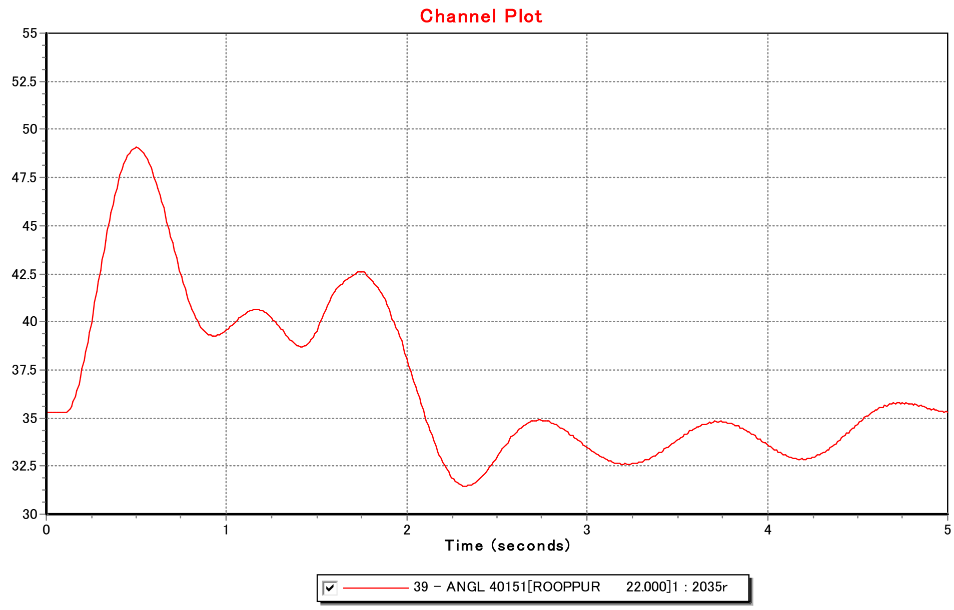
(1) Power transmission from Rooppur nuclear power station

The case of fault clearance by opening the circuit breakers of the transmission lines of Rooppur-Kaliakoir and Rooppur-Aminbazar after occurrence of a short circuit fault around the Rooppur 400kV bus, in 2025 and 2035, is simulated as a double circuit fault around the nuclear power station. The results of the simulation show that the system can be kept stable.
The following figure shows the power angle oscillation of a Rooppur nuclear power generator in this case.



Source: JICA Survey Team

Figure 15-13 Power Angle Oscillation of a Rooppur Nuclear Power Generator in Case of Double Circuit Fault at 400kV Transmission Lines of Rooppur-Kaliakoir and Rooppur-Aminbazar (2025)

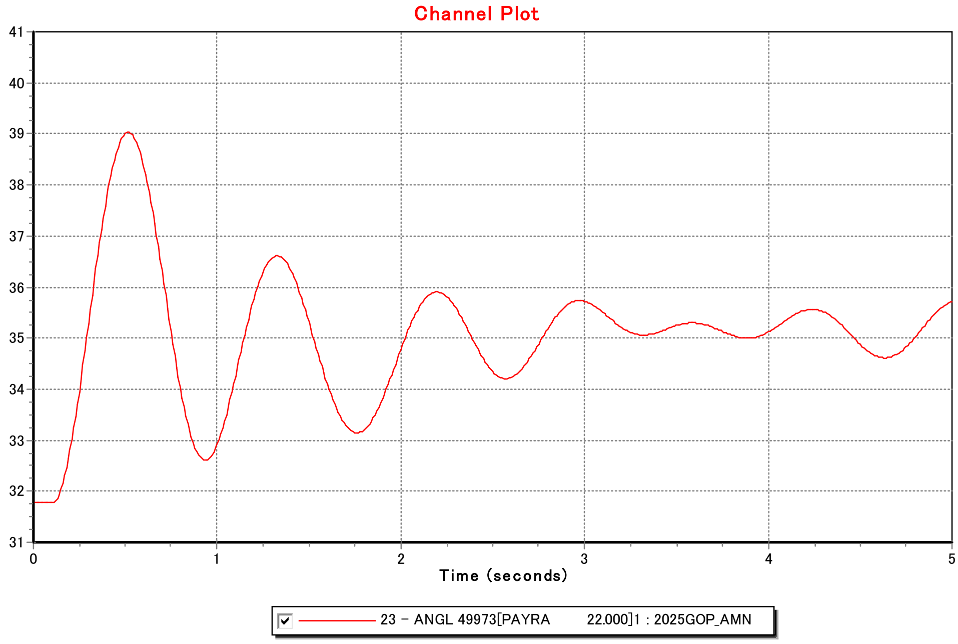


Source: JICA Survey Team

Figure 15-14 Power Angle Oscillation of a Rooppur Nuclear Power Generator in Case of Double Circuit Fault at 400kV Transmission Lines of Rooppur-Kaliakoir and Rooppur-Aminbazar (2035)

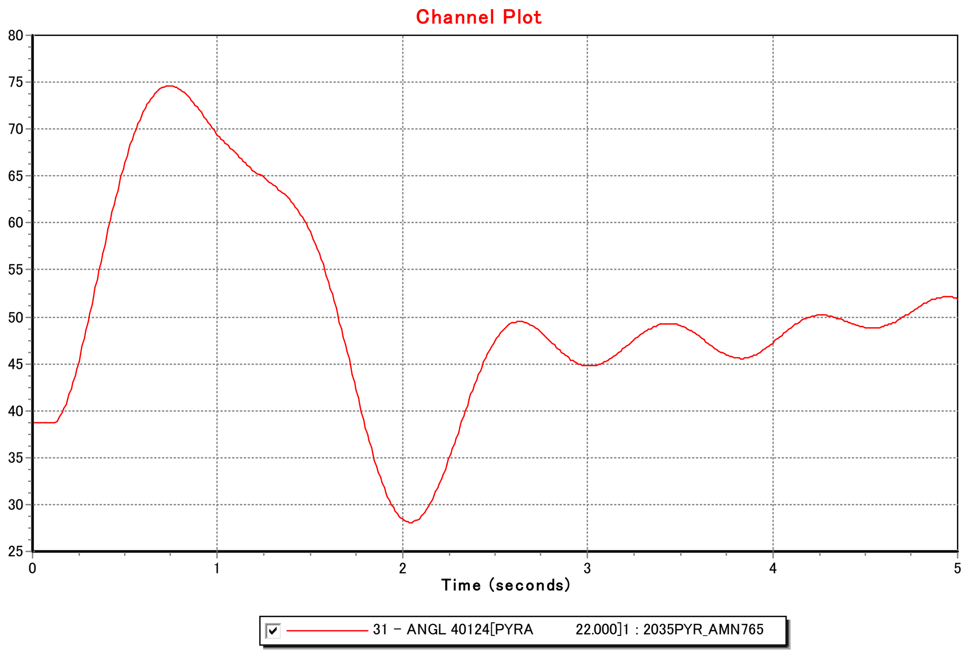
(2) Power transmission from Mongla and Pyra (Patuakhali) thermal power stations

System stabilities in the cases of single circuit faults at the 400kV transmission lines of Gopalganj-Aminbazar in 2025, and the 765kV transmission lines of Pyra-Aminbazar in 2035, are simulated respectively. The results of the simulation show that the system can be kept stable. The following figures show the power angle oscillation of a Pyra thermal power generator in these cases.



Source: JICA Survey Team

Figure 15-15 Power Angle Oscillation of a Pyra Thermal Power Generator in Case of Single Circuit Fault at 400kV Transmission Line of Gopalganj-Aminbazar (2025)

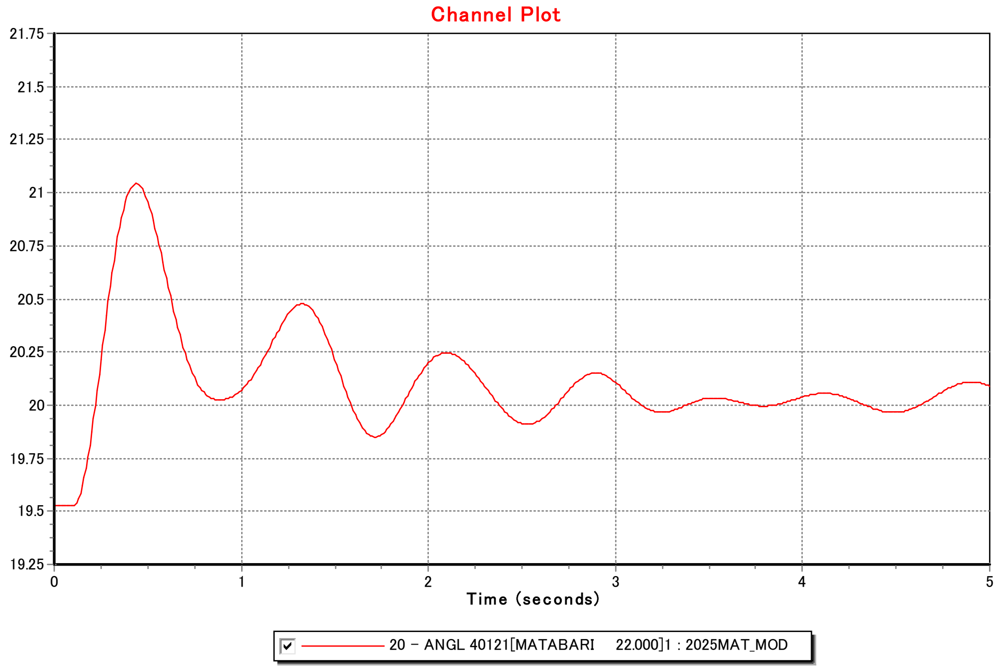


Source: JICA Survey Team

Figure 15-16 Power Angle Oscillation of a Pyra Thermal Power Generator in Case of Single Circuit Fault at 765kV Transmission Line of Pyra-Aminbazar (2035)

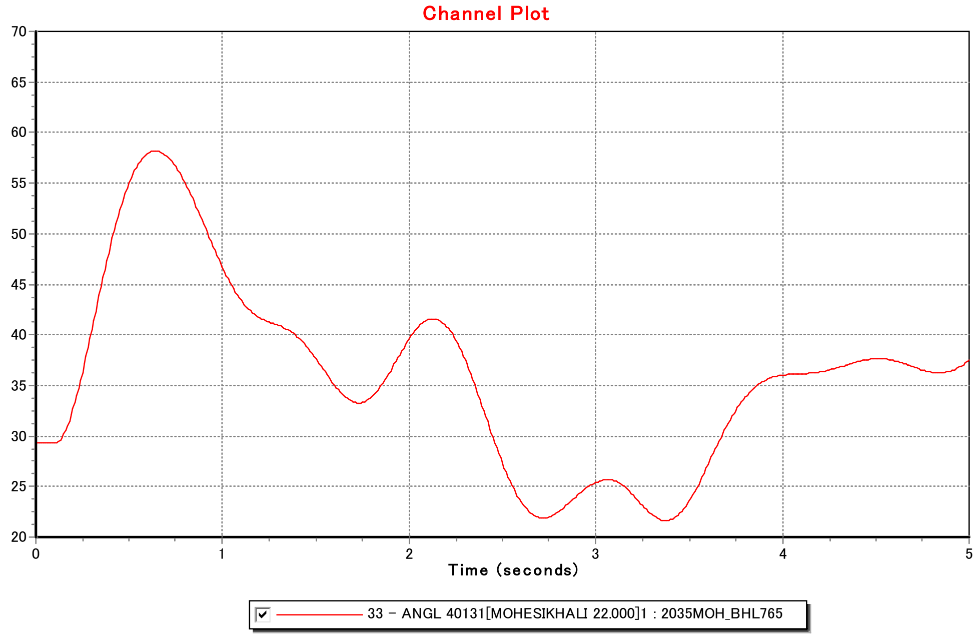
(3) Power Transmission from the thermal power stations located in Chittagong area

System stabilities in the cases of single circuit faults at the 400kV transmission lines of Matabari-Madunaghat in 2025, and the 765kV transmission lines of Mohesikali-Bhulta in 2035, are simulated respectively. The results of the simulation show that the system can be kept stable. The following figures show the power angle oscillations of a Matabari thermal power generator and a Mohesikali thermal power generator in these cases.



Source: JICA Survey Team

Figure 15-17 Power Angle Oscillation of a Matabari Thermal Power Generator in Case of Single Circuit Fault at 400kV Transmission Line of Matabari-Madunaghat (2025)



Source: JICA Survey Team

Figure 15-18 Power Angle Oscillation of Mohesikali Thermal Power Generator in Case of Single Circuit Fault at 765kV Transmission Line of Mohesikali-Bhulta (2035)

15.5 Recommendations Regarding Power System Network Plan

The following is recommended with regard to the power network system plan.

- 765kV transmission lines and substations and 400kV underground transmission lines are applied in some countries. However, because of their technically shallow histories, their design should be carefully studied, especially with regard to countermeasures for over voltage.
- The application of compact type facilities such as GIS and Gas Insulated Transformers or underground substations should be studied for the Dhaka and Chittagong systems, where high demand density is observed.
- A sufficient amount of shunt capacitors should be installed to improve the system voltage at the 230kV and 132kV substations in systems such as Dhaka, where large voltage drops are observed.
- The multi circuits of the 400kV transmission lines are derived from Rooppur nuclear power station. Thus, the fault current levels may exceed 50kA at the 400kV bus of the nuclear power station. In order to solve this issue, upgrading the ability of the fault breaking current to 63kA at the 400kV bus of Rooppur nuclear power station should be studied.
- The fault current may exceed 50kA in dense power transmission systems such as Dhaka and Chittagong. In order to solve this issue, split operation of buses or transmission lines in and around Dhaka and Chittagong, and the application of high impedance transformers, should be studied.
- Feasibility studies on the individual projects confirmed in this master plan for 2025 and 2035 should be carried out.

15.6 Cost Estimation Assumptions

The cost estimation was carried out based on the following assumptions, which were confirmed between PGCB and the JICA Survey Team:

- The unit costs were set as per Table 15-14, determined by PGCB and the JICA Study Team's experience.
- For the transmission lines inside the Dhaka 400kV transmission line circle, underground cables were applied. The others were overhead lines.
- Major river crossing lengths (5km and over) for transmission lines are: 400kV transmission line between Aminbazar and Gopalganj (6km), and 400kV transmission line between Kaliakoir and Bogra (5km).
- For all the substations, including 765/400kV, 400/230kV and 230/132kV substations, GIS was applied rather than AIS.
- The locations of substations and transmission lines were based on the rough assumptions in the Study.
- 132kV substations, transmission lines, and shunt capacitors were left out of the development cost estimation because including realistic 132kV substations in the long term planning is difficult and a vast amount of analysis time is needed if an analysis including 132kV substations is to be carried out.
- From FY2036 to FY2041, the development cost is calculated approximately by using the average annual construction costs from FY2031 to FY2035, rather than conducting detailed planning.

Table 15-14 Unit Cost Table

Equipment		Construction cost	
Overhead Line	230kV D/C (Twin Conductor)	0.63	mil. USD/km/2cct
	400kV D/C (Quad Conductor)	0.87	mil. USD/km/2cct
	765kV D/C (Hexa Conductor)	1.8	mil. USD/km/2cct
Underground Cable	230kV	2	mil. USD/km/1cct
	400kV	4	mil. USD/km/1cct
River Crossing OHL	400kV	34.8	mil. USD/km/2cct
Substation	230/132kV(2x300MW, GIS)	17	mil. USD/station
	400/230kV(3x750MW, GIS)	80.2	mil. USD/station
	765/400kV(2x2,250MW, GIS)	165	mil. USD/station
	765/400kV(4x2,250MW, GIS)	247	mil. USD/station
Static Capacitor	230kV	0.029	mil. USD/MVar
	400kV	0.051	mil. USD/MVar
	765kV	0.1	mil. USD/MVar

Source: PGCB and JICA Survey Team

15.7 Power System Expansion

15.7.1 Amount of equipment expansion from FY2016 to FY2025

(1) Transmission lines

The 230kV and 400kV transmission lines for which construction is necessary from FY2016 to FY2025 are shown in Table 15-15 and Table 15-16.

Table 15-15 230kV transmission lines required from FY2016 to FY2025

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
FARIDPUR-GOPALGANJ	2	60	37.8
JOYDEPUR-KABIRPUR	2	15	9.5
SYLHET-SYLHET (N)	2	12	7.6
SYLHET-BIBIYANA	2	33	20.8
KABIRPUR-KALIAKOIR	4	15	18.9
MOGBAZAR-RAMPURA (cable)	2	6	24.0
BASUNDHARA 2-ULLON (cable)	2	7	28.0
BAROAWLIA-HATHAZARI	2	10	6.3
BAGHABARI-ROOPPUR	2	55	34.7
BARAPUKURIA-PURBASADIPUR	4	45	56.7
BARAPUKURIA-RANGPUR	4	45	56.7
GHORASAL-TONGI	2	28	17.6
HARIPUR-SIDDHIRGANJ (cable)	1	2	4.0
HARIPUR-SIGNBORD (cable)	2	6	25.2
HASNABAD-KERANIGANJ	2	8	5.0
HATHAZARI-MADUNAGHAT	2	15	9.5
ISHURDI-HVDC	2	10	6.3
ISHURDI-RAJSHAJHI	4	70	88.2
HATHAZARI-AKSPL	2	10	6.3

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
OLDAIRPORT-DHANMONDI (cable)	2	6	24.0
RAMPURA-ULLON (cable)	2	4	16.0
SIRAJGANJ-BOGRA (S)	2	72	45.4
TONGI-KALIAKOIR	2	22	13.5
TONGI-BASUNDHARA (cable)	4	10	78.4
AKSPL-RAMPUR	2	8	5.0
BARISAL (N)-GOPALGANJ	2	65	41.0
BHULTA-JALLSHIRI	2	11	6.7
BOGRA (S)-NAOGAON	4	45	56.7
BSRM-MIRSARAI	2	1	0.6
MIRSARAI-FENI	2	1	0.6
MIRSARAI-CHOWMUHAN	2	30	18.9
KALIAKOIR-BIRULIA	2	20	12.6
KERANIGANJ-DHAKA (S) (cable)	4	6	48.0
KHULNA (S)-MONGLA	2	24	15.1
MADUNAGHAT-SIKALBAHA	2	25	15.8
MADUNAGHAT-MADUNAGHAT (O)	2	8	5.0
CHANDPUR-CHOWMUHAN	2	50	31.5
CHANDPUR-DAUDKANDI	2	35	22.1
NAOGAON-JOYPURHAT	2	45	28.4
RAMPUR-ANOWARA	2	15	9.5
SHAMPUR-SIGNBORD (cable)	2	4	15.2
SHAMPUR-MEGHNAGHAT	4	17	20.8
SIKALBAHA-ANOWARA	2	12	7.6
ULLON-GREENMODEL (cable)	2	10	38.8
DHAMRAI-ROOPPUR	2	110	69.3
DHANMONDI-GABTOLI (cable)	2	7	28.8
MADANGANJ-BHOLAIL (cable)	2	7	28.0
MADANGANJ-MEGHNAGHAT	6	10	18.9
MONGLA-RUPSHA	2	20	12.6
GREENMODEL-DHOLAIKHAL (cable)	2	6	24.4
DHAKA (S)-BHOLAIL	2	20	12.8
Total			1234.8

Source: JICA Survey Team

Table 15-16 400kV transmission lines required from FY2016 to FY2025

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
BHULTA-MEGHNAGHAT	2	20	17.4
BHULTA-GREENMODEL (cable)	2	13	104.8
BIRULIA-AMINBAZAR	1	10	4.4
BIRULIA-KALIAKOIR	1	40	17.4
KALIGANJ-BASUNDHARA 2	2	20	17.4
KALIGANJ-BHULTA	2	31	27.0
KALIGANJ-KALIAKOIR	2	40	34.8
MIRERSHARAI-MADUNAGHAT	2	70	60.9
MIRERSHARAI-FENI	2	21	18.3
AMINBAZAR-ROOPPUR	1	167	72.6
AMINBAZAR-GABTOLI	2	3	2.6
ASHUGANJ-BHULTA	2	70	60.9
BIBIYANA-KALIAKOIR	2	168	146.2
KALIAKOIR-ROOPPUR	1	137	59.6
KALIAKOIR-MYMENSINGH	2	95	82.4
KALIAKOIR-BOGRA	2	133	285.4
MADUNAGHAT-ANOWARA	2	38	33.1
MADUNAGHAT-SALAM	2	90	78.3
MEGHNAGHAT-ORION	2	1	0.9
MEGHNAGHAT-FENI	2	123	107.0
ANOWARA-MATABARI	2	62	53.9
GOPALGANJ-MONGLA	2	85	74.0
GOPALGANJ-ROOPPUR	1	165	71.8
AMINBAZAR-GOPALGANJ	2	85	277.5
GOPALGANJ-PYRA	2	163	141.8
MATABARI-SALAM	2	35	30.5
ROOPPUR-BOGRA	1	100	43.5
AMINBAZAR-DHAKA (S)	2	15	13.1
ORION DHAKA (S)	2	40	34.8
COMILLA (N)-COM_INDA	2	100	87.0
BARAPUKURIA-BOGRA	2	116	100.9
Total			2159.9

Source: JICA Survey Team

(2) Substations

The 230kV/132kV and 400kV/230kV substations for which construction is necessary from FY2016 to FY2025 are shown in Table 15-17 and Table 15-18, where the number of 230kV/132kV substations assumes that two transformers are installed in one substation.

Table 15-17 230kV/132kV substations required from FY2016 to FY2025

Location required for 230/132kV SS	No. of Tr	Cost [Million USD]
FARIDPUR	2	17.0
BHULTA	1	8.5
DHAMRAI	3	25.5
JOYDEPUR	2	17.0
SYLHET	2	17.0
SYLHET (N)	2	17.0
KABIRPUR	4	34.0
MOGBAZAR	2	17.0
BASUNDHARA	5	42.5
BAROAWLIA	3	25.5
AMINBAZAR	3	25.5
ASHUGANJ	2	17.0
BAGHABARI	1	8.5
BARAPUKURIA	1	8.5
BARISAL (N)	3	25.5
BHERAMARA	2	17.0
BOGRA (S)	3	25.5
CHANDPUR	2	17.0
CHOWMUHAN	3	25.5
COMILLA (N)	1	8.5
DAUDKANDI	2	17.0
DHANMONDI	3	25.5
GHORASAL	3	25.5
HASNABAD	1	8.5
JOYPURHAT	3	25.5
KHULNA (S)	1	8.5
MADANGANJ	5	42.5
MADUNAGHAT	3	25.5
MANIKNAGAR	1	8.5
MONGLA	2	17.0
NAOGAON	2	17.0
OLDAIRPORT	1	8.5
RAMPURA	2	17.0
RANGPUR	3	25.5
DHOLAIKHAL	3	25.5
SHAMPUR	3	25.5

Location required for 230/132kV SS	No. of Tr	Cost [Million USD]
GREENMODEL	5	42.5
SIKALBAHA	3	25.5
TONGI	2	17.0
ULLON	4	34.0
BASUNDHARA	5	42.5
FENCHUGANJ	2	17.0
JESSORE	3	25.5
JHENAIDAH	3	25.5
KERANIGANJ	3	25.5
RAJSHAJHI	3	25.5
RAJSHAJHI	3	25.5
RAMPUR	3	25.5
SIDDHIRGANJ	2	17.0
SRIPUR	3	25.5
BIRULIA	1	8.5
GOPALGANJ	1	8.5
RUPSHA	3	25.5
FENI	4	34.0
BHOLA	1	8.5
GABTOLI	2	17.0
SIGNBORD	1	8.5
BHOLAIL	4	34.0
MADOBDI	3	25.5
Total		1,266.5

Source: JICA Survey Team

Table 15-18 400kV/230kV, 132kV Substations Required from FY2016 to FY2025

Substation	Cost [Million USD]
PYRA	80.2
BHULTA	80.2
BASUNDHARA	80.2
MIRSARAI	80.2
ASHUGANJ	80.2
BARAPUKURIA	80.2
COMILLA (N)	80.2
GHORASAL	80.2
MYMENSINGH	80.2
KALIAKOIR 400/132kV	80.2
KALIAKOIR 400/230kV	80.2
MATABARI	80.2
GOPALGANJ 400/132kV	80.2
GOPALGANJ 400/230kV	80.2
AMINBAZAR	80.2

Substation	Cost [Million USD]
BIBIYANA	80.2
MEGHNAGHAT	106.9
HVDC	80.2
MADUNAGHAT	80.2
MONGLA	80.2
ROOPPUR	80.2
GREENMODEL	80.2
DHAKA (S)	80.2
GABTOLI	80.2
BOGRA	80.2
Total	2,031.7

Source: JICA Survey Team

(3) Capacitors

The capacitors for which construction is necessary from FY2016 to FY2025 are shown in Table 15-19.

Table 15-19 Capacitors required from FY2016 to FY 2025

Substation	Capacity [MVar]	Cost [Million USD]
400kV GOPALGANJ	100	5.1
400kV GOPALGANJ	100	5.1
400kV BARAPUKURIA	800	40.8
230kV RAMPURA	37.5	1.1
Total		52.1

Source: JICA Survey Team

15.7.2 Amount of equipment expansion from FY2026 to FY2035

(1) Transmission lines

The 230kV, 400kV and 765kV transmission lines for which construction is necessary from FY2026 to FY2035 are shown in Table 15-20 to Table 15-22.

Table 15-20 230kV transmission lines required from FY2026 to FY2035

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
SYLHET-BIBIYANA	2	33	20.8
KCHAR-DHANMONDI (cable)	2	3	13.2
KCHAR-GABTOLI (cable)	2	7	26.0
GHORASAL-DHAMRAI	2	70	44.1
HATHAZARI-MADUNAGHAT	2	15	9.5
TONGI-KALIAKOIR	2	43	27.1
BOGRA (S)-BOGRA	2	21	13.4
MIRSARAI-CHOWMUHAN	2	30	18.9
HVDC-JHENAIDAH	2	75	47.3
RAMPUR-ANOWARA	2	15	9.5
SIKALBAHA-ANOWARA	2	12	7.6
Total			237.1

Source: JICA Survey Team

Table 15-21 400kV transmission lines required from FY2026 to FY2035

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
DHAMRAI-BIRULIA	2	20	17.4
DHAMRAI-ROOPPUR	2	110	95.7
BIBIYANA-PSPP	2	100	87.0
GHORASAL-TONGI	2	28	24.4
MYMENSINGH-JAMALPUR	2	62	53.9
Total			278.4

Source: JICA Survey Team

Table 15-22 765kV transmission lines required from FY2026 to FY2035

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
PYRA-AMINBAZAR	2	248	446.4
MOHESIKHALI-BHULTA	2	335	603.0
MIRERSHARAI-MOHESIKHALI	2	170	306.0
Total			1355.4

Source: JICA Survey Team

(2) Substations

The 230kV/132kV, 400kV/230kV and 765kV/400kV substations for which construction is necessary from FY2031 to FY2035 are shown in Table 15-23 to Table 15-25, where the number of 230kV/132kV substations assumes that two transformers are installed in one substation.

Table 15-23 230kV/132kV substations required from FY2026 to FY2035

Location required for 230/132kV SS	No. of Tr	Cost [Million USD]
FARIDPUR	1	8.5
DHAMRAI	2	17.0
SYLHET	1	8.5
SYLHET (N)	1	8.5
BHERAMARA	1	8.5
CHOWMUHAN	1	8.5
COMILLA (N)	3	25.5
ISHURDI	1	8.5
KAMRANGIRCHAR	4	34.0
RANGPUR	1	8.5
SIKALBAHA	2	17.0
RAMPUR	2	17.0
BIRULIA	2	17.0
Total		187.0

Source: JICA Survey Team

Table 15-24 400kV/230kV, 132kV substations required from FY2026 to FY2035

Substation	Cost [Million USD]
DHAMRAI	80.2
BIRULIA	80.2
MIRERSHARAI	80.2
JAMALPUR	80.2
MYMENSINGH (upgrading)	26.7
KALIAKOIR (upgrading)	26.7
TONGI	80.2
HVDC (upgrading)	26.7
ANOWARA	80.2
GREENMODEL (Upgrading)	26.7
Total	588.1

Source: JICA Survey Team

Table 15-25 765kV/400kV substations required from FY2026 to FY2035

Substation	Cost [Million USD]
PYRA	247.0
BHULTA	247.0
MOHESIKHALI	165.0
AMINBAZAR	165.0
Total	824.0

Source: JICA Survey Team

(3) Capacitors

The capacitors for which construction is necessary from FY2026 to FY2035 are shown in Table 15-26.

Table 15-26 Capacitors required from FY2026 to FY2035

Substation	Capacity [MVar]	Cost [Million USD]
230kV AMINBAZAR	400	11.6
400kV JAMALPUR	400	20.4
400kV JAMALPUR	400	20.4
400kV BARAPUKURIA	400	20.4
400kV BARAPUKURIA	100	5.1
230kV BASUNDHARA 2	350	10.2
230kV BOGRA (S)	12.5	0.4
230kV PURBASADIPUR	50	1.5
230kV BASUNDHARA	200	5.8
Total		95.7

Source: JICA Survey Team

15.8 Development Costs Summary

The development costs for FY2016-25, FY2026-35 and FY2036-41, which are calculated in the above sections, are summarized in Table 15-27.

Table 15-27 Cost estimation summary

Unit: Million USD

FY2016-25	FY2026-35	FY2036-41
6,737	3,566	2,139

Source: JICA Survey Team

15.9 Rural Electrification

15.9.1 Government policy and definition

While the government has established the "Electricity for all" by 2021[1], in its Vision Statement, there is no single internationally-established definition for electricity access. IEA uses in its analysis "electricity access at the household level, that is, the number of people who have electricity in their home. It comprises electricity sold commercially, both on-grid and off-grid. It also includes self-generated electricity for those countries where access to electricity has been assessed through surveys by government or government agencies. The data does not capture unauthorized connections. The national, urban and rural electrification rates shown indicate the number of people with electricity access as a percentage of the total population" [2].

In Bangladesh, there exist in fact four different definitions and figures for "electrification rate" by four governmental institutions, though the government adopts the Power Division figure.

- Power Division (Power Cell) Definition

  As of December 2015, Power Division recognizes the electrification rate of Bangladesh is 77%. In the government policy statement such as 7th Five Year Plan, the Power Division's figure is adopted. Their equation is as follows:

$$Access\ to\ Electricity\ (\%) = \frac{On-grid\ Electrified\ Polulation + Off-grid\ Electrified\ Population}{Total\ Polulatoin}$$

$$= \frac{\sum(Nunber\ of\ Residential\ Customer\ of\ each\ Distribution\ Entity \times Family\ member\ parameter) + SHS\ customer}{Total\ Polulatoin}$$

This equation indicates that the electrification rate improvement has two paths; one is on-grid connection, the other is off-grid connection (e.g. SHS). The detail of Power Division's calculation is as follows:

---

[1] In the 7th Five Year Plan adopted in December 2015, the target by 2020 is set as "electricity coverage to be increased to 96 percent with uninterrupted supply to industries".

[2] https://www.iea.org/media/weowebsite/energydevelopment/Poverty_Methodology.pdf

Table 15-28 Electrification Rate Calculation Detail by Power Division

	BPDB	REB	DPDC	DESCO	WZPDCL	SHS
No. of Domestic (Residential) customer	2,721,205	12,223,002	910,336	641,978	728,453	4,000,000
Family member parameter	5.5	6.5	4.5	4.5	5.5	4.0
No. of people with electricity access	14,966,628	79,449,513	4,096,512	2,888,901	4,006,492	16,000,000
Total No. of population with electricity access	121,408,045					
Total population of Bangladesh	157.8 million					
Access to Electricity	77%					

Source: Power Cell, Power Division

- BPDB Definition

Electrification rate adopted by BPDB is ratio of number of access and all population. Access to Electricity is calculated by the below equation.

$$Access\ to\ Electricity\ (\%) = \frac{Number\ of\ Electrified\ Customer \times 7^{*1} + Number\ of\ SHS \times 4^{*2}}{Total\ Population}$$

Source: BPDB System Planning Division

*1 It assumes that the number of people per grid connection (per household) is 7. Household: Husband, wife, children x 2, father, mother + 1. There are big customers such as hospitals, so 1 is added.

*2 It assumes that the number of people per off-grid connection (renewable) is 4 (-2014) or 5 (2013-). This is based on the assumption that a household using SHS, has smaller of family members than the grid-connected household.

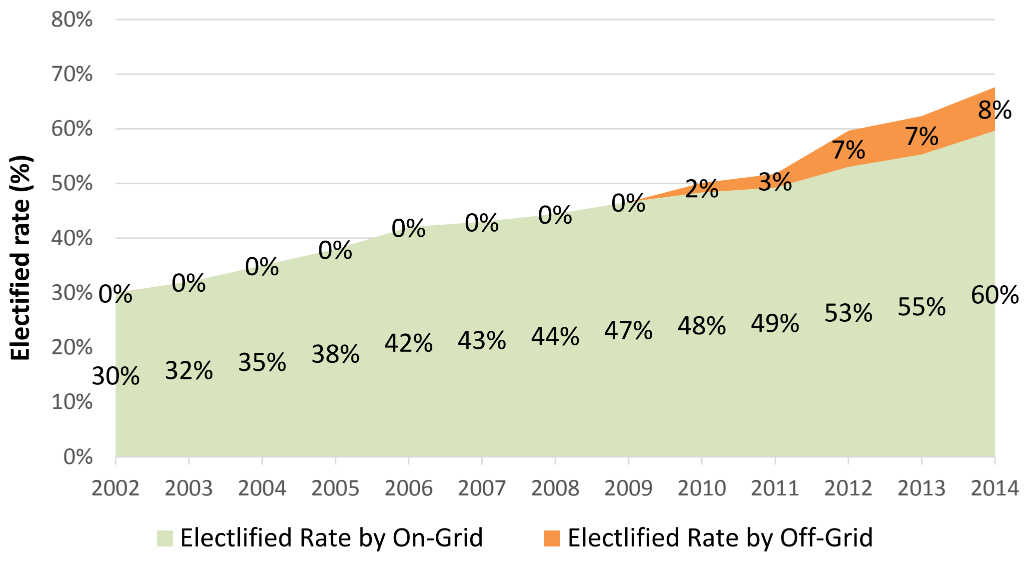
This BPDB definition indicates that the electrification rate improvement has two paths; one is on-grid connection, the other is off-grid connection (e.g. SHS).

Table 15-29 and Figure 15-19 shows the Access to Electricity provided by BPDB. According to Figure 15-19, 60% of population was electrified by grid connection; 8% of population was electrified by SHS installation. In total 68% were electrified in 2014 in Bangladesh.

Table 15-29 Annual Status of Power Sector (2005-2014)

Item (FY)	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Installed Capacity (MW)	4995	5245	5202	5305	5719	5823	7264	8716	9151	10416
Generation Capacity (derated), MW)	4364	4614	4623	4776	5166	5271	6639	8100	8537	9821
Maximum Generation (MW)	3721	3782	3718	4130	4162	4606	4890	6066	6434	7356
Net Energy Generation (MkWh)										
(a) Public Sector	13223	14456	14539	15167	15449	16072	14673	15201	17994	19644
(b) IPP & Mixed	7939	8286	8244	9138	10173	11398	14811	18196	18488	18386
(c) Power Import										2265
(d) REB	246	236	484	641	911	1777	1871	1721	1747	1899
Total Net Energy Generation (MkWh)	21408	22978	23267	24946	26533	29247	31355	35118	38229	42195
Transmission Line (400, 230 &132kV)(Ckt. Km.)	6759 (ckt.km)	6844 (ckt.km)	7044 (ckt.km)	7848 (ckt.km)	8330 (ckt.km)	8465 (ckt.km)	8616 (ckt.km)	8949 (ckt.km)	9322 (ckt.km)	9536 (ckt.km)
Distribution Line (K.M)	244104	264891	271142	256143	259963	269877	274347	281123	288787	302760
Total Consumer Number (lacs)	88.47	97.33	104.2	107.9	115.05	119.88	123.51	135.427	142.32	154.41
Agricultural Consumer (lacs)	1.78	2.16	2.26	2.34	2.82	2.7	2.76	2.95	2.97	2.98
No. of Village Electrified	47612	49435	50360	50724	52334	53837	53925	54216	54638	56312
Population in Million	137	138.8	140.6	142.4	144.2	146	148	151.6	153.6	155.8
Access to Electricity (%) (Grid)	38	42	43	44.43	46.63	48.36	49.23	53.04	55.31	59.66
Access to Electricity (%) (Renewable)								7	7	8
Access to Electricity (%)	38	42	43	44.43	46.63	48.36	49.23	60.04	62.31	67.66
Per Capita Generation (kWh) (Grid)	158	165	165	175	184	200	212	232	249	271
Per Capita Generation (kWh) (Captive)				47	55	64	68	68	72	77
Per Capita Generatio (kWh)	158	165	165	222	239	264	280	300	321	348
Per Capita Consumption (kWh) (Grid)		131	134	143	152	168	180	198	213	233
Distribution Loss (%)		18.89	15.52	14.72	14.57	13.49	12.66	12.10	11.88	11.8
System Loss (Tr. & Dist) (%)	22.79	21.3	19.3	18.16	17.25	15.9	15.21	14.65	14.36	14.13

Source: BPDB



Source: JICA Survey Team, based on the data provided by BPDB

Figure 15-19 Development of Access to Electricity (BPDB definition)

- BREB

BREB defines the electrification rate as below:

Rural Electrification Rate = Current Distribution Line Distance (km) / Targeted Distribution Line Distance (km)

As of February 2016, the current distance 300,000km / Targeted distance 440,000km = 68% (the 300,000km is the total distance of 33kV line, 11kV line and lower voltage lines). BREB does not use the BPDB's definition of rural electrification (the electrification rates of both organizations happen to be the same).

- Bangladesh Bureau of Statistics (BBS)

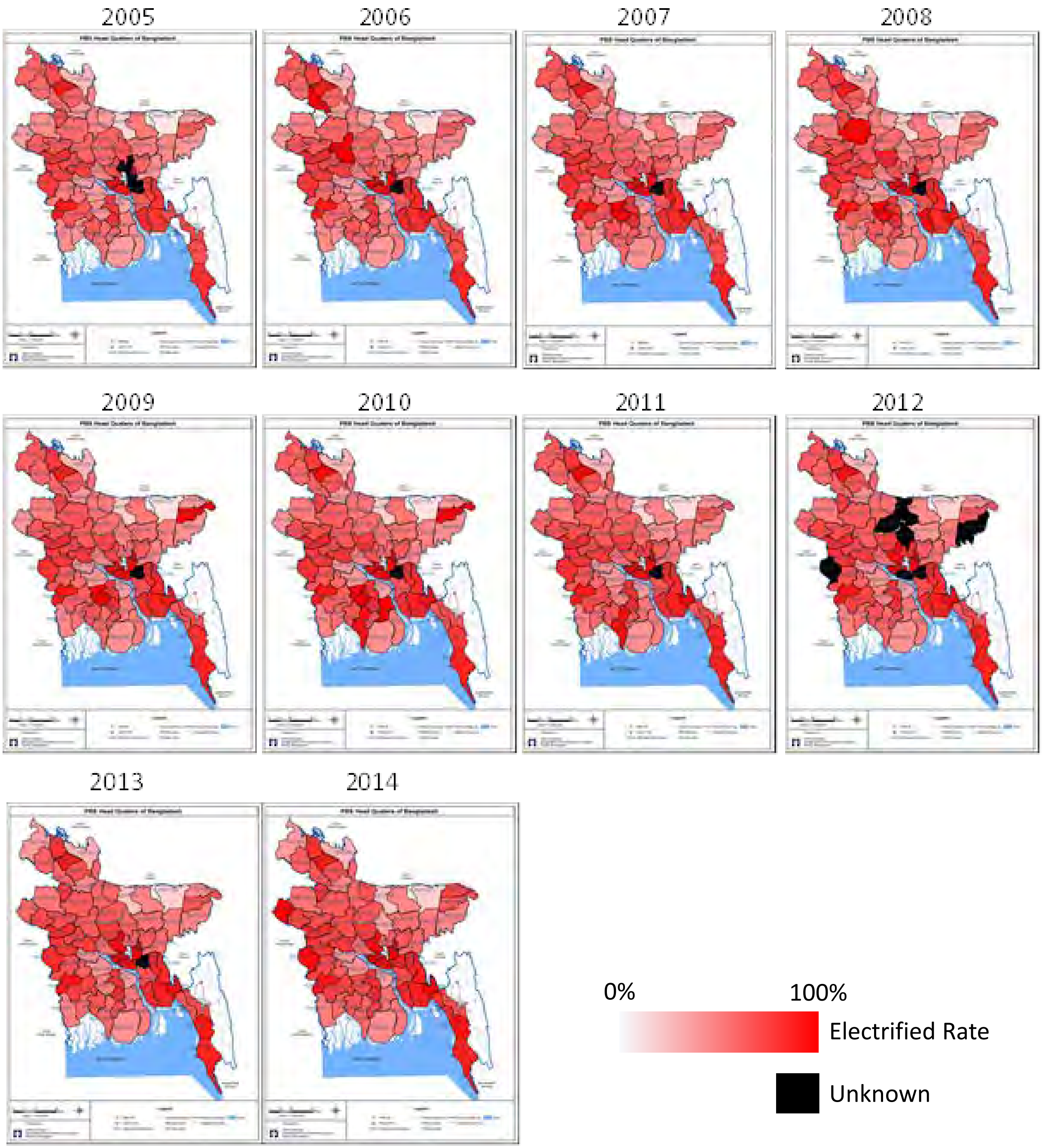
As discussed in the previous Chapter 6, BBS adopts the electrification 86.4%. However, the definition of this figure is unclear and it might be over evaluated.

15.9.2 Power distribution entities in Bangladesh

Refer to "Power Sector Overview" in Chapter 2.

15.9.3 On-grid electrification (distribution line extension)

The following figures show the progress of electrification (approximately 300,000km). According to the BREB, if all of projects are completed, on-grid electrification will be 100%.



Source: JICA Survey Team based on the BREB information

Figure 15-20 BREB's Distribution Line Extension Progress

According to BREB, another 140,000km lines are required for the completion of on-grid extension, which means the total 440,000km is needed for the on-grid electrification by 2021. For the financial needs to materialize this target, BREB is optimistic since several development partners indicate their interest to finance projects.

In addition, BREB has plan to expand its grid after 2022 (when the on-grid electrification is supposed to be completed), as exhibited in the next Table.

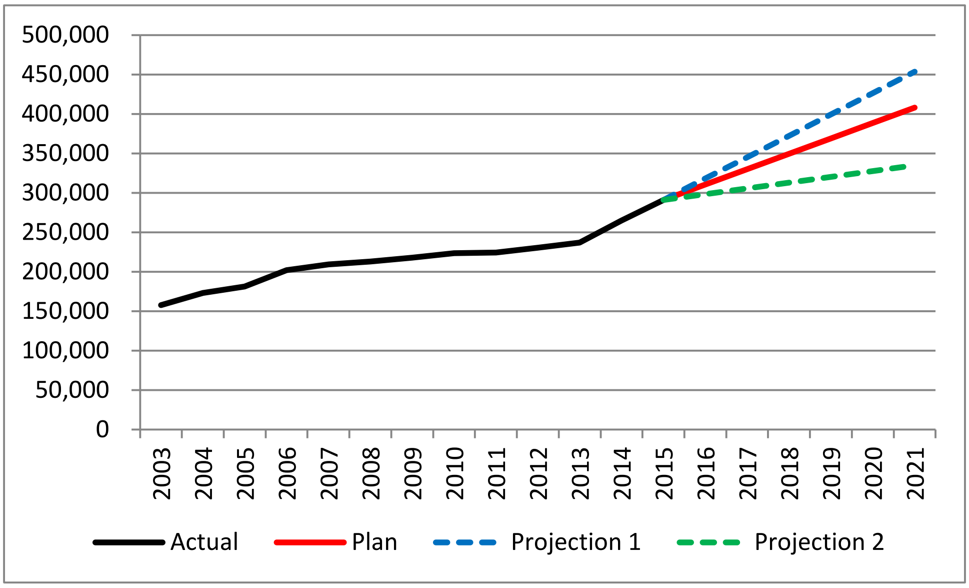
Table 15-30 Rural Electrification Plan up to 2041

SL. No.	Description	December, 2021	December, 2030	December, 2041
1	No. of Consumers (Crore)	2	3	3
2	Quantity of Distribution Line (km)	440,000	500,000	550,000
3	33/11 KV Substations (MVA)	15,100	23,000	30,000
4	Electricity Peak Demand (MW)	9	15,000	20,000

Source: BREB

The below Figure shows the BREB's grid extension projections by 2021, compared with the actual trend in the past up to 2015. The solid black line shows the actual implementation, and red solid line indicates the sum of the individual grid extension projects (as of February 2016).

It should be noted that BREB made a great improvement on grid extension implementation between 2014 and 2015, when BREB substantially increased the grid extension speed compared with the past (between 2003 and 2013). The dotted blue line (Projection 1 in the Figure) means, if BREB keeps the implementation speed as fast as between 2014 and 2015, it will in theory reach 100% on-grid extension (in other words 440,000km distribution line development) by 2021 (it should be also noted, however, that there is a technical issue for on-grid extension, as described later). On the other hand, if BREB loses its grid extension implementation speed as slow as between 2003 and 2013, it would end up far below its target (green dotted line, projection 2 in the Figure).



Source: JICA Survey Team

Figure 15-21 BREB On-grid Extension Plan Comparison

Here is a technical issue of BREB grid extension: according to BREB, the rest 10% of 140,000km (which is 14,000km) are population-scarce or river-crossing areas and thus low economic viability for grid extension. Furthermore these areas do not have PGCB transmission lines nearby, and transmission line expansion is the prerequisite for distribution line expansion.

For these difficult areas, BREB could extend their 33kV lines but not technically recommendable (huge voltage decline could occur). Otherwise, off-grid technologies such as SHS are required for electrification.

In this sense, a good communication and coordination between BREB and IDCOL is required; however, it is observed that such communication or coordination is not taking place. IDCOL is communicating to BPDB for project planning, but BPDB seems not liaising with BREB properly. If the Government seriously pursue the achievement of "Electrification for All" by 2021, the good communication and coordination between BREB and IDCOL must be taken, and both parties (and BPDB as a coordinator too) need to improve in this area.

The following table shows the forecasts of Access to Electricity estimated by BPDB. According to the below Table, Access to Electricity reaches 90% by line extension by 2021.

Table 15-31 Power Utility Plan by Year

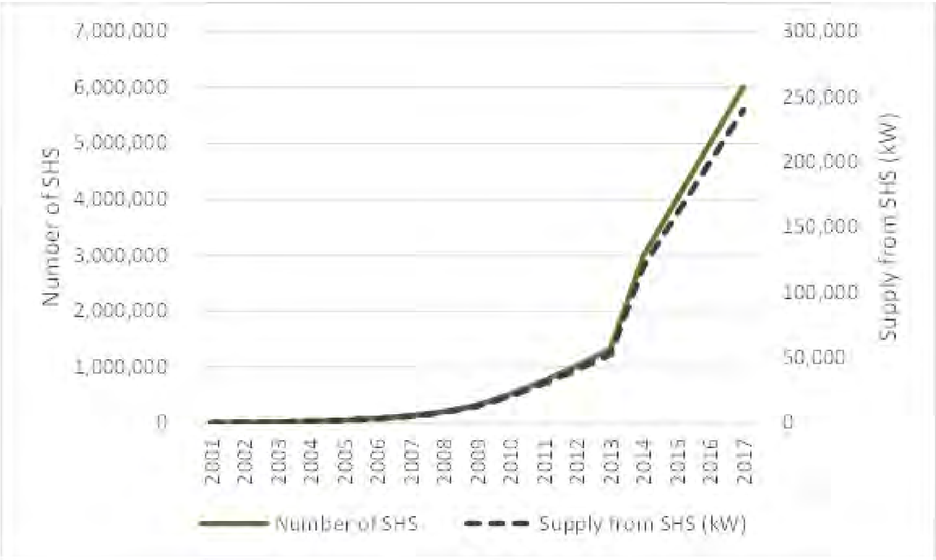
ITEM (FY)	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
GENERATION CAPACITY (DERATED), MW)	9631	12185	13640	15161	17111	18571	22571	24000
NET ENERGY GENERATION (MKWH) *	48713	54047	59945	66457	73658	81610	90950	99838
NET ENERGY GENERATION (MKWH) (REVISED)	42195	46200	51200	56200	62382	68620.2	75482.22	83030.44
TOTAL POPULATION IN MILLION	155.8	157.6	159.6	161.6	163.6	165.6	167.6	169.6
TOTAL DOMESTIC CONSUMER (IN MILLION)	13.28	14.2	15.1	16.2	17.6	18.9	20.3	21.8
ACCESS TO ELECTRICITY (%) (GRID)	60%	63%	66%	70%	75%	80%	85%	90%
PER CAPITA GENERATION (KWH) (GRID)	313	343	376	411	450	493	543	589
PER CAPITA GENERATION (KWH) (GRID) (REVISED)	271	293	321	348	381	414	450	490
PER CAPITA CONSUMPTION (KWH) (GRID)	269	295	324	356	391	429	473	514
PER CAPITA CONSUMPTION (KWH) (GRID) (REVISED)	233	254	279	304	336	367	401	441

* as per PSMP 2010
Source: BPDB

15.9.4 Off-grid electrification

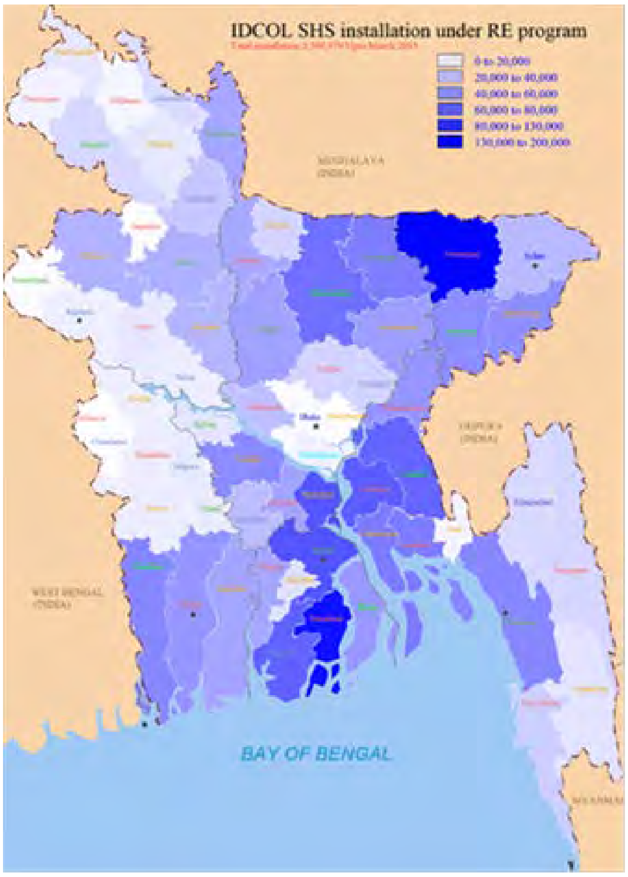
As discussed in the previous section, BREB's on-grid extension has technical limit. In order to achieve the electrification policy by 2021, off-grid technology needs to be employed to complement the on-grid extension.

The SHS installment has been implemented by IDCOL and the progress is world renowned pace (as seen in the below figure). IDCOL has a 6 million target by 2017. For solar micro-grid, IDCOL submits a plan to Power Division for project approval. On the other hand, the each installment for a household is selected by PO (refer to the Chapter 13) and the coordination between BREB is not working effectively as described in the previous section. In order to achieve 100% electrification by 2021, more efficiency (including inter-institution coordination) is required for SHS implementation.



Source: JICA Survey Team

Figure 15-22 Number of SHS under IDCOL Program

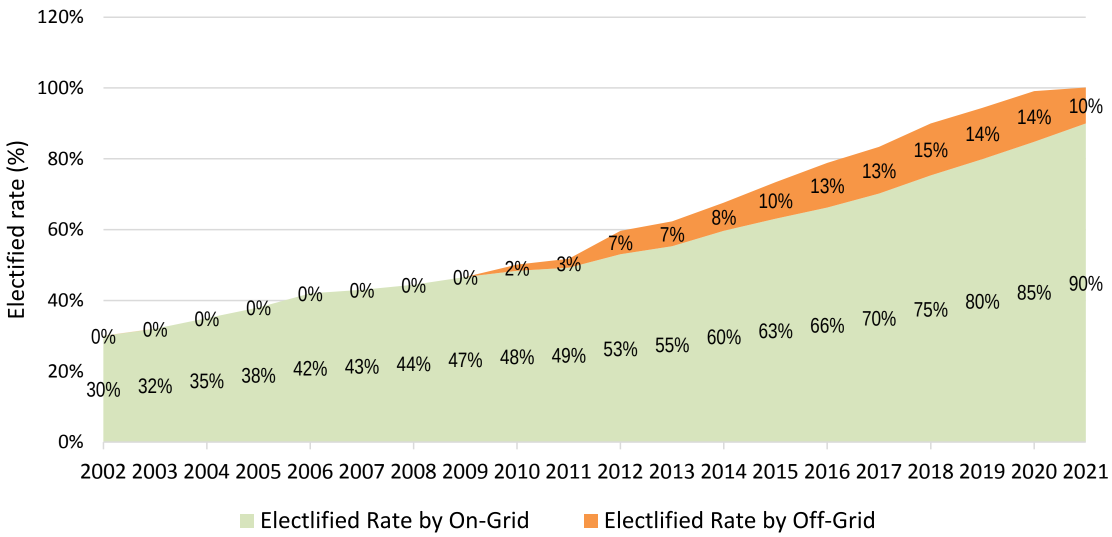


Source: IDCOL homepage

Figure 15-23 Status of SHS Installation

15.9.5 Approach for "Electricity for All"

Based on the estimation of Access to Electricity by BPDB (on-grid extension plans provided by BREB) and SHS installation by IDCOL (Off-Grid), JICA Survey Team estimates the pace of "Electrification for All". It is assumed that the Access to Electricity becomes 100% in 2021. Figure below shows the path to achieve the target.



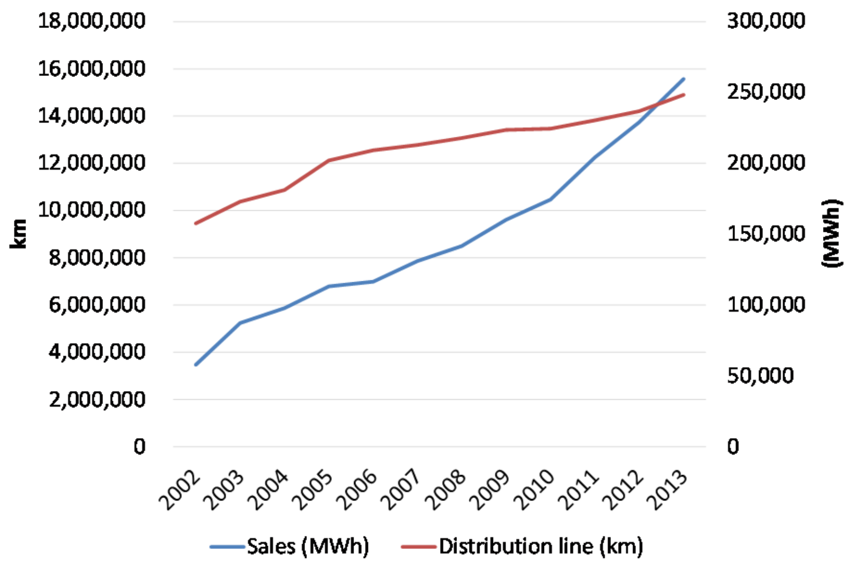
Source: JICA Survey Team

Figure 15-24 Projection of Access to Electricity (On-grid + Off-grid SHS)

It should be noted, however, that there are two issues to materialize the on-grid electrification by 2021. First of all, as pointed out earlier, BREB needs to keep its implementation speed as fast as between 2014 and 2015. Secondly, BREB needs to accommodate with a geological issue. According to the interview with BREB, 10% of future electrification area is not economically viable due to the scarce population density or river-crossing areas. Because transmission lines are not extended to these area, if PGCB does not extend the transmission line, it is difficult to extend the line to these areas. From the view point of the information from BREB, there will be off-grid electrification areas at the first period of the 100% electrification.

15.9.6 Demand estimation from electrification

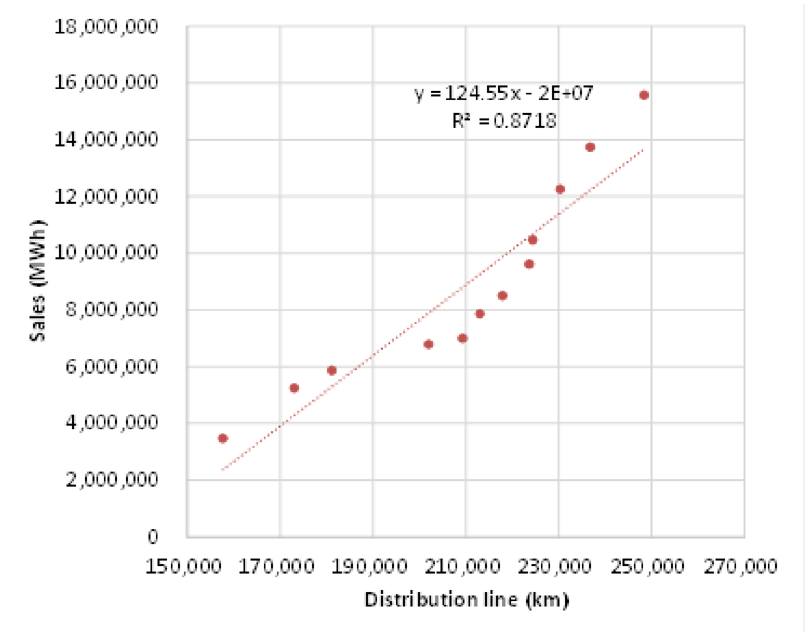
The below figure shows the pace of the grid line extension and the sales growth at BREB in the past 10 years.



Source: JICA Survey Team

Figure 15-25 Line Extension and Sales Growth

As shown in the below Figure, there is a correlation between line extension and sales growth.



Source: JICA Survey Team

Figure 15-26 Relation between Line Extension and Sales Grows

According to regression line, sales of 123.55MWh are increased by 1km distribution line extension. Therefore demand when electrification is completed is calculated by the below equation.

140,000 (km) x 124.55 (MWh/km) = 17,437 (GWh)

When load factor is 80%, maximum demand is estimated by the below equation.

17,437 (GWh) / 8760 (h) / 80% (LF) = 2,488 (MW)

According to the hearing from BREB, yearly average consumption per one customer (of residence customer type and non-residence customer type) is 372(kWh/person/year). According to the BBS statistics, because average number in one family is 4.6, consumption of one family is 1,71(kWh/contract/year). (371kWh/person*4.6person/contract=1.711kWh/contract/year) On the other hand, BSS statics estimates the contract will increase from 14.2 million to 24.0 million[3]. The consumption is calculated by the below equation based on the contract increment.

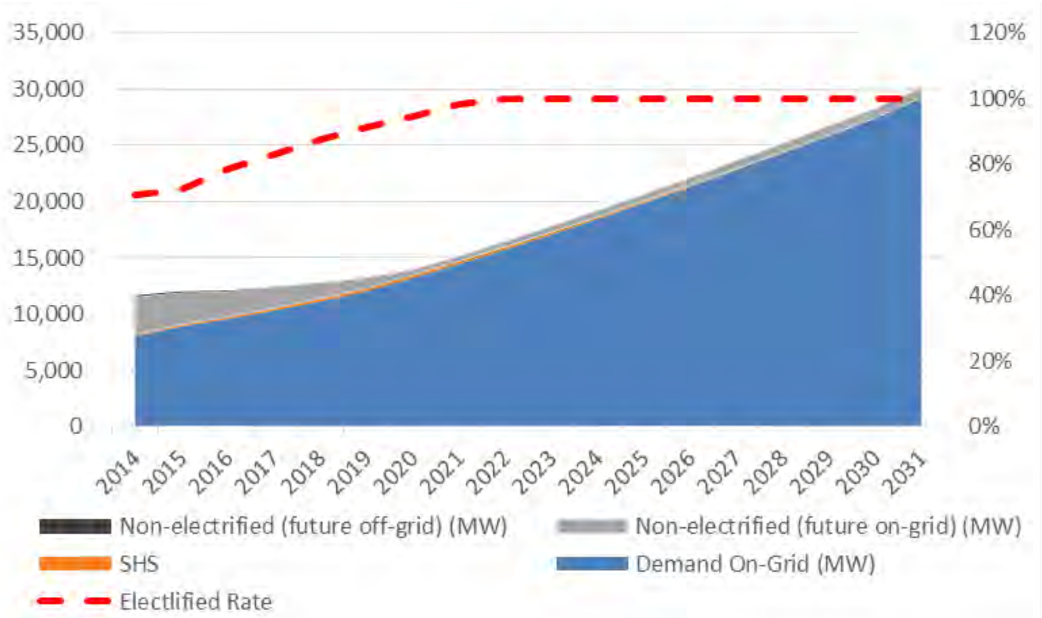
1,711 (kWh / contract / year) x (2,400(contract) - 1,420(contract)) = 16,770 (GWh)

Demand is calculated by the following equation, when load factor is 80%.

16,770 (GWh) / 8760 (h) / 80% (LF) = 2,417 (MW)

Because these two demands are similar, approximately 2,400 – 2,500MW demand will be increased when electrification rate becomes 100%.

Figure 15-27 shows the projection of the improvement of non-electrified capacity.



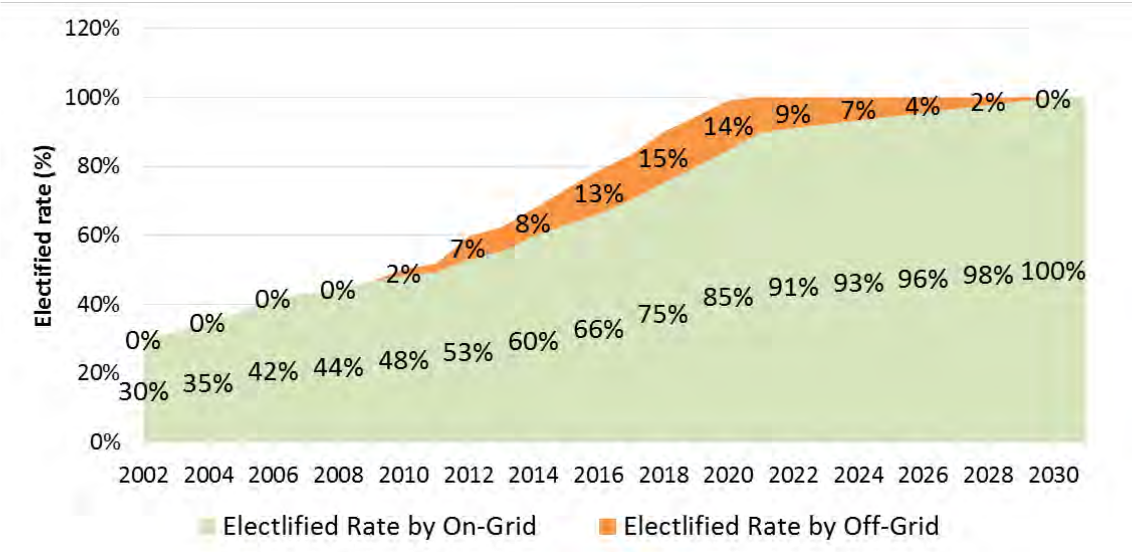
Source: JICA Survey Team

Figure 15-27 Relation between Non Electrified Energy and Demand

15.9.7 Future grid connection

If two issues described earlier can be cleared, electrification rate will be 100%. When distribution line extended to the area where SHSs were already installed, customer, which already installed SHS, will connect to the distribution line, because customer gets the merit according to the cost and limitation by the connection to the grid. When electrification rate extends by the growth rate shown in Figure 15-24, almost all of the customer will be connected to the grid by 2031 as shown in Figure 15-28.

[3] Based on the PSMP2016 Survey Team interview with BBS, February 2016.



Source: JICA Survey Team

Figure 15-28 Estimation of Progress of Grid Connection

15.9.8 Concerns on future wastes from SHSs

Once the stable power supply from grid is achieved, millions of SHSs would be disposed. Most of SHS substances are recyclable (e.g. glass and iron), but the popular SHS batteries in Bangladesh are inexpensive plumbic acid batteries, where lead and lead compounds are used for electrodes and dilute sulfuric acid are used for electrolyte.

Lead and lead compounds can have impacts to organs and nerve systems. Dilute sulfuric acid can cause respiratory disease if absorbed and chemical burn if contacted through skin. If the soil and ground water are contaminated with these substances, agricultural products and ecosystem in-taking these products (including human) would be affected. These substances will not be released to the environment as far as the battery is under usage; however, once a used battery is improperly treated the risk of substance release to the environment could occur. In addition, cadmium, extremely harmful to human body, can be contained in a small amount in a solar panel. It is also a risk of environmental contamination, if the used panel is improperly treated.

There is a report claiming the risk of these harmful substances in the solar generation system in India and China. In these countries, the handling of harmful substances is not very efficient nor well monitored. Such situation causes the loss of these harmful substances within manufacturing and recycling process, and may indicate the inappropriate exposure of these substances into the environment, resulting health risks of people living there[4]. Such loss is not necessarily caused by the illegal dumping or improper recycling of these substances; however, these cases have good implications to Bangladesh, for the importance of appropriate management of these substances.

IDCOL recognized the issues of future SHS wastes and health and environmental risks and implements countermeasures[5]

- Used battery collection process by POs,
- Incentive for POs to bring batteries to a designated recycling facility,
- Acquisition of ISO14001:2004 and OHSAS 18001:2007 by all domestic battery manufactures

[4] Gottesfeld, Perry and Christopher R. Cherry (2011): Lead emissions from solar photovoltaic energy systems in China and India, Energy Policy, 39(9), pp. 4939-4946

[5]

(most of SHS batteries are domestically manufactured)
- Incentive for users (households) to comply with SHS battery recycling

15.9.9 Future issues to address

- Only one definition of electrification rate should be selected. Also, the national census tells the average family member size is 4.6, while 7 adopted by BPDB.
- Grid extension in the next 5 years requires the same implementation speed as seen between 2014 and 2015, or twice faster than the historical pace (average between 2003 and 2015).
- BREB and IDCOL coordination and communication should be improved for efficient planning and implementation. BPDB's current role as "coordinator" could be reconsidered.
- SHS waste recycling needs will drastically increase after early 2020s. It should be confirmed whether the current scheme is proven effective and scalable.

Chapter 16 Power Quality

16.1 Fundamentals of Electricity Demand/supply Operation Process

"Demand/supply Operation" is the coordination of various kinds of power sources with demand in order to realize the most economical dispatch under the conditions of maintaining power system reliability or quality, such as system frequency and voltage.

To conduct appropriate demand/supply operation, work starts with the planning and development of adequate power plants and transmission facilities based on the correct demand forecast for a long range of 10 to 20 years. Then, this is seamlessly improved with detailed information on demand forecast or planned/unplanned outages by year-ahead, month-ahead, week-ahead, day-ahead and day plans.

The following is a brief explanation of demand/supply operation planning in Japan.

16.1.1 Demand/supply operation planning

(1) Yearly plan

In this phase, the combination of various kinds of power sources such as hydro, thermal and nuclear power plants is optimized so that economical dispatching is realized for the demand forecasted throughout the year. Development plans for power plants, periodic maintenance plans for thermal and nuclear power plants, fuel operation plans for oil or gas and water operation plans for reservoirs are taken into consideration.

(2) Monthly plan

In this phase, fuel operation plans and maintenance plans for generation facilities are expected to become firm, and the yearly plan is revised with these detailed plans.

(3) Weekly plan

Weekly start-and-stop plans for the thermal power plants and generating plans for hydro power plants (reservoir, pondage and pumped-storage type) are formulated because the accuracy of the demand forecast will be improved and maintenance plans for generation facilities are expected to be finalized in this phase.

(4) Day-ahead plan

Daily start-and-stop schedule for thermal power units, generating plans for hydro power units, and economical load dispatching plans are formulated and final demand/supply operation plans are fixed because the accuracy of the demand forecast is highly improved.

16.1.2 Real-time operation

(1) Economical load dispatching control (EDC)

EDC is the operation of the output of generators every ten or so minutes in order to realize an economically optimal allocation based on past records.

In the case of a power system connected with a large amount and various kinds of generating units, and in the case where the system load is greatly changing, EDC is largely dependent on automatic calculation and online instruction via computers, and instructions by phone in manual operations by shift engineers are performed only when unforeseeable events occur, such as enormous changes in weather or temperature, or sudden shut-off of generators.

(2) Load frequency control (LFC)

LFC is the control of generating output on a cycle in the range of several minutes to several tens of minutes in order to keep the system frequency constant.

LFC is almost completely dependent on automatic and centralized control by computer systems in the national (central) dispatching center. It is an essential condition for realizing power frequency quality in developed countries (0.2-0.3Hz or less).

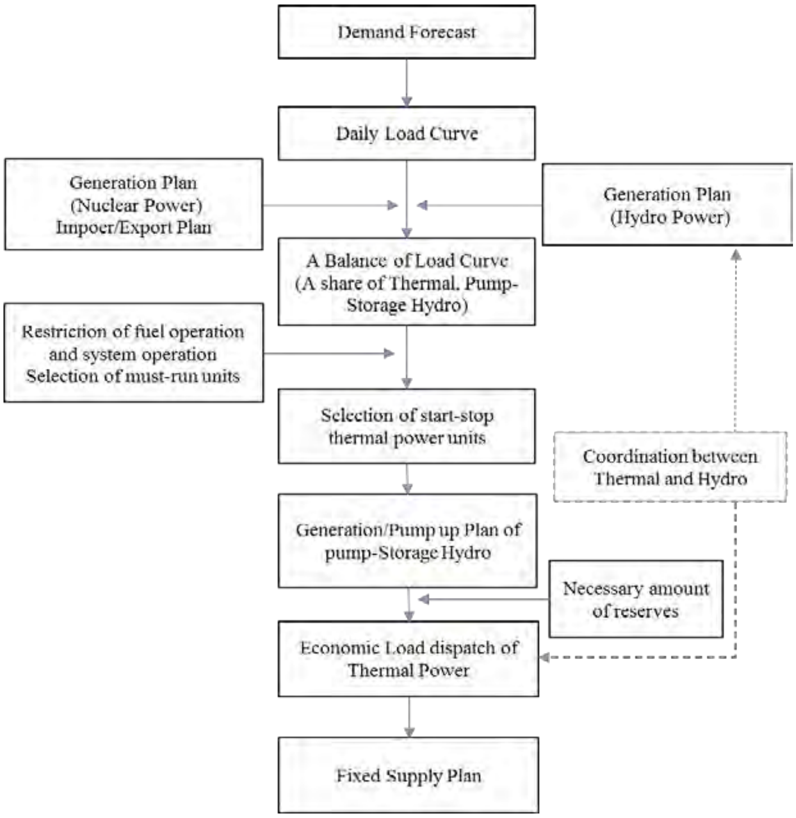
(3) Free governor mode operation (FGMO)

With more frequent load fluctuations ranging from several tens of seconds to several minutes, free governor mode operation by generators is effective for absorbing these.

FGMO is a kind of distributed control system, which can be performed by each unit independently. It is also an essential item for power quality.

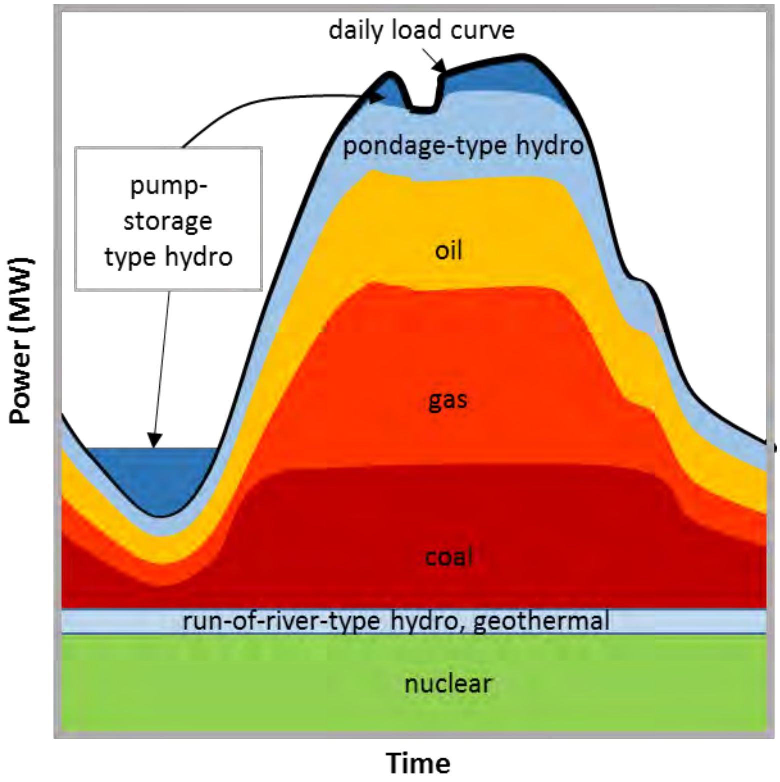
(4) Self-regulating characteristics of load

For more fine fluctuations of several tens of seconds or less, it is impossible to control these artificially because of the delay or dead band in a control system, such as LFC. Fortunately, these fine fluctuations can be absorbed by the inherent frequency-load characteristics or inertia of generators.



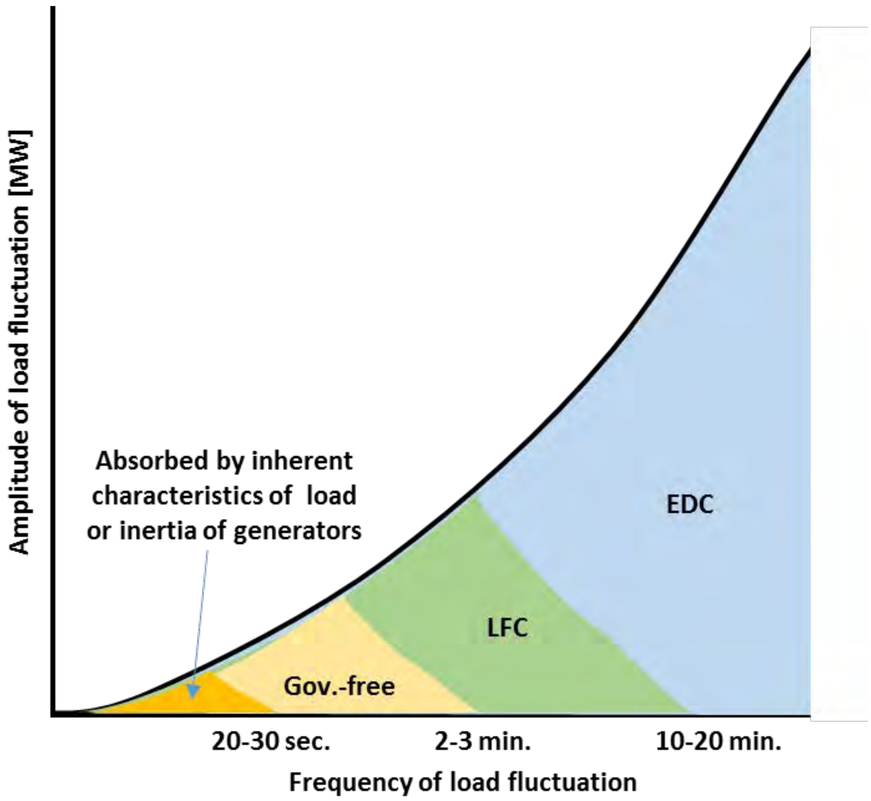
Source: JICA Survey Team

Figure 16-1 Flow Diagram of Day-ahead Demand/supply Planning Process



Source: JICA Survey Team

Figure 16-2 Example of Typical Daily Load Curve and Allocation of Power Sources in Japan



Source: JICA Survey Team

Figure 16-3 Conceptual Diagram of Role Sharing for Each Control Method

16.2 Present Status and Necessity of Improving Power Frequency Quality in Bangladesh

16.2.1 Electricity demand-supply operation in Bangladesh

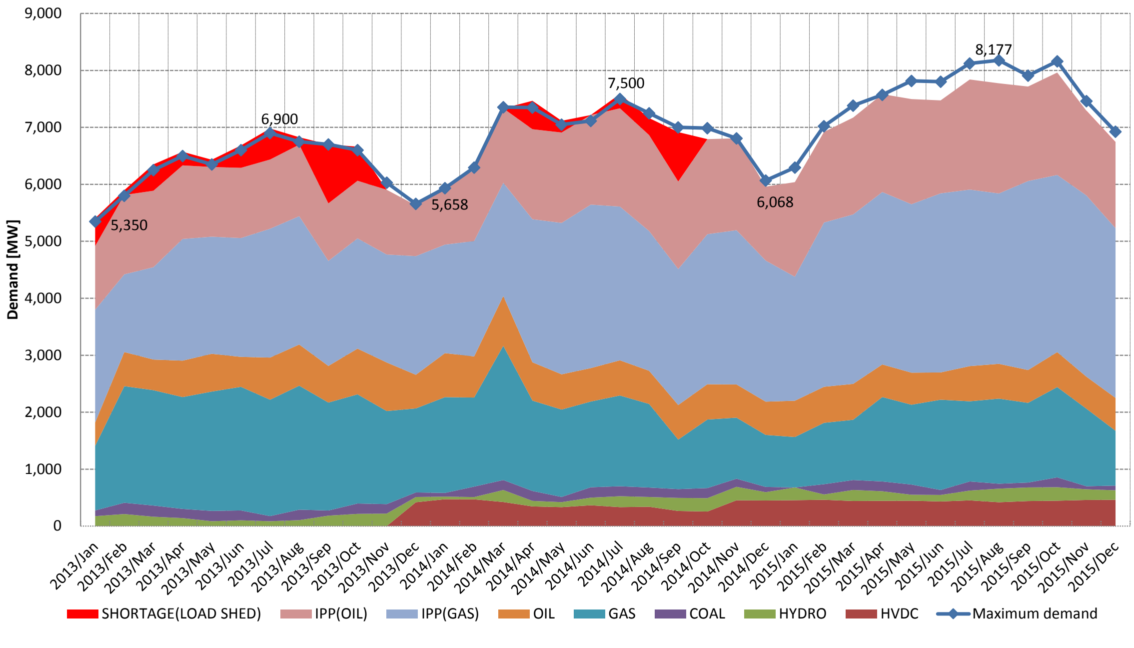
(1) Long-term planning

As shown in Fugure 16-4, load-shedding operations used to be conducted throughout the year in the past. However, it has gradually been limited to the peak load period and, in 2015, it was reduced to several days per year. (The graph in Fugure 16-4 shows supply-demand balance for the day of maximum peak load for every month. Therefore, if load-shedding operations were performed on other days, they are not illustrated in this graph.)

From the results of interviews with key persons, it is found that the following conditions only were good at supply-demand balancing operations, and they are short-lived situations:

- Commencement of operation of newly installed generators
- Commencement of electricity imports from India via HVDC interconnection
- Falling short of forecast demand

Therefore, a load-shedding scheme is still one of the major solutions for a deficiency in power sources.



Source: Created based on daily reports in NLDC

Figure 16-4 Monthly Trend of Peak Load Power Sources in Bangladesh

(2) Short-term planning

The results of the site investigations give us a glimpse of how serious the situation concerning short-term supply/demand balance planning is. In the process of settling the short-term plan, NLDC, primarily, should have authority to gather necessary information, to integrate this for finalizing plans and to instruct according to the plans. As a matter of fact, BPDB or generating companies finalize the generation plan, and NLDC has no authority to coordinate plans.

Variety of the Term of Planning

- A day plan and a day-ahead plan is formulated in NLDC. Weekly, monthly, yearly or longer term plans are not dealt with.

Integration of the Generation Plans (Maintenance Outage Plans)

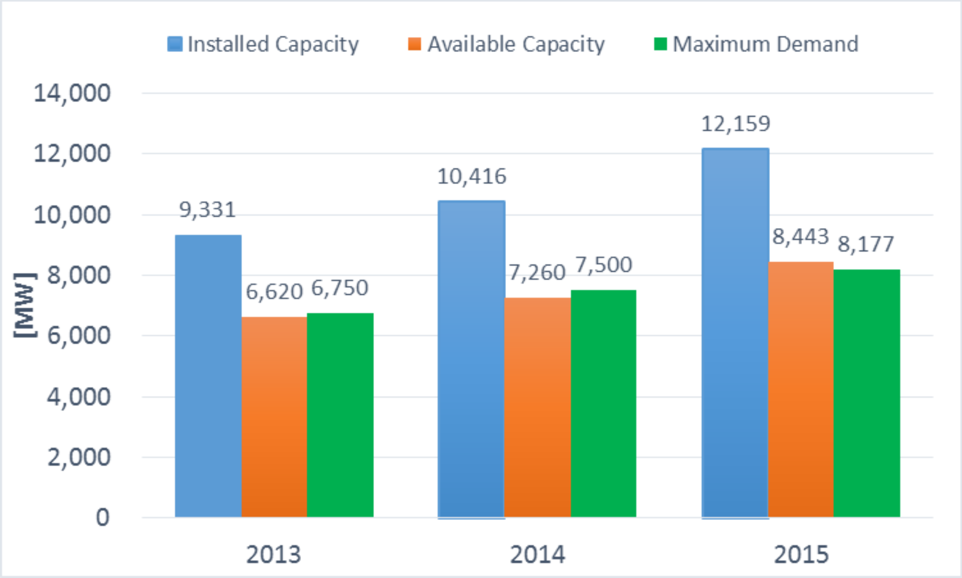
- Generation plans are not provided to NLDC until the previous day of actual operation.
- Coordination of the maintenance outage plans is performed by BPDB, and NLDC can't take part in the decision making process for the plan.

Plans of Demand-supply balancing and Unit Commitment

- The day-ahead plan is formulated at the timing of two peak hours in daytime and night-time.
- The day plan is formulated on an hourly basis from 16:00 to 15:00 of the next day.

(3) The actual condition of existing generation plants

According to the Daily Report of the Bangladeshi NLDC, the installed capacity of generators has been gradually increased corresponding to the demand rise, Figure 16-5 shows the situation of the supply-demand balance on the day of maximum peak demand from 2013 to 2015.



Source: Created based on daily reports in NLDC

Figure 16-5 Situation of Supply/Demand Balance on the Day of Maximum Peak Demand (from 2013 to 2015)

The installed capacity rate has been adequately secured at more than 130% every year. In reality, however, the available capacity is chronically insufficient due to decreases in the output and thermal efficiency and failures of power generators mainly due to insufficient periodic maintenance, which results in a decrease of around 30% in installed capacity. Until 2014, in particular, load shedding had been performed due to the shortage of power sources.
In 2015, load shedding could be prevented because the available capacity barely exceeded the maximum demand.
However, the rate of capacity decrease is remaining unchanged and the risk of load shedding is still high. Therefore, drastic measures for securing power sources are urgently required to be taken.

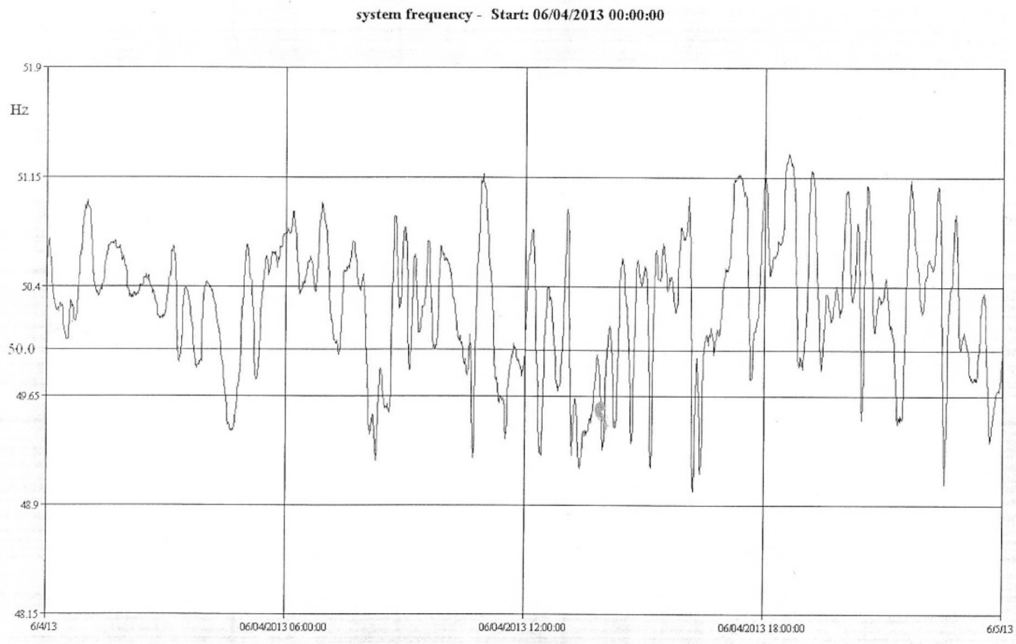
(4) Necessary actions for improving demand/supply balance

While steady development of power sources and repair of the existing power sources based on an appropriate demand forecast is hoped for in the mid to long terms, in the short term, eliminating the causes that obstruct efficient demand-supply operations, such as gaps between the demand forecast and actual demand, gaps between generating plans and actual operation, an increase in the loss of power transmission and electricity stealing, is important.

16.2.2 The Actual Situation regarding Power Frequency Quality

(1) The actual condition of power frequency control

At present, adjustment of the output of generators is instructed by phone (online instructions from SCADA are not issued). As shown in Figure 16-6, system frequency deviation from 50 Hz often exceeds ±1.0 Hz even in the normal operating condition (Grid Code stipulates that the system frequency shall be controlled within 50Hz±1.0Hz under normal conditions.)



Source: Provided by NLDC

Figure 16-6 Actual Situation of Frequency Adjustments in Bangladesh

PGCB kindly provided us with the following opinions in relation to the actual situation:

- Installation of a nuclear power station is currently planned for 2024, but it will be difficult to keep generating operation stable with the existing quality of frequency. An enhancement of frequency quality is eagerly desired.
- Before the unbundling of the electricity industry in 1996, the fluctuation in frequency was smaller than the present situation because about 50% of generators could offer reserves for frequency control, including generators in Kaptai hydro power station. However, since the unbundling, the number of generators which can offer the reserves has gradually decreased.
- PGCB estimates the following 2 causes of degradation of the frequency quality.
  1. There is almost no remaining power which can be offered for frequency control due to a significant deficiency in power sources. That is, all generators have no other choice except to keep their outputs at the maximum of available capacity.

2. The electricity industry was unbundled without rules and authorities for demand-supply control.

BPDB and Siddhirganj power station also gave us the following comments on the problems at present:

- It may be possible to operate in AGC (Automatic Generation Control) mode with the necessary modifications and testing conducted by the manufacturer (GE), yet the generators have not been set to respond to the LFC (Load-Frequency Control) signal from the NLDC system.
- They consider that the burden of FGMO should be shared among as many generators as possible, in order to reduce the power fluctuation of each generator.
- They have a willingness to cooperate on frequency control if a system is developed that can provide compensation for the opportunity loss of power selling.
- They have a strong desire to obtain detailed information about the situation of a power system among the stakeholders, because this operation should be performed under fair and transparent terms.

(2) Necessity of improving power frequency quality

To adjust the frequency, it is necessary to supply part of the generator output as adjustment power, and the power generation operator that supplies the adjustment power needs to shoulder a specific loss in the opportunity to generate power and a fall in power generation efficiency. The resource to make up for the loss comes from electricity charges or tax, which means that citizens eventually have to bear the burden. The economic effect brought by the technological power and improvement of frequency quality in a given era and the burden of the people are in a trade-off relationship.
Quantitative evaluation is extremely difficult in reality, and the target frequency deviation values of Japan, the U.S., and European countries vary as shown in the table below.

Table 16-1 Target Frequency Deviation Values of Japan, North America, and Europe

Region	Target frequency deviation value	Criteria
Bangladesh	50±1.0 Hz max.	Instantaneous
Hokkaido	50±0.3 Hz max.	Instantaneous
Eastern region (Tohoku & Tokyo Electric Power Co.)	50±0.2 Hz max.	Instantaneous
Mid-western region (Chubu Electric Power Co. & westward)	60±0.2 Hz max.	Instantaneous
North America (NERC)	East: 0.018 Hz max. West: 0.0228 Hz max. Texas (ERCOT): 0.020 Hz max. Quebec: 0.0212 Hz max.	Annual standard deviation (average in 1 minute)
Europe (UCTE)	50±0.04 Hz max., 90% min. 50±0.06 Hz max., 99% min.	Hour stay rate

Source: JICA Survey Team

Consumers, and especially general households, use electric appliances and IT products that have an inverter circuit and distributed power source systems such as for solar and wind power generation are connected to an inverter in many cases. For this reason, the influence of frequency fluctuation on electric equipment is smaller than before. It is therefore becoming more difficult to dig out the need for suppressing frequency from general consumers than before.
On the other hand, however, industries are said to suffer from the adverse influences stemming from frequency fluctuation as shown in the table below, and the potential need for frequency fluctuation suppression is considered to remain high.
From the viewpoint of suppressing frequency fluctuation, it will be very effective to coordinate

synchronization with other countries (coordination through AC transmission lines). In this case, however, there is a risk that a decrease in power quality or a power outage in one country spreads to the other countries. Realizing such coordination is therefore considered very difficult. However, the potential need for suppressing frequency fluctuation to the equivalent of that of developed nations is considered high in the future.

Table 16-2 Examples of Adverse Influence of Power Frequency Fluctuation on Industries

Industry	Influences of frequency fluctuation
Chemical fiber	Yarn may break or the thickness may become uneven because the speed of winding varies.
Paper manufacturing	Paper may break or the thickness may become uneven because the speed of winding varies.
Oil	Controlling pressure for decomposition and desulfurization may be affected and impurities cannot be removed.
Steel & aluminum	Rolling process may be affected, making the thickness of the product uneven.
Automobile	Welding strength and quality of appearance may be affected because the energization time of the body panel varies.

Source: JICA Survey Team

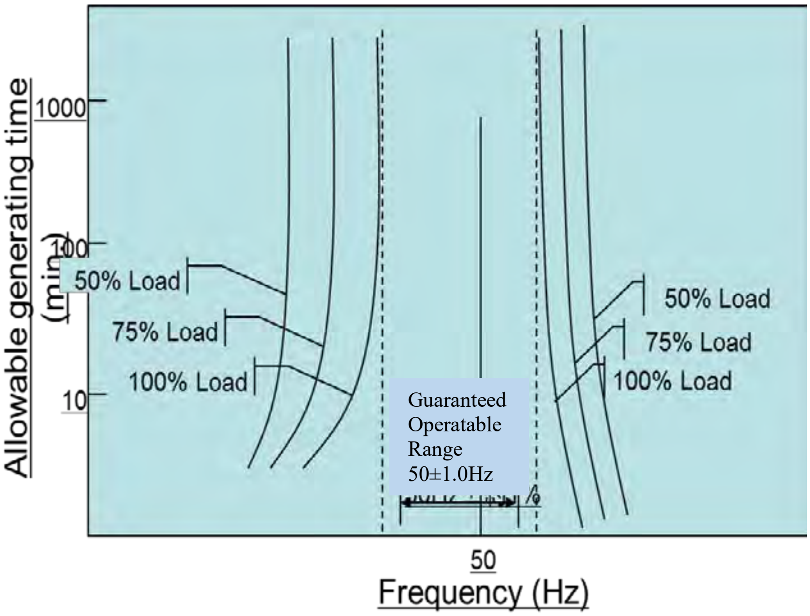
Thermal power generators and synchronous power generators have the following restrictions. These generators are designed not to operate continuously, from the viewpoints of generation of repetitive stress and member fatigue due especially to resonation of the turbine moving blade and shaft vibration, unless the frequency fluctuation is kept to within a specific value (within ±1% in Japan). Therefore, the need for suppressing frequency fluctuation is potentially high from the viewpoint of protecting machines and equipment. The effect of reducing failures of generators by suppressing frequency fluctuation can also be expected.

Table 16-3 Example of Operational Restrictions of Synchronous Generators

Turbine	Resonation of moving blade, shaft vibration
Generator	Over excitation, overload
Boiler, auxiliary device	Drop in capability of feed water pump, etc.

Source: JICA Survey Team

Figure 16-7 illustrates a conceptual diagram of a characteristic curve that indicates how long a generator is allowed to operate by the restrictions concerning resonation and shaft vibration of the turbine moving blade at a frequency (which is proportional to the number of revolutions of the turbine).
This generator can continuously run in the vicinity of the reference frequency (50 Hz) but the duration it can operate is rapidly shortened in the region outside the allowable limit. In addition, the lighter the load of the generator, the wider, though slightly, the frequency region where the generator can operate. In general, the allowable range in the higher frequency region is narrower than in the lower frequency range because the problem of centrifugal force is added to the problem of resonation of the turbine moving blade.



Source: Created based on documents made public

Figure 16-7 Conceptual Diagram of Frequency vs Continuous Operable Time Characteristics of Synchronous Generator

Based on the information described above, it can be said that the existing status of the frequency quality is inadequate from the viewpoint of protection management of generators.
Particularly, in order to maintain stable operation of a nuclear power generator planned to be connected to a power system in around 2024, it will be eagerly desired to enhance the quality level of frequency fluctuation to the global standard as shown in Table 16-1.

According to "Electric Grid Reliability and Interface with Nuclear Power Plants", issued by the IAEA, the following frequency quality shall be required in the case of connecting nuclear power plants:

- A generating unit is able to operate continuously at full output for the normal range of variation of grid frequency -- +/-1.0% (49.5Hz～50.5Hz).
- A generating unit is able to operate for a limited time, on a few occasions per year, perhaps at reduced output, for a range of frequency outside the normal range -- +4%, -5% (48.0Hz～r 52.0Hz).

In order to fulfill these requirements, frequency fluctuation must be improved to half or less within the coming decades, so it is an urgent problem for Bangladesh.

16.3 Scope of This Investigation

The scope of this project is as follows:

(1) Proposal for preparation of a legal framework, revision of rules and work procedures

- JICA survey team will propose and provide support for preparation or amendment of various rules with reference to the rules in Japan (or Europe/America, if necessary) and TEPCO.
- JICA survey team will check process of supply-demand balance planning and frequency control, and propose several improvement points.

(2) Draft of plan for frequency quality improvement

- Estimation of frequency sensitivity in response to sudden change of power supply or demand, and evaluation of frequency quality improvement by introducing generators equipped with frequency control function.
- Development of future plan for securement of spinning reserve, such as FGMO and LFC, considering generation development plan and roadmap for frequency quality improvement.

(3) Improvement plan for EMS/SCADA system in NLDC

- Confirming needs for introducing new functions or adding data to the EMS/SCADA system, in order to realize online output instruction orders to power stations.

16.4 Investigation of the Regulatory Framework for Electricity Business

16.4.1 Regulatory framework for power system planning/operation

(1) The case in Japan

The majority of the electric power companies are profit-making corporations with a joint-stock (limited liability) company system. Therefore, their business managements are subject to/under the protection of the provisions of general laws, such as civil laws, commercial laws or criminal laws.

In addition, they are regulated by a special law - the Electricity Business Act - in order to promote their sound development, to protect consumers' interests, to secure public safety and to preserve the environment.

As shown in Figure 16-8, the legal and regulatory structure in relation to the power system operation, and in particular the demand/supply operation or frequency control, consists of 3 stages.

Regulation by the Nation
- Electricity Business Act
  - Operational regulations concerning the law
  - Ordinance regarding the foundation of the Organization of Cross-regional Coordination of Transmission Operations (OCCTO)

Regulation by OCCTO
- Rules on Services
  - Guidelines on Demand Forecast
- Detailed Rules on Network Operations

Self-management Rules on Transmission and Distribution Sector in General Electricity Utilities
- Rules on Power System Operation
- Rules on Information Publication

Source: JICA Survey Team

Figure 16-8 Regulatory Framework for Electricity Supply Industry in Japan

The Organization of Cross-regional Coordination of Transmission Operations

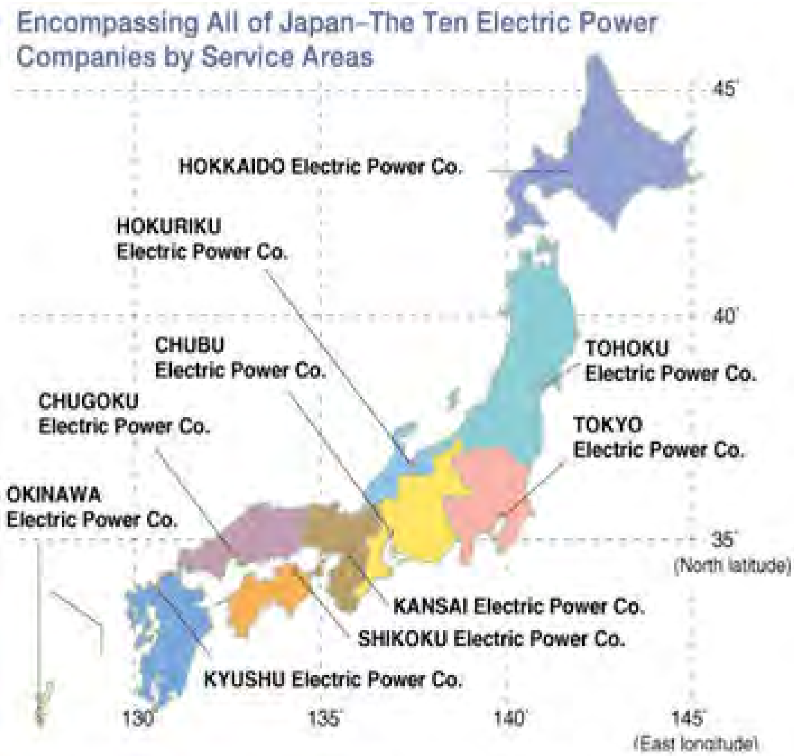
The Organization of Cross-regional Coordination of Transmission Operations (hereinafter shortened to OCCTO) was founded in April 2015, in order to manage the development work for nation-wide bulk power networks and to enhance the function of nation-wide power exchange under normal and emergency conditions. All electricity supply companies become a member of OCCTO, and are regulated neutrally and fairly under the rules, mentioned in Figure 16-8 (hereinafter "OCCTO Grid Code".)

The following are the main tasks:

- To enhance the nation-wide transmission facilities such as interconnection lines, including frequency converting stations, and the nation-wide power exchange though these inter-ties, by coordinating the demand/supply balancing plans and the network development plans.
- To perform nation-wide backups for regional operation of demand/supply balancing and frequency control under normal conditions, conducted by each operator of general electricity utilities.
- To take the initiative in coordinating the nation-wide power supply under emergency conditions such as disasters.
- To conduct the reception work for generators' access to the network in a neutral and transparent manner by publicizing power system information.

General Electricity Utility

A General Electricity Utility means a major electric power company supplying electric power to meet the needs of the general electricity demand in Japan. As shown in Figure 16-9, there are 10 regional service areas and, in each area, there is one company. (In total, there are 10 companies in Japan.)



Source: JICA Survey Team

Figure 16-9 Ten General Electricity Utilities and their Service Areas

Since the foundation of the companies in 1952, based on the current Electricity Business Act, they had been vertically integrated monopolies in each area. Then, partial liberalization of the electricity retail market started in 2000. After that, as described in Figure 16-10, full liberalization of the electricity retail market started in April 2016, and general electricity utilities will be unbundled into 3 sectors – power generation sector, transmission and distribution sector and retailing sector - by 2020.

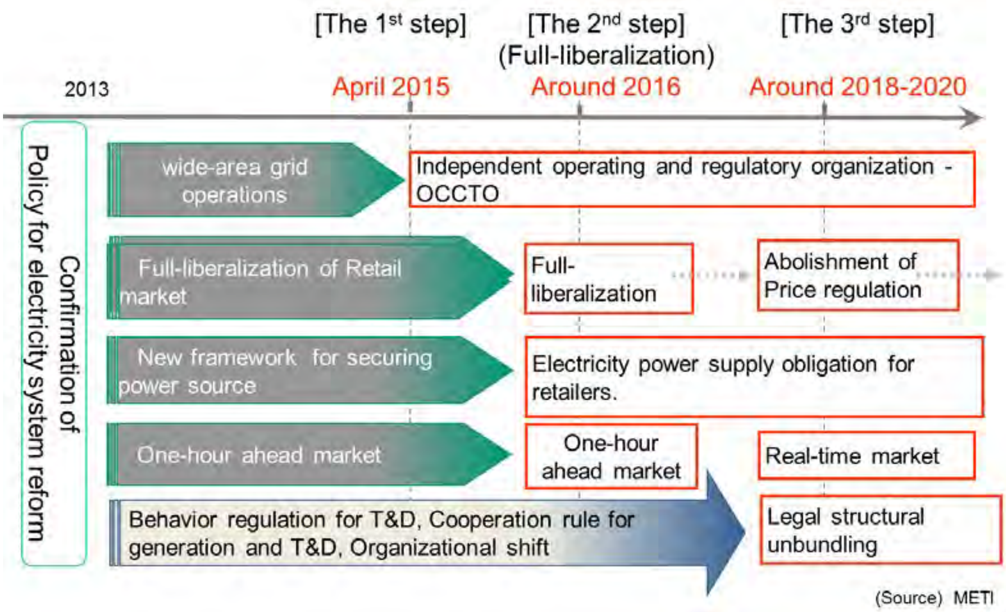
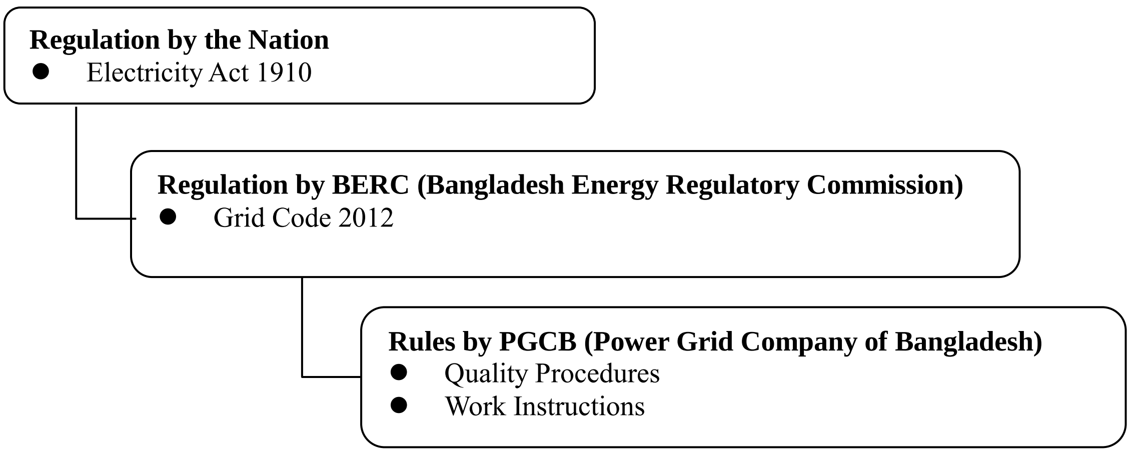


Figure 16-10 Schedule of Deregulation and Unbundling in Japanese Electricity Industry

The network operation sector will still monopolize and own the network facilities, and, like TSOs in Europe, will continue to implement the construction and O&M work.
For these reasons, the network operation sector in each area is regulated by the OCTTO Grid Code, and detailed local rules, bearing each area's circumstances fully in mind, are drawn up and disclosed to the public as "self-management rules".

(2) The case in Bangladesh

As shown in Figure 16-11, the legal framework in relation to supply/demand balancing and frequency control for the electricity industry in Bangladesh consists of 3 stages, like in Japan.



Source: JICA Survey Team

Figure 16-11 Regulatory Framework for Electricity Supply Industry in Bangladesh

16.4.2 Regulation by the Electricity Acts

The following are those things required in legal restraints, in general:

- ✧ To secure continuous power supply for all consumers with adequate quality
- ✧ To give authority to some entities to impose penal provisions on offenders

The Electricity Business Act in Japan has various regulatory terms on electricity supply companies (in particular, the public utilities) with the aim of sound expansion of the industry and protection of consumers.

Above all, the following are the important items in relation to stable demand/supply operation and frequency control:

- ✧ Obligation to supply
- ✧ Obligation of preparing and obtaining official approval for general supply provisions and their amendments
- ✧ Obligation to endeavor to maintain voltage/frequency value
- ✧ Obligation of preparing and notifying of a supply plan and its amendments
- ✧ Restriction on use of electricity
- ✧ Penal provisions

Table 16-4 describes the results of a rough comparative study between the provisions of Japan and Bangladesh.

A detailed comparative investigation and some proposals are drafted in Table 16-5.

Table 16-4 Rough Comparison of the Electricity Act between Japan and Bangladesh

Provisions	General Remarks	Electricity Business Act (Japan)			Electricity Act 1910 (Bangladesh)		
		Article	Obliges	Penalty	Article	Obliges	Penalty
Obligation to supply	Key rules in order to force the utilities to maintain and guarantee the following power quality: ✧ No interruptions. ✧ Proper voltage/frequency value.	18	Electricity Utilities	Imprisonment, fine, or both	None	-	-
Obligation to prepare "General Supply Provisions"		19, 19-2 20, 21	Electricity Utilities	Imprisonment, fine, or both	22	Licensee	None
Obligation to endeavor to maintain voltage/ frequency value		26	Electricity Utilities	Fine	None (Only in the Grid Code)	-	-
Obligation to prepare a "Supply Plan"	Key rules in order to force the utilities to promote development of power plants and to procure adequate power sources	29	Electricity Utilities	Fine	None	-	-
Restrictions on Use of Electricity	Key rules in order to prevent wide area interruption as a last resort	27	Consumers	Fine	None (Only in the Grid Code)	-	–
Other related penal provisions		115 Obstructions to Business	Offenders	Imprisonment, fine	29 [30 [39 Dishonest abstraction, etc. of energy	Offenders	Imprisonment, fine
		116 Unlicensed Business	Offenders	Imprisonment, fine, or both	39A Installation of artificial means, etc.	Offenders	Imprisonment, fine
					32 [40 Maliciously wasting energy or injuring works	Offenders	Imprisonment, fine
					36 [41 Unauthorized supply of energy by non-licensees	Offenders	Imprisonment, fine
					38 [43 Illegal transmission or use of energy	Offenders	Imprisonment, fine

Source: JICA Survey Team

Table 16-5 Comparison between the Terms of Electricity Business Act in Japan and Electricity Act 1910 in Bangladesh

Provisions	General Remarks	Electricity Business Act (Japan)	Electricity Act 1910 (Bangladesh)	Considerations/Proposals
Obligation to supply **Obligation of preparing and obtaining official approval for general supply provisions and their amendments**	In order to maintain adequate power quality, it can be simply said that: ✧ There are no interruptions. ✧ Voltage/frequency value is stably constant. Purpose of these three provisions are to guarantee the above mentioned power quality.	● An Electricity Utility shall not refuse to supply electricity without justifiable grounds. ● A General Electricity Utility shall formulate general supply provisions to set rates and other supply conditions, obtain official approval for them and publicize them. ● These articles carry penalties (imprisonment, fine, or both)	Following are the main points of provisions of "**Obligation on licensee to supply energy"** (Article 22)[1] ● Where energy is supplied by a licensee, every person within the area of supply shall, in principle, be entitled to a supply on the same terms as those on which any other person in the same area is entitled in similar circumstances to a corresponding supply. ● Provided that no person shall be entitled to continue to receive from a licensee a supply of energy unless he has agreed with the licensee to pay to him such minimum annual sum as will; ➢ give him a reasonable return on the capital expenditure ➢ cover other standing charges incurred by him ● There seem to be no penal provisions	Provisions of "obligation of supply" and "obligation to endeavor to maintain the voltage/frequency value" are among the most fundamental terms to force an Electricity Utility to promote development of power plants or voltage control equipment and to secure adequate active/reactive power sources and reserves from a long/medium-term viewpoint. This provision in Bangladesh corresponds to "general supply provision" in Japan. Moreover, it carries no penal provisions, so this provision seems to be a kind of exemption clause for utilities. Therefore, the provisions of "Obligation of supply", carrying a penalty, should be added to the Act in order to protect consumers' interests via administrative control.
Obligation to endeavor to maintain voltage/frequency value		● An Electricity Utility shall endeavor to maintain the voltage value or frequency value of electricity at the levels as below. ✧ Voltage: Nominal Voltage / Acceptable Range: 100V / 101V±6V; 200V / 202V±20V ✧ Frequency: specified value (50Hz, 60Hz) ● Official order for improvements of values, with penalty (fine) ● Obligation to measure/record/preserve[2] values, with penalty (fine)	● Provisions in relation to voltage/frequency quality are stipulated not in Electricity Act 1910, but in Grid Code and relevant rules. (refer to Table 16-13) ● There seem to be no penal provisions.	
Obligation of preparing and notifying of a supply plan or its amendments	Provision of "Supply Plan", together with the "obligation of supply", is another of the most important terms to force an Electricity Utility to promote development of power plants and to secure adequate power sources and reserves from a long/medium-term viewpoint.	● An Electricity Utility shall prepare a plan on the supply of electricity[3] and the installation and operation of Electric Facilities[4] (hereinafter referred to as a "Supply Plan") and notify the competent minister of the plan or its amendments (via OCCTO), with a penalty (fine). ● Official recommendation or order for improvements to plan, with penalty (fine).	There seem to be no provisions concerning securing the long-term adequacy of power sources in Electricity Act 1910, nor in Grid Code. There seem to be no penal provisions.	In Bangladesh, There may be no need to regulate the electricity utilities for the purpose of long/medium-term adequacy of power sources, because it may be secured by policy makers and national-level initiatives. The important thing is that an appropriate decision-making process is eagerly required and legislated, in which all relevant entities can participate, such as national government, regulatory authorities, electricity utilities, power system operators, etc., in order to realize a stable power supply by legally binding regulatory control.
Restrictions on Use of Electricity	There is a risk of affecting the supply-demand balance and wide area interruption caused by the excessive consumption of electricity by certain users.	● The competent minister may restrict the use of electricity, by limiting the power usage or peak load or specifying the purpose of use or the date and time when power usage should be stopped, if no adjustment is made to the supply and demand of electricity and a shortage of	Provisions in relation to load shedding are stipulated not in Electricity Act 1910, but in Grid Code and relevant rules.	This provision is applied only to the emergency condition that all countermeasures to secure the power source to meet the demand by power system operators have been exhausted. Under the condition of chronically significant deficiency of power sources in Bangladesh, this provision may be a severe term for

[1] **Obligation on licensee to supply energy**
22. Where energy is supplied by a licensee, every person within the area of supply shall, except in so far as is otherwise provided by the terms and conditions of the license, be entitled, on application, to a supply on the same terms as those on which any other person in the same area is entitled in similar circumstances to a corresponding supply:
Provided that no person shall be entitled to demand, or to continue to receive, from a licensee a supply of energy for any premises having a separate supply unless he has agreed with the licensee to pay to him such minimum annual sum as will give him a reasonable return on the capital expenditure, and will cover other standing charges incurred by him in order to meet the possible maximum demand for those premises, the sum payable to be determined in case of difference or dispute by arbitration.

[2] Following items in relation to frequency shall be recorded and preserved for 3 years.
- Specified value
- Daily maximum and minimum values, Monthly accumulated deviation
- Type and number of the meter
- Name of the person who is in charge of metering

[3] Major notification items in relation to "supply of electricity":
- Yearly maximum power and energy (from 1 to 10 years ahead)
- Monthly maximum power and energy (1 year ahead)

[4] Major notification items in relation to the "installation and operation of the Electric Facilities"
- New construction or enhancement plans for generating stations, generation costs (which will commence to operate or be constructed within 10 years, and have rated capacity of 350MW or more)
- New construction or enhancement plans for substations or transmission facilities (which will commence to operate within 10 years)
- Generating plan (1 year ahead)
- Fuel operation plan for the thermal power plants (1 year ahead)
- Electricity marketing plans (from 1 to 10 years ahead), Documents for marketing plans (1 year ahead)
- Power system maps and power flow diagrams (1, 5 and 10 years ahead)
- others

Provisions	General Remarks	Electricity Business Act (Japan)	Electricity Act 1910 (Bangladesh)	Considerations/Proposals
	Therefore, in an unavoidable case, restrictions of usage even to sound consumers are strongly required by the administrative control.	electricity supply will adversely affect the national economy and standard of living or public interest. ● This article carries a penalty (fine).		system operators because they have no choice except to conduct load shedding even under normal conditions, according to the Grid Code or rules for work process. However, in order to prevent unforeseeable outages, fair and transparent processes and rules for load shedding or rolling outages under administrative control may be eagerly required.
Penal provisions		In addition to the penal provisions carried by provisions of obligation and administrative orders, there are other specific penal provisions in the Electricity Business Act. The following are examples of penalties in relation to demand/supply operation or frequency control: ● **Obstructions to Business** ✓ Obstructions to the generation, transformation, transmission or distribution of electricity; ➢ by damaging the Electric Facilities or causing interference with the functioning of Electric Facilities. ➢ by operating the Electric Facilities without due cause. ✓ These articles carry a penalty (imprisonment, fine) ● **Unlicensed Business** ✓ Electricity supply under unlicensed conditions. ✓ This article carries a penalty (imprisonment, fine, or both)	The following are examples of penalties in relation to demand/supply operation or frequency control: ● Penalty for dishonest abstraction, etc. of energy[5] ● Penalty for installation of artificial means, etc.[6] ● Penalty for maliciously wasting energy or injuring works[7] ● Penalty for unauthorized supply of energy by non-licensees[8] ● Penalty for illegal transmission or use of energy[9]	

Source: JICA Survey Team

[5] **29[30[39.** (1) Whoever dishonestly abstracts, consumes or uses energy shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to three years and shall also be liable to a fine of ten thousand taka.

[6] **39A.** Whoever installs or uses any device, contrivance or artificial means for dishonest abstraction, consumption or use of energy of a licensee, whether he derives any benefit therefrom or not, 31[shall be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a fine which may extend to twenty thousand taka] and if it is proved that any device, contrivance or artificial means for such abstraction, consumption or use exists or has existed on a premises, it shall be presumed, unless the contrary is proved, that such person has committed an offence under this section.

[7] **32[40. (1)** Whoever maliciously causes energy to be wasted or diverted, or, with intent to cut off the supply of energy, cuts or injures, or attempts to cut or injure, any electric supply-line or works shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to five years and shall also be liable to a fine of ten thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such second or subsequent conviction be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a fine which may extend to twenty thousand taka.]

[8] **36[41. (1)** Whoever, in contravention of the provisions of section 28, engages in the business of supplying energy shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to five years and shall also be liable to a fine which may extend to fifteen thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such-second or subsequent conviction, be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a daily fine of one thousand taka.]

[9] **38[43. (1)** Whoever, in contravention of the provisions of section 30, transmits or uses energy without giving the notice required thereby, shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to three years and shall also be liable to a fine of ten thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such second or subsequent conviction, be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a daily fine of one thousand taka.]

16.4.3 Regulation by independent regulatory organization

This section provides a comparative study between the two Grid Codes established by the regulatory commission of both countries, BERC and OCCTO.

As shown in Figure 16-8 and Figure 16-11, there are detailed rules or work process manuals based on the Grid Code in both countries. However, these rules will be referred to only when necessary, because the major scope of this section is to provide an overview of the general framework of both Grid Codes.

In this section, the JICA survey team performed a comparative study of the following provisions in relation to the supply-demand operation and frequency control:

- Long-term supply-demand operation plan
  - A) Supply plan
- Short-term supply-demand operation plan
  - A) Demand forecasting
  - B) Planned Outage Coordination of Generator/Network
  - C) Plans for Demand-supply Balance and Generation Schedule
  - D) Real-time System Operation and Frequency Quality Control
  - E) Information Publication for Power System

Table 16-6 describes an outline of the items in both Grid Codes.

Table 16-6 Outline of Grid Codes in Both Countries concerning Supply-demand Operation and Frequency Control

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)
Supply Plans (Power Plants and Network Development Plan)		● Responsibility of OCCTO to collect, coordinate and study the Supply Plans from the nation-wide viewpoint.	None
Demand Forecasting	**Variety of Forecasting**	● Type, contents and deadline for submission	● Type, contents and deadline for submission
	Responsibility of Forecasting	● General Electricity Utilities: Area-wide forecast ● OCCTO: Nation-wide forecast	● The Distribution Utilities: each demand and load shedding estimation. ● The Licensee: Integrated demand estimation.
	Post Facto Inspection	● Responsibility of OCCTO to perform post facto inspection of demand estimation by General Electricity Utilities.	None
Planned outage coordination of generator /Network	**Integration for the Draft Plans**	● Responsibility of OCCTO to integrate "original plans" submitted by utilities into yearly and monthly "draft plan" of Generator/Transmission Outage.	● Responsibility of the Licensee to integrate into a draft Outage program based on a transmission outage planned by itself and the plans of generator/distribution utility.
	Coordination between Users and Finalization of the Plans	● Responsibility of OCCTO to re-coordinate the "draft plan" in response to the requirement from members and formulate and share the "final plan".	● Responsibility of the Licensee to interact with all Users as necessary to review and optimize the draft plan.
	Particular Points to note	● Preparation of a list of operation steps prior to actual operation. ● Operation shall be implemented based on the instructions by dispatching office. ● Work process in case of suspension, reconsidering or extension of outage.	● Restriction of removal from service without specific release from the NLDC. ● Responsibility of NLDC and Users concerned to inform the other party of suspension of works together with revised estimation of restoration time.
Plans for Demand - supply Balance and Generation Schedule	**Preparation of the plan and Monitoring the balance**	● Responsibility of each Electricity Utility, Supplier and OCCTO to submit, coordinate, prepare and monitor the supply-demand plans and generation plans.	● Responsibility of the NLDC, Licensee, and generators to submit, coordinate, and prepare the load/generation balance schedules and generation schedules.
	Operating Reserves	● Responsibility of General Electricity Utilities to strive to secure reserves which can promptly raise their output against a deficiency in power sources.	None
	Spinning Reserves	● There is no description in OCTTO Grid Code. Instead, the self-management rule in TEPCO	None

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)
		has provision for CLDO's responsibility to strive to secure adequate spinning reserves.	
	Margin for lowering	● Responsibility of CLDO to secure margin for lowering the power source when frequency rises during lower demand season.	None
	Measures when supply demand balance worsens	● Instruction by OCCTO when supply-demand balance grows worse gradually ● Instruction by OCCTO when supply-demand balance reaches emergency condition ● Sanctions on members who refuse to obey the instructions	● The processes of normal load control and emergency load control are stipulated in the "Load Control (Load Shedding) (WI-PSO-02)"
Real-time System Operation and Frequency Quality Control	**Frequency Control**	● There is no description of frequency target value in OCTTO Grid Code. Instead, Self-management rules of General Electricity Utilities have the values as 50Hz +/- 0.2-0.3Hz or 60Hz +/- 0.2-0.3Hz. ● Detailed operation processes under normal conditions and abnormal conditions are stipulated in self-management rules in General Electricity Utilities.	● Normal state : 49.0Hz-51.0Hz ● Emergency state: Generating unit is capable of operating at full rated power output within the range of frequency: 47.5Hz-52.0Hz, voltage: +/-10% rated value and power factor: 0.8 lagging to 0.95 leading. ● Detailed operation processes for frequency control are stipulated in the "Frequency & Voltage Control (WI-PSO-01)" and "Load Control (Load Shedding) (WI-PSO-02)"
	Power Quality Analysis	● Responsibility of OCCTO and work processes to put together a report on the results of analysis for power quality in relation to frequency, voltage and interruptions based on the data provided from General Electricity Utilities.	None
Information Publication		● There are provisions to publicize several items of network information on the websites of OCCTO and each General Electricity Utility.	None

Source: JICA Survey Team

In the following several sections, the JICA survey team conducts a detailed comparative study between the Grid Codes of both countries, and proposals for necessary improvements are drafted from Table 16-7 to Table 16-13.

(1) Long-term supply-demand operation plan

(a) Supply plan (power plants and network development plan)

In order to maintain the supply-demand balance for an extended period, demand should be estimated properly, and steady development of power plants and enhancement of the network based on the estimation is crucial.
Development or enhancement of electric facilities needs an appropriate duration of more than several years or several tens of years, for planning, engineering, procuring and construction.

Bangladesh has very high potential in economic progress and rapid growth in power demand. Therefore, it is essential to secure power sources in a long-term, sustained way.

In Japan, Electricity Utilities are obliged to prepare a "Supply Plan", as described in previous sections, and OCCTO collects and analyzes the plans to monitor the long-term circumstances of the nation-wide balance. As a result of their study, OCCTO can require the utilities to revise the plans.

(2) Short-term supply-demand operation plan

(a) Demand forecasting

Demand Forecasting is an important process for preparing the supply-demand operation plan from the long-term viewpoint of steady development of power sources, and from the short-term viewpoint of stable operation with adequate power sources and reserves.

In Japan, the official demand forecast is implemented by the following 3 entities:

- OCCTO — Nation-wide forecast
- TDS of the General Electricity Utilities — Area-wide forecast
- Electricity retailing companies — Each company's own forecast

The area-wide forecast is the most important value because the TDS in General Electricity Utilities is legally responsible for maintaining the supply-demand balance in their own service area. For this reason, the OCCTO Grid Code has several provisions regarding a common method of area-wide demand estimation. The OCCTO Grid Code also has terms of study, revision and post facto evaluation process for these estimations in comparison with the nation-wide demand estimated by itself.

In the case of the Bangladeshi Grid Code, there are some simple provisions for a Licensee's obligations. According to the Grid Code, demand forecasting from 2-year ahead to day ahead estimation shall be implemented by the Licensee. Unfortunately, participation of NLDC in the process of estimation seems not to be clear.

(b) Planned outage coordination for generator/network

As preparation for the supply-demand operation plan, it is essential to implement fair and transparent coordination between generation outage plans or network outage plans which affect the generating operation (their necessity, season, duration, and so on) from the following points of view:

- Interests of network owners or operators: To maintain the healthiness of network facilities by certain implementation of periodic maintenance, on the premise of securing adequate power sources (including reserves).
- Interests of generators: In addition to obtaining approval for the necessary maintenance outage plans, to coordinate on network outages and adjust the outage time and duration in order not to affect the generation plans.

(c) Plans for demand-supply balance and generation schedule

Short term demand-supply balance plans and generation plans shall be reviewed at every occasion of preparing yearly, monthly, weekly, day-ahead, and day plans incorporating revised demand forecast, generation plans and outage plans.
In the Grid Code, it is important to stipulate the provisions for monitoring and regulating from the viewpoint of adequacy of power sources, including reserves to meet the forecasted demand.

The OCCTO Grid Code has not only the above-mentioned provisions, but also terms giving OCCTO the authority to instruct electricity utilities to exchange power to solve partial power shortages.

In Bangladesh, the provisions for the preparation process are appropriately stipulated in the Grid Code and Quality Procedures/Work Instructions (PGCB). However, there seem to be no provisions for securing reserves (operating reserves, spinning reserves and so on).

(d) Real-time system operation and frequency quality control

In Japan, the OCCTO Grid Code stipulates several provisions for the fundamental framework, and self-management rules of each TDS in General Electricity Utilities stipulate rules for specific values and detailed processes because there are some special necessities in each service area.

In Bangladesh, the Grid Code has almost the same framework as Japan, and it sufficiently stipulates the

necessary items, these processes and responsible entities.
Unfortunately, there are some provisions that seem to be not as efficacious as they are expected to be, based on the results of investigations at sites.

(e) Information Publication for Power System

Publication of power system information has a risk of threatening the system security. However, under the liberalized and unbundled structure, it is necessary to disclose information to users of the network. In Japan, as shown in Table 16-13, a wide-range of power system information is publicized for fair and transparent business processes. In Bangladesh, there seem to be no rules in the BERC Grid Code.

When visiting the power stations in Bangladesh, there were some comments such as:
“At present, there are only one-sided instructions from NLDC regarding increase/decrease of output.”
“We would like to know information on the overall supply-demand balance to cooperate with NLDC”

The content of system information in Japan is still said to be insufficient, but information publication is important for users and, in particular, generators to make estimations of profitability, and for fair and transparent transactions of energy, reserves and ancillary services at the electricity market.

16.4.4 Summary

In general, amendment of the relevant Acts is urgently required regarding several kinds of obligation rules, their penal provisions, etc., in order to maintain and improve the power quality by administrative control.

Grid Code and work process rules in Bangladesh, on the other hand, seem to be still rougher than those in Japan, but have most of the necessary and minimum provisions which clearly mention the must-have terms and their responsibilities.

However, unfortunately, these provisions seem to be not as efficacious as they were expected to be because they do not correspond to the actual conditions found in some field surveys. For these reasons, it is essential to tighten the regulations by means of social sanctions such as post facto investigations or deprivation of licenses for offenders. It is also eagerly desirable to implement the necessary legal steps to accuse offenders of civil or criminal responsibility.

The Grid Code should be amended so that the NLDC has fitting authority and independence for their important responsibility of maintaining and improving the power quality. PGCB, BPDB and BERC should devote themselves to providing backup support.

Interviews with staff in NLDC reveal the following issues, which can be fully appreciated:

- BPDB deals with all processes from generation planning through implementing plans to O&M; NLDC cannot take part in these processes.
- There is no obligation/responsibility or penal rule for the generators to provide reserves for FGMO/LFC.
- Grid Code 2012 has already come into operation, but still has no effectiveness.
- Establishment of ancillary services in relation to frequency control is eagerly desirable in Code 2012.

Table 16-7 Grid Code concerning the Demand Forecast/Demand Estimation

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
Supply Plans (Power Plants and Network Development Plan)		● OCCTO shall request from all members their 10 year-ahead plans for power plants and network development in order to integrate, coordinate and study them from the nation-wide viewpoint, and then, submit them to the competent minister and publicize them. ● OCCTO shall investigate whether the plans are adaptable to the "Detailed Rules of Network Operations (OCCTO)"and "Guidelines on Demand Forecast (OCCTO)". If necessary, according to the results of this study, OCCTO coordinates them or requests that members make a revision of them. For the coordination, the following points are taken into consideration: ✧ Trends of actual demand ✧ Past records of demand estimation in the plans ✧ Guidelines and description requirements set separately by the nation ✧ The level of reserves ✧ Any factor that significantly affects the supply-demand balance ✧ Others ● OCCTO shall investigate the following points, based on the "Detailed Rules of Network Operations" or business experiences: ✧ Appropriateness of the plans ✧ Adequacy of power source to meet the estimated demand.	There seems to be no provisions concerning this category.	In Bangladesh, where is expected to be under the high potential of economic growth and remarkable demand rise, development of large-scale power plants and enhancement of the network need to be forwarded in cooperation with national policy, including the issue Whether the NLDC or PGCB should shoulder the consistent responsibility throughout the plans to actual operation. Therefore, it is not the matter of being stipulated in Grid Code, but being clarified within the policy-making process in relation to overall electricity industry.
Demand Forecasting	**Variety of Forecasting**	● For long term: From 3 to 10 year-ahead Max. kW and kWh each year ● For short term: Refer to Table 16-9.	● The year ahead: Monthly peak/off peak period demand ● The month ahead: Daily peak/off peak period demand ● The day ahead: Hourly demand	
	Entity and Process of Forecasting	**Area-wide demand estimation** ● General Electricity Utilities shall forecast the electricity demand based on the "Guidelines on Demand Forecast"[10], economy forecast, the latest trend of demand, past records of actual demand, specific matters, and so on. **Nation-wide demand estimation** ● OCCTO shall prepare a "Reasonable Level of Nation-wide Electricity Demand" in order to perform an appropriate estimation. In the preparation, the results of studies, regression analysis among the population, economic indicators and actual demand will be taken into account. ● OCCTO shall study the appropriateness of area-wide demand forecast compared with the "Level", adaptivity to the "Detailed Rules of Network Operation" and "Guideline on Demand Forecast", and then, if necessary, require revision of the estimation from General Electricity Utilities. ● OCCTO shall publicize the demand forecast for nation-wide and area-wide by the end of January, each year.	● The **Licensee**[11] shall make a demand estimation for every division described above, based on the demand estimation[12] and load-shedding estimation by **Distribution Utilities**. According to the "Procedure for Power System Operation & Control (QP-PSO-1)" ● DMLDC makes daily demand planning on the basis of the following: ➢ Season & weather condition ➢ Previous day's/year's demand conditions ➢ Working days or holidays ➢ Existence of any emergency/priority situation, etc.	According to the Grid Code 2012 in Bangladesh, Licensee and NLDC shall separately estimate the demand from 2-year ahead to the day ahead, and the day respectively. For seamless planning, it is important to make enormous efforts to cooperate with each other, though both entities are members of the Operating Committee. The JICA Survey Team heard in the field survey that there is a reorganization plan for NLDC to become an Independent System Operator (ISO). Bangladesh should take the opportunity to centralize responsibility and authority in the new organization.
	Post Facto Inspection	● General Electricity Utilities shall submit the following information to OCTTO. ✧ Actual demand for 10 years (Max. kW and kWh) ✧ Influence of temperature on the actual demand. ✧ The results of self-comparative study between estimated and actual demand[13] ● OCCTO shall study the following points based on its business experiences: ✧ Difference between estimated and actual area-wide demand, causes and trends. ✧ Appropriateness of concept and process for self-studies performed by General Electricity Utilities.		In general, it is difficult to accurately estimate electricity demand because it is influenced by various factors such as temperature, humidity, social activities, or other factors. So, establishment of a continuous improvement cycle, a so-called PDCA cycle, is an effective measure. In this cycle, participation of a disinterested party such as BERC may be an essential requirement.

---

[10] OCCTO prepares "Guideline on Demand Forecast" so that the estimation works well and smoothly. This guideline includes the following contents:
- Fundamentals for demand forecasting (Duration, Responsible entities, etc.)
- Correcting method based on the temperature, an intercalary year, and so on.
- Estimation method for area-wide demand (short term, long term)
- Estimation method for each electricity supplier. (short term, long term)

[11] In Grid Code 2012, "Licensee" is defined as "The holder of the Transmission License for the bulk transmission of electricity between Generators and Distributors"

[12] **Distribution Utilities** shall provide to the **Licensee** their estimation of each inter-connection point on a 2 year ahead, year ahead, month ahead, week ahead and day ahead basis.

[13] In comparative studying, factors which can influence the electricity demand, such as temperature, population, economic trends and so on, should be taken into account.

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
Planned outage coordination of generator /network	**Integration for the Draft Plans**	OCCTO shall prepare the "draft plan" of Generator/Transmission Outage by integrating the "original plans" submitted by TDS in General Electricity Utilities. **Varieties of the plan** (For preparation schedule, refer to Table 16-8) ✧ Yearly plan (1 & 2 years ahead) ✧ Monthly plan (1 & 2 months ahead) **Plans to be coordinated** ● Outage plans for following network facilities and Generators connected to them. ✧ Inter-area lines ✧ Transmission lines, Bus-bars operated at the highest and the second highest voltage in each area, and transformers connected to them. ✧ Network facilities whose outages can affect the ATC of the inter-area lines. ● Outage plans for remaining facilities are prepared and coordinated within the general electricity utilities and members who have interests. **Items to be considered when coordinating scheduled outages** ✧ Public and personnel safety ✧ Electric facilities' preservation ✧ Power system security, reliability ✧ Adequacy of reserves ✧ Degree of influence on major electricity consumers' operation plans ✧ Avoidance of unplanned restraint of generating operation ✧ Rationality of outage schedule ✧ Others	All **Generators** and all **Distribution Utilities** shall provide their proposed Outage programs according to the following manner: ● 2 year ahead, and year ahead (July to June) ● Generators' program: to Licensee and NLDC by 31st March each year ● Distribution Utilities' program: to Licensee by 31st March each year The **Licensee** shall prepare a draft Outage program based on a yearly transmission Outage program produced by itself and the information received from **Generators** and **Distribution Utilities**, taking into account the demand estimation. The Licensee, the NLDC and the Generators shall establish Operating Committees, and establish procedures relating to the operational interfaces between parties. They shall include Outage coordination, generation scheduling, and so on.	
	Coordination between Users and Finalization of the Plans	● Any member who comes under the following can ask for re-coordination of the draft plans: ✧ Members whose utilization plan for inter-area lines may be affected. ✧ Members whose generating plan may be affected. ➢ OCCTO shall re-coordinate the "draft plan" and formulate and share the "final plan".	The Licensee shall interact with all Users as necessary to review and optimize the draft plan, and then release the finally agreed transmission outage plan to all Users by 31st May each year. The Licensee shall review the plan monthly, and Users' requests for additional outages will be considered and accommodated to the extent possible.	
	Process of Outages	● TDS in General Electricity Utilities and on-site engineers shall cooperate with each other to prepare a list of operation steps prior to actual operation in order to prevent an unexpected accident and interruption. ● An actual operation shall be implemented based on the instruction from shift engineers of load dispatching office. ● Both parties shall confirm the starting and finishing time of outages. ● In the case of suspension, reconsidering or extension of outage, both parties shall confirm all the facts and reasons for these changes.	Notwithstanding provision in any approved Outage plan, no cross boundary circuits or Generating Unit of a Generator shall be removed from service without specific release from the NLDC. Once an Outage has commenced, if any delay in restoration is apprehended, the NLDC or Users concerned shall inform the other party promptly together with a revised estimation of restoration time.	This provision seems not to be as efficacious as it is expected to be because it does not correspond to the actual conditions – the JICA survey team heard that many generators are not operated conforming to the instructions issued by NLDC. For these reasons, it is vital to tighten the regulation by NLDC.
Plans for Demand - supply Balance and Generation Schedule	**Preparation of the plan and Monitoring the balance**	● Each Electricity Utility and Supplier shall submit the supply-demand plan (Table 16-9), generation plan (Table 16-10) or its amendment to TDS in General Electricity Utility. ● Each General Electricity Utility shall integrate the supply-demand plan in its service area, and submit it to OCCTO. ● OCCTO shall supervise the following items: ✧ Supply (including reserves) and demand balance of each Utility ✧ Supply (including reserves) and demand balance of each area ✧ Supply (including reserves) and demand balance of the whole of Japan	**Load/generation Balance Schedule** ● The NLDC and the Licensee shall coordinate and prepare load/generation balance schedules and generation schedules, and shall provide them to the Licensee and Generators according to the schedules shown in Table 16-12. **Generation Schedules** ➢ All Generators shall provide the MW/MVAR declared availability capacity (0:00-24:00 hours) of all Generating Units, to the NLDC during each hour of the day commencing 36 hours ahead and provisionally, for the day immediately after (plant availability notification) by 12:00 hours. ➢ Hydro Power Stations shall take into account their respective reservoir levels and any other restrictions and shall report the same to the NLDC. ✧ The NLDC shall produce a day ahead hourly generation schedule after consolidation of the data provided by Generators. It shall consist of Availability, Scheduled generation, Allocated spinning reserve and Generating Unit Standby requirements	This provision also seems not to be as efficacious as it is expected to be. For these reasons, it is necessary to give authority to NLDC (PGCB) and BERC to take the initiative in the procurement of reserves.
	Operating Reserves	● TDS in General Electricity Utilities shall strive to secure reserves which can promptly raise their output against the deficiency of power sources caused by trouble at electric facilities, estimation errors of demand or total generation output. ● Reasonable level of operating reserves is under consideration. ● According to the self-management rules of TDS in TEPCO: ➢ CLDO shall strive to secure operating reserves of more than 5% of maximum demand forecast for the day taking following items into account: ✧ Error in maximum demand forecast caused by error in temperature ✧ Trouble at generator ✧ Congestion of generation caused by trouble in network		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
		➢ Operating reserves shall be secured by the following measures: ✧ Hydro and thermal power in partial load ✧ Hydro power in stand-by mode ✧ Emergency Gas Turbine Generators		
	Spinning Reserves	● According to the self-management rules of TDS in TEPCO: ➢ CLDO shall strive to secure spinning reserves of more than 3% of maximum demand forecast for the day against sudden change of load or shut-off of generators ➢ Spinning reserves shall be secured by the following measures: ✧ FGMO of generators ✧ Emergency power injection from HVDC or FC ✧ Switching off the pump up operation of pump-storage hydro power		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.
	Margin for lowering	● CLDO shall secure margin for lowering the power source when frequency rises during the lower demand season. ● Reasonable level for the margin is under consideration.		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.
	Measures when supply demand balance worsens	**Instruction by OCCTO when supply-demand balance grows worse gradually** ● OCCTO can instruct members to exchange surplus power or lease network facilities. **Instruction by OCCTO when supply-demand balance reaches emergency condition** ● Heavy load case: suspension of planned outage, start of stand-by generators, output increase of in-service generators, restriction of electricity use based on the contracts ● Light load case: export to the area which has adequate lowering margin **Sanctions on members who refuse to obey the instructions** ➢ Notification to the competent minister	**According to the "Load Control (Load Shedding) (WI-PSO-02)"** ● The whole country is divided into 9 distribution zones -- DESA, Chittagong, Comilla, Sylhet, Mymensing, Khulna, Barisal, Rajhsahi, and Rangpur ● Load control will be imposed in proportion to the demand of the respective zones as per the load control chart. **Normal Load Control** ➢ Load dispatching control room will send the message for load allocation (together with amount, duration and cause) to the respective zone over carrier telephone. ➢ The despatcher closely monitors whether the load control is implemented properly or not with the help of telemetering/SCADA system. ➢ If any zone does not carry out the given load control plan properly, the despatcher will implement forced load control by switching off 33kV feeders, after giving an alert to the zone. **Emergency Load Control** ➢ The direct actions of switching off 33kV feeders by the despatcher will be prioritized. Refer to "**Operation in a frequency drop"**, described below.	In Bangladesh, load shedding is performed not only in emergency operation, but in normal operation, frequently. In Japan, OCCTO Grid Code and Self-management rules of TDS stipulate that load shedding is performed only when the power source deficiency condition has gone beyond the operator's control. The principle that the load shedding scheme is the last resort should be specified in the Grid Code, so that electricity utilities are urged to make efforts to procure sufficient reserves.
Real-time System Operation and Frequency Quality Control	**Frequency Control**	● There is no description of the frequency target value in OCTTO Grid Code. Instead, Self-management rules of General Electricity Utilities have the values as 50Hz +/- 0.2-0.3Hz or 60Hz +/- 0.2-0.3Hz. ● Reasonable level of LFC or FGMO capacity is under consideration. ● In the case of significant frequency deviation due to sudden trip of electric facilities or change in demand, the following measures shall be taken, in addition to LFC and FGMO: ✧ Emergency trip or rapid output control of generation/pump up ✧ Emergency power exchange through the inter-area lines ✧ Load control or shedding as a last resort ✧ Disconnection of inter-area lines to prevent nation-wide blackout.	**Responsibility** ● NLDC shall monitor actual load and generation balance and regulate generation and demand to maintain frequency. ● Generators shall follow the dispatch instructions issued by NLDC. ● All Generating Units shall have the governor available and in service and must be capable of automatic increase or decrease in output within the normal declared frequency and within their respective capability limit. **Acceptable frequency range** ● Normal state : 49.0Hz-51.0Hz ● Emergency state: Generating unit is capable of operating at full rated power output within the range of Frequency: 47.5Hz-52.0Hz, Voltage: +/-10% rated value, Power factor: 0.8 lagging to 0.95 leading	Effectiveness of this provision in Grid Code 2012 is crucial for future improvement of power quality.
	Frequency Control (Detailed)	**According to the self-management rules in TEPCO** **Control under normal conditions** ● CLDO shall adjust the supply-demand balance in each service area by means of output control instruction to the generators in response to the change in demand. ● CLDO shall secure the reserves for LFC amounting to 1-2% of total demand. ● Acceptable range: 50.0±0.2Hz Acceptable time-lag：±15 sec. ● All generators shall obey the instructions issued from CLDO, and inform of any change of circumstances if they cannot obey the instructions without delay. ● All generating units which can serve the output control or LFC operation shall be operated under FGMO, in general. **Control under abnormal conditions**	**Generation Dispatch** ● All Generators shall comply with a dispatch instruction issued by NLDC. ● In absence of any dispatch instructions by the NLDC, Generators shall generate according to the day ahead generation schedule. ● Dispatch instruction feedback from Generators shall be issued by telephone or computer to computer communication. ● The generator shall promptly inform the NLDC in the event of any unforeseen difficulties in carrying out an instruction. ● Generators shall inform the NLDC of any change of AVR and/or governor control mode of service with reasons. ● Generators shall not de-synchronize Generating Units without instruction from the NLDC except on the grounds of safety to plant or personnel. ● Generators shall report any abnormal voltage and frequency-related operation of Generating Units promptly to the NLDC.	It is vital to tighten the regulations by means of social sanctions such as post facto investigations or deprivation of licenses for offenders or uncooperative entities. It is also eagerly desirable to implement the necessary legal steps to accuse offenders of civil or criminal responsibility.

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
		In the case of significant frequency deviation due to sudden trip of electric facilities or change in demand, the following measures shall be taken: ● CLDO shall issue an instruction of manual trip or output change to the most effective generating unit to restore the frequency quality, such as a unit which is rapidly adjustable or has wide margins. ● CLDO can issue the load control/shedding instructions only when control by the generating units cannot meet the required amount for restoration from under-frequency condition. ● CLDO shall disconnect the inter-area lines to prevent the cascading blackout. **Abnormal under-frequency conditions** ➢ CLDO shall endeavor to rapidly restore the frequency to 48.5Hz or above, by generation or load control. **Abnormal over-frequency conditions** ➢ CLDO shall endeavor to rapidly restore the frequency to 50.5Hz or below, by generation or load control.	**According to the results of site investigation work, “Frequency & Voltage Control (WI-PSO-01)” and “Load Control (Load Shedding) (WI-PSO-02)”** **Operation in a frequency drop (Supply < Demand)** ● In the situation of load shedding, each generator output is operated at available capacity and not in FGMO (in load-limit mode instead). ● Demand-supply balancing control is performed by load shedding. To be concrete, NLDC allocates a cap of available power to each of the 9 ALDC (Area Load Dispatching Center). And then the ALDC shuts off the 33kV distribution lines so that the power demand in the ALDC = allocated available power. ● In the case of a sudden decrease in frequency due to the unplanned outage of a generator, inadequate load shedding, and so on, automatic switching control by SCADA system is performed. (Controllable capacity is 547 ccts of distribution lines; maximum demand of 6,837MW in whole power system) ● In the case of further frequency decrease despite the SCADA control, load shedding by UFR (Under Frequency Relay) is performed in the range of 48.90Hz to 49.50Hz. UFR can shed a maximum of 2,000MW loads. **Operation in a frequency rise (Supply > Demand)** ● Operated in following manner and order: ① Re-charging of shed distribution lines ② Instruction for power output decrease	In Bangladesh, load Shedding is performed not only in emergency operation, but in normal operation, frequently. In Japan, OCCTO Grid Code and Self-management rules of TDS stipulate that load shedding is performed only when the power source deficiency condition has gone beyond the operator’s control. The principle that the load shedding scheme is the last resort should be specified in the Grid Code, so that electricity utilities are urged to make efforts to procure sufficient reserves.
	Power Quality Analysis	● OCCTO shall put together a report on the results of analysis for power quality in relation to frequency, voltage and interruptions based on the data provided from General Electricity Utilities. ● All General Electricity Utilities shall submit, every year, the actual data for a duration time ratio per year that the frequency deviation was controlled within 0.1Hz, 0.2Hz, 0.3Hz and more than 0.3Hz, to OCCTO.		Framework of continuous monitoring, analysis and evaluation of frequency quality should be stipulated in Grid Code 2012.

Source: JICA Survey Team

Table 16-8 Submission of Outage Plans to General Utilities (Japan)

	Annual plan (1 & 2 years ahead)	Monthly plan (1 & 2 months ahead)	Revision Unplanned Outage
Original	The end of October, each year	1st, each month	Any time (without delay)
Draft	The end of December, each year	10th, each month	
Final	Mid-February, each year	The middle of each month	

Source: JICA Survey Team

Table 16-9 Submission of Supply-demand Plans by Each Utility (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	The end of October every year	The 1st day of every month	Every Tuesday	Every noon	Any time
Forecasted demand	Max./Min. power (kW) by weekday/holiday of each month	Max./Min. power (kW) by weekday/holiday of each week	Max./Min. power (kW) and time every day	Energy (kWh) every 30 min.	Energy (kWh) every 30 min.
Supply for demand	Total planned value of supply power (procured/unprocured)				

Source: JICA Survey Team

Table 16-10 Submission of Generation Schedule by Each Supplier (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	The end of October every year	The 1st day of every month	Every Tuesday	Every noon	Any time
Schedule by power stations	Max./Min. power (kW) by weekday/holiday of each month	Max./Min. power (kW) by weekday/holiday of each week	Max./Min. power (kW) and time every day	Energy (kWh) every 30 min.	Energy (kWh) every 30 min.

Source: JICA Survey Team

Table 16-11 Integration of Supply-demand Plans (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	25th March every year	25th every month	Every Thursday	17:30 every day	Any time
Demand of service area	Maximum demand of each month	Maximum demand of each week	Maximum demand every day	Max./Min. power (kW) and time of the next day	Max./Min. power (kW) and time of the day
Supply for demand	Total value of supply power				

Source: JICA Survey Team

Table 16-12 Generation Scheduling by Licensee (Bangladesh)

	Annual plan (year ahead)	Quarterly plan (quarter ahead, remaining quarter of current year)	Monthly plan (following 2 months)	Weekly plan (week ahead)	Day ahead schedule
Deadline	Not less than 90 days before the beginning of each calendar year	Not less than 60 days before the beginning of each quarter	Not less than 14 days before the beginning of each month	Not less than 48 hours before the beginning of each week	Not less than 7 hours before the beginning of each day
Items	Monthly basis	Weekly basis	Daily basis	Hourly basis	Hourly basis

Source: JICA Survey Team

Table 16-13 Details of Information Publication Rules in OCCTO Grid Code

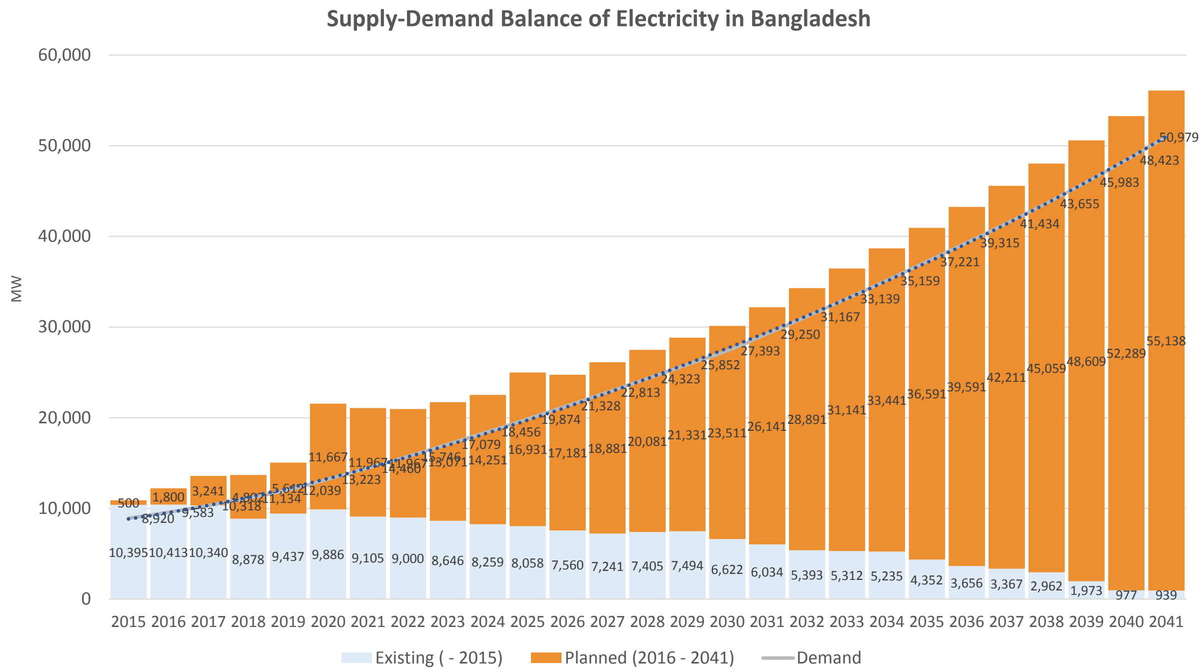
On the Website of OCCTO	On the Website of General Electricity Utility
(a) Information for system interconnection ・ Simplified diagram of transmission system drawn on a map showing restriction in system interconnection of generation facilities (154kV or over) ・ Plans for the construction of network system	(a) Information for system interconnection ・ Simplified diagram of transmission system drawn on a map showing restriction in system interconnection of generation facilities (154kV or over) ・ Plans for the construction of network system
(b) Nationwide demand forecasting ・Nationwide demand power Maximum demand power in each month for 1 and 2 years ahead Maximum demand power in the following month Maximum/minimum demand power and forecasted time on the following day ・Nationwide supply power Maximum supply power in each month for 1 and 2 years ahead Maximum supply power in the following month Maximum supply power on the following day	(b) Area-wide demand forecasting ・Area-wide demand power Maximum demand power and forecasting time in the following month Maximum demand power and forecasted time on the following day ・Area-wide power supply Maximum supply power on the following day Maximum supply power on the day
(c) Actual demand power ・Total amount for nationwide; present demand power actual demand curve of the day and previous day ・Total amount for nationwide and area-wide; actual maximum demand power of the day generation time of the day	(c) Actual demand power ・Total amount for area-wide; present demand power actual demand curve of the day and previous day actual maximum demand power of the day generation time of the day
(d) Output limitation of RES ・Area where output limitation occurred ・Date and time when output limitation occurred ・Total amount of output limitation ・Causes	(d) Output limitation of RES ・Date and time when output limitation occurred ・Total amount of output limitation ・Causes
(e) OCCTO Grid Code ・Rules for Services ・Detailed Rules for Network Operations ・Guidelines on Demand Forecast	(e) Rules for TDS ・Rules for information publication ・Rules for system development ・Rules for interconnection ・Rules for power system operation

Source: JICA Survey Team

16.5 Proposal for Frequency Quality Improvement Roadmap

16.5.1 Future electricity demand and power sources in Bangladesh

The relationship between future electricity demand and power sources in Bangladesh is shown in Figure 16-12.



Source: JICA Survey Team

Figure 16-12 Prospect of Demand and Supply Balance to 2041 (PSMP2016)

Future demand is assumed to increase at a rate of about 5 to 10% per year. Supply for the increase in demand is planned to be secured by the increase in imports due to the new construction and expansion of coal-fired and gas-fired power plants, nuclear power, and an international tie-line of high-voltage direct current (HVDC).

In the range of this Master Plan existing generators (pale blue colored) are expected to continue as part of supply. However, these cannot be expected as a stable supply and primary reserve because machine trouble or output reduction due to aging and lack of maintenance has frequently occurred.

Fortunately, these existing units are gradually being dismantled or replaced by new units. Moreover, along with the strong economic development, generators which are planned to be newly constructed and expanded after 2015 (orange colored) are expected to occupy an overwhelming share. Therefore, the following matters should be taken into account:

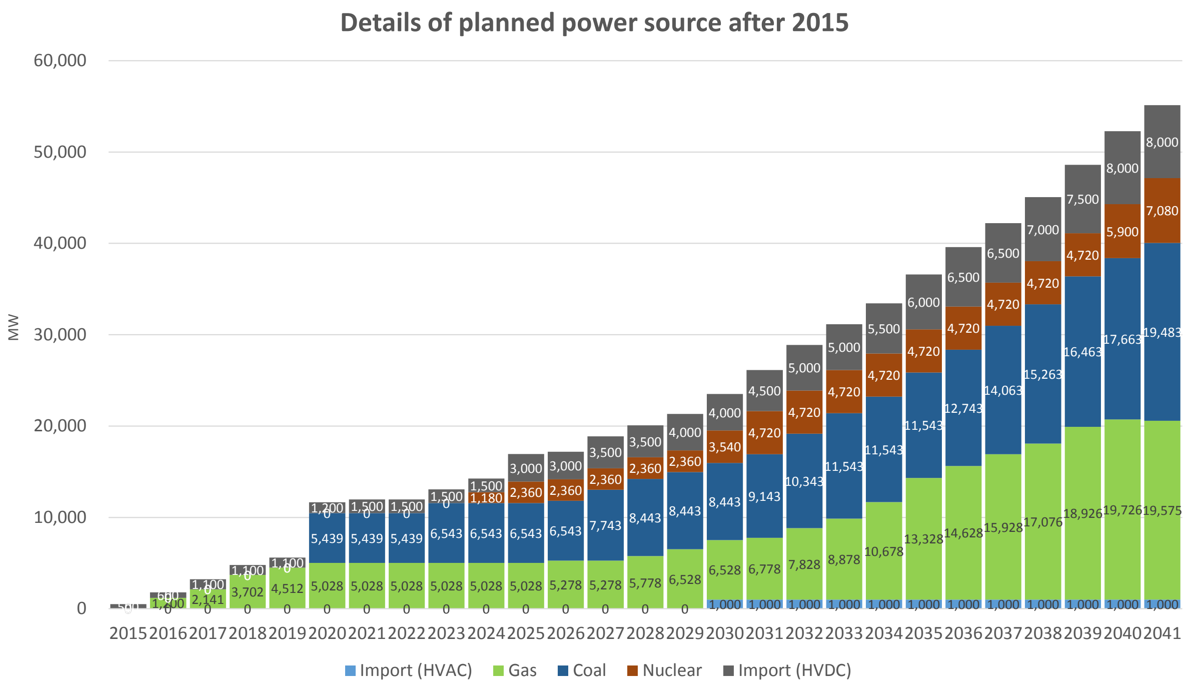
- To establish a system of periodic maintenance, so that these generators can stably output up to the rated capacity throughout their life.
- To consider the free-governor mode operation (FGMO) and load frequency control (LFC) at the design stage, so that the frequency control function is appropriately provided from the commencement of operation.

16.5.2 Reserves for power frequency control

(1) Trial calculation of availability for reserves

(a) Availability from newly constructed generation units (commissioned after 2015)

Figure 16-13 shows details of planned power sources after 2014, which are classified by types, fuels and power producers in the case of gas-fired type. Power sources in the future highly depend on the coal-fired and gas-fired plants (producers have not been decided yet). Power imports from neighboring countries and nuclear power, planned for 2024 and 2025, also account for more than a few power sources. In addition, there is a development plan for hydroelectric power in Meghalaya, India after 2030 (pumped-storage hydro power is highly recommended), which is, as one of the ideas, directly interconnected to the power system in Bangladesh through an AC transmission line. Although its proportion is small, the flexibility of demand-supply control is expected to be increased.



Source: JICA Survey Team

Figure 16-13 Details of Planned Power Sources after 2015

All of the newly constructed power sources should ideally provide reserves. In fact, there are the following problems and risks:

HVDC international tie-line — From a technical point of view, it is possible to equip the LFC function in normal and emergency conditions, such as the Hokkaido-Honshu HVDC Link in Japan. Actually, international agreements and the establishment of fair and transparent rules are strictly required because this function affects the power frequency quality of another country.

Nuclear power generation — From a technical point of view, while FGMO and LFC (AGC: Automatic Generation Control) can be applied to nuclear power plants, a political decision-making process may be required to be undertaken. In Japan, in order to give priority to the stable operation of the plant, power system operators are restricted in issuing FGMO and LFC instructions, to say nothing of output change.

Coal-fired generation — In Japan, the generation cost for coal-fired is low because of the low fuel cost (variable cost). Therefore, from the point of view of the most economical dispatch and the merit order, it is expected, together with nuclear power, to provide base load capacity (24 hour full operation). In order to recover the equipment cost of the regulation function (fixed cost) and ancillary service cost (variable cost), such as FGMO and LFC, the development of a framework for cost recovery (including the market mechanism) is necessary.

According to the interviews with PGCB, BPDB and NLDC, they plan to impose an obligation to provide reserves on 50% of coal-fired generators, while HVDC tie-lines and nuclear power plants are not expected to provide reserves. Besides, all providable generators are required to provide 10% - 15% of rated capacity as reserves, each. Therefore, the JICA survey team performed the trial calculation on the condition that each of the available newly constructed hydro, oil-fired and gas-fired generators, and half of the coal-fired generators, should provide 10% - 15% of rated capacity power as reserves (in units of 1%). [14]

(b) Efforts of existing generation units (commissioned before 2014)

In November 2015, the first discussion meeting between power producers and BPDB was held in the Ministry of Power, Energy and Mineral Resources (MOPEMR), concerning the expansion of contribution for frequency control of existing generators. In order to rapidly improve the power quality, the following content was discussed and agreed:

- In order to secure at least 300MW of primary reserve, there is an urgent need to carry out the FGMO, at least by 8-10 power plants, and to secure 300MW of primary reserves.
- Thus, the generation units listed in Table 16-14 agreed to carry out FGMO around January 2016.

As described in section 16.5.1 , although the JICA survey team has some concerns about the existing generating units as qualified providers of primary reserves, above all, the power plants in Table 16-14 can be expected to provide the primary reserve.
However, it is difficult to expect a long-term primary reserve, because the existing generating units are being gradually dismantled or replaced by new units. Therefore, they are not incorporated into the primary reserve.

Table 16-14 The List of Existing Units Which are Expected to Perform FGMO from January 2016

SL. No	Name & Capacity	Owner
1	Sikalbaha 1x150 MW	BPDB
2	Sylhet 1x150 MW	BPDB
3	Baghabari 100 MW	BPDB
4	Baghabari 71 MW	BPDB
5	Kaptai 4&5	BPDB
6	Shahajibazar 8&9 (2x35 MW)	BPDB
7	Siddhirganj 2x120 MW	EGCB
8	RPCL (Steam 75 MW)	RPCL
9	Sirajganj 225 MW (150+75 MW)	NWPGCL
10	Khulna 1x150 MW	NWPGCL
11	Summit Bibiyana-2 (1x222 MW)	Summit Power
12	Summit Meghnaghat (2x110 GT+1x110 ST MW)	Summit Power

Source: JICA Survey Team

[14] The upper and lower limits of LFC control are generally set as follows in TEPCO. Therefore, to determine whether it is possible to require the supplying of 10% to 15% of rated output, it is necessary to undergo a careful process.

- Thermal power generator : The upper/lower limits are ±5% of output instruction (base output)
- Hydro power generator : The difference between current output and the upper/lower limits of machine output
- Nuclear power generator: No settings.

Incidentally, the JICA survey team was separately provided with the list of existing units which currently obey the output adjustment instructions from NLDC by phone, as shown in Table 16-15.
Although they mostly overlap with the lineup of Table 16-14, the yellow-colored units are out of FGMO test operation. They urgently require maintenance to be able to contribute to the reserve expansion.

Table 16-15 The List of Existing Units Which Obey Instructions of Output Adjustment from NLDC

SL. No	Name & Capacity	Owner
1	Sikalbaha 1x150 MW	BPDB
2	Sylhet 1x150 MW	BPDB
3	Baghabari 100 MW	BPDB
4	Baghabari 71 MW	BPDB
5	Kaptai 4&5	BPDB
6	Shahajibazar 8&9 (2x35 MW)	BPDB
7	Siddhirganj 2x120 MW	EGCB
8	Haripur Power Ltd. (1x235+125)	HPL
9	Sirajganj 225 MW (150+75 MW)	NWPGCL
10	Khulna 1x150 MW	NWPGCL
11	Summit Bibiyana-2 (1x222 MW)	Summit Power
12	Meghnaghat Power Ltd (2x150+150 MW)	MPL

Source: JICA Survey Team

(c) Estimation of the planned outages (maintenance outages) and unplanned outages

The ratio of planned outages (maintenance outages) and unplanned outages of generators is one of the most uncertain but important elements in conducting a trial calculation.
Unfortunately, information on this point could not obtained in the investigation in Bangladesh, so the JICA survey team assumed the outage rates as 0% to 20% (in 5% increments).

(d) Risk of delay in developing the LFC by SCADA/EMS in NLDC

Moreover, as per the details described in section 16.6 , a risk of delay in developing the LFC by SCADA/EMS in NLDC should be taken into consideration. Thus, preparation of the available primary reserve list provided by only FGMO is required.
Fortunately, there seems to be no risk in realizing FGMO with the newly constructed generators commissioned after 2015, for the following reasons:

- All generators are generally equipped with governors for the purpose of maintaining constant rotor speed.
- FGMO can be easily realized by setting up the permanent speed variation and limiter of the governor.

From TEPCO's experiences, the primary reserves (FGMO + LFC) have been secured from 3% to 5% of the maximum demand. Spinning reserves (FGMO) have been secured at around 2% of the maximum demand. Thus, the ratio of FGMO among the primary reserves amounts to one-third to two-thirds.
In the case of Bangladesh, the primary reserve is planned to secure at least 10% of the maximum demand, so the contribution of FGMO can be estimated at about 3% to 7% of the maximum demand.

(e) The results of calculations

Table 16-16 shows the available primary reserves, when both FGMO and LFC are carried out.
Table 16-17 shows the available primary reserves, when only FGMO are carried out.

Hereinafter, the study will be performed based on Table 16-17, for a more severe estimation.

Table 16-16 Available Primary Reserve List

Rate of operation	Rate of reserve	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
100%	10%	0	120	214	370	451	775	775	775	830	830	830	855	915	1000	1075	1175	1235	1400	1565	1745	2010	2200	2396	2571	2816	2956	3032
	11%	0	132	235	407	496	852	852	852	913	913	913	940	1006	1100	1182	1292	1358	1540	1721	1919	2211	2420	2636	2828	3097	3251	3335
	12%	0	144	257	444	541	930	930	930	996	996	996	1026	1098	1200	1290	1410	1482	1680	1878	2094	2412	2640	2875	3085	3379	3547	3638
	13%	0	156	278	481	587	1007	1007	1007	1079	1079	1079	1111	1189	1300	1397	1527	1605	1820	2034	2268	2613	2860	3115	3342	3660	3842	3941
	14%	0	168	300	518	632	1085	1085	1085	1162	1162	1162	1197	1281	1400	1505	1645	1729	1960	2191	2443	2814	3080	3354	3599	3942	4138	4244
	15%	0	180	321	555	677	1162	1162	1162	1245	1245	1245	1282	1372	1500	1612	1762	1852	2100	2347	2617	3015	3300	3594	3856	4224	4434	4548
95%	10%	0	114	203	352	429	736	736	736	788	788	788	812	869	950	1021	1116	1173	1330	1487	1658	1909	2090	2276	2442	2675	2808	2880
	11%	0	125	224	387	471	810	810	810	867	867	867	893	956	1045	1123	1228	1290	1463	1635	1823	2100	2299	2504	2686	2942	3089	3168
	12%	0	137	244	422	514	883	883	883	946	946	946	975	1043	1140	1225	1339	1408	1596	1784	1989	2291	2508	2731	2931	3210	3370	3456
	13%	0	148	264	457	557	957	957	957	1025	1025	1025	1056	1130	1235	1328	1451	1525	1729	1933	2155	2482	2717	2959	3175	3477	3650	3744
	14%	0	160	285	492	600	1030	1030	1030	1104	1104	1104	1137	1217	1330	1430	1563	1642	1862	2081	2321	2673	2926	3187	3419	3745	3931	4032
	15%	0	171	305	527	643	1104	1104	1104	1183	1183	1183	1218	1304	1425	1532	1674	1760	1995	2230	2487	2864	3135	3414	3663	4012	4212	4320
90%	10%	0	108	193	333	406	697	697	697	747	747	747	769	823	900	967	1057	1111	1260	1408	1570	1809	1980	2156	2314	2534	2660	2729
	11%	0	119	212	366	447	767	767	767	822	822	822	846	906	990	1064	1163	1223	1386	1549	1727	1990	2178	2372	2545	2788	2926	3001
	12%	0	130	231	400	487	837	837	837	896	896	896	923	988	1080	1161	1269	1334	1512	1690	1885	2171	2376	2588	2776	3041	3192	3274
	13%	0	140	250	433	528	906	906	906	971	971	971	1000	1070	1170	1258	1375	1445	1638	1831	2042	2352	2574	2803	3008	3294	3458	3547
	14%	0	151	270	466	568	976	976	976	1046	1046	1046	1077	1153	1260	1354	1480	1556	1764	1972	2199	2532	2772	3019	3239	3548	3724	3820
	15%	0	162	289	500	609	1046	1046	1046	1120	1120	1120	1154	1235	1350	1451	1586	1667	1890	2113	2356	2713	2970	3234	3470	3801	3990	4093
85%	10%	0	102	182	315	383	659	659	659	705	705	705	727	778	850	914	999	1050	1190	1330	1483	1708	1870	2037	2185	2393	2512	2577
	11%	0	112	200	346	422	724	724	724	776	776	776	799	855	935	1005	1099	1155	1309	1463	1631	1879	2057	2240	2404	2633	2764	2835
	12%	0	122	218	378	460	790	790	790	847	847	847	872	933	1020	1096	1198	1260	1428	1596	1780	2050	2244	2444	2622	2872	3015	3092
	13%	0	133	237	409	499	856	856	856	917	917	917	945	1011	1105	1188	1298	1365	1547	1729	1928	2221	2431	2647	2841	3111	3266	3350
	14%	0	143	255	440	537	922	922	922	988	988	988	1017	1089	1190	1279	1398	1470	1666	1862	2076	2392	2618	2851	3059	3351	3517	3608
	15%	0	153	273	472	575	988	988	988	1058	1058	1058	1090	1167	1275	1371	1498	1575	1785	1995	2225	2563	2805	3055	3278	3590	3769	3865
80%	10%	0	96	171	296	361	620	620	620	664	664	664	684	732	800	860	940	988	1120	1252	1396	1608	1760	1917	2057	2253	2365	2425
	11%	0	106	188	326	397	682	682	682	730	730	730	752	805	880	946	1034	1087	1232	1377	1536	1769	1936	2108	2262	2478	2601	2668
	12%	0	115	205	355	433	744	744	744	797	797	797	821	878	960	1032	1128	1186	1344	1502	1675	1930	2112	2300	2468	2703	2837	2910
	13%	0	125	223	385	469	806	806	806	863	863	863	889	952	1040	1118	1222	1284	1456	1628	1815	2090	2288	2492	2674	2928	3074	3153
	14%	0	134	240	415	505	868	868	868	930	930	930	958	1025	1120	1204	1316	1383	1568	1753	1954	2251	2464	2683	2879	3154	3310	3395
	15%	0	144	257	444	541	930	930	930	996	996	996	1026	1098	1200	1290	1410	1482	1680	1878	2094	2412	2640	2875	3085	3379	3547	3638

Source: JICA Survey Team

Table 16-17 List of Primary Reserve by FGMO Only

Rate of operation	Rate of reserve	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
	3%	0	36	64	111	135	232	232	232	249	249	249	256	274	300	322	352	370	420	469	523	603	660	719	771	845	887	910
	4%	0	48	86	148	180	310	310	310	332	332	332	342	366	400	430	470	494	560	626	698	804	880	958	1028	1126	1182	1213
100%	5%	0	60	107	185	226	387	387	387	415	415	415	427	457	500	537	587	617	700	782	872	1005	1100	1198	1285	1408	1478	1516
	6%	0	72	128	222	271	465	465	465	498	498	498	513	549	600	645	705	741	840	939	1047	1206	1320	1438	1542	1689	1773	1819
	7%	0	84	150	259	316	542	542	542	581	581	581	598	640	700	752	822	864	980	1095	1221	1407	1540	1677	1799	1971	2069	2122
	3%	0	34	61	105	129	221	221	221	237	237	237	244	261	285	306	335	352	399	446	497	573	627	683	733	802	842	864
	4%	0	46	81	141	171	294	294	294	315	315	315	325	348	380	408	446	469	532	595	663	764	836	910	977	1070	1123	1152
95%	5%	0	57	102	176	214	368	368	368	394	394	394	406	435	475	511	558	587	665	743	829	955	1045	1138	1221	1337	1404	1440
	6%	0	68	122	211	257	442	442	442	473	473	473	487	522	570	613	670	704	798	892	995	1146	1254	1366	1465	1605	1685	1728
	7%	0	80	142	246	300	515	515	515	552	552	552	569	608	665	715	781	821	931	1041	1160	1337	1463	1593	1710	1872	1966	2016
	3%	0	32	58	100	122	209	209	209	224	224	224	231	247	270	290	317	333	378	423	471	543	594	647	694	760	798	819
	4%	0	43	77	133	162	279	279	279	299	299	299	308	329	360	387	423	445	504	563	628	724	792	863	925	1014	1064	1091
90%	5%	0	54	96	167	203	349	349	349	373	373	373	385	412	450	484	529	556	630	704	785	904	990	1078	1157	1267	1330	1364
	6%	0	65	116	200	244	418	418	418	448	448	448	462	494	540	580	634	667	756	845	942	1085	1188	1294	1388	1520	1596	1637
	7%	0	76	135	233	284	488	488	488	523	523	523	539	576	630	677	740	778	882	986	1099	1266	1386	1509	1620	1774	1862	1910
	3%	0	31	55	94	115	198	198	198	212	212	212	218	233	255	274	300	315	357	399	445	513	561	611	656	718	754	773
	4%	0	41	73	126	153	263	263	263	282	282	282	291	311	340	365	399	420	476	532	593	683	748	815	874	957	1005	1031
85%	5%	0	51	91	157	192	329	329	329	353	353	353	363	389	425	457	499	525	595	665	742	854	935	1018	1093	1197	1256	1288
	6%	0	61	109	189	230	395	395	395	423	423	423	436	467	510	548	599	630	714	798	890	1025	1122	1222	1311	1436	1507	1546
	7%	0	71	127	220	268	461	461	461	494	494	494	509	544	595	640	699	735	833	931	1038	1196	1309	1426	1530	1675	1759	1804
	3%	0	29	51	89	108	186	186	186	199	199	199	205	220	240	258	282	296	336	376	419	482	528	575	617	676	709	728
	4%	0	38	68	118	144	248	248	248	266	266	266	274	293	320	344	376	395	448	501	558	643	704	767	823	901	946	970
80%	5%	0	48	86	148	180	310	310	310	332	332	332	342	366	400	430	470	494	560	626	698	804	880	958	1028	1126	1182	1213
	6%	0	58	103	178	217	372	372	372	398	398	398	410	439	480	516	564	593	672	751	838	965	1056	1150	1234	1352	1419	1455
	7%	0	67	120	207	253	434	434	434	465	465	465	479	512	560	602	658	692	784	876	977	1126	1232	1342	1440	1577	1655	1698

Source: JICA Survey Team

(2) Trial calculation of the required amount of reserves

Fundamental concept of assumption of possible faults

In order to make a trial calculation, the assumption of possible faults is an important factor in calculating the required amount of reserves, i.e.:

N-0 → Frequency control under no contingency situation
N-1 → The largest loss of power supply due to single apparatus contingency, such as sudden trip of one maximum capacity generating unit or sudden trip of one transmission line which results in loss of multiple generating units.
N-2 → The largest loss of power supply due to double simultaneous apparatus contingency.

The probability of simultaneous multi-apparatus faults is smaller than that of a single fault, while the impact on the frequency fluctuation is larger. In case studies for demand-supply operation planning, N-1 tends to be applied as the severest contingency from the viewpoint of global trends, including TEPCO. Therefore, the JICA survey team also considered the N-0 and N-1 contingency in this study.

(a) N-0 Case (Normal Conditions)

In this section, the JICA survey team will perform a trial calculation for the necessary primary reserves. Unfortunately, there is no globally standardized method to calculate the necessary reserve in frequency control. Therefore, it should be noted that the following description is a very challenging study, and no more than a rough estimation.

The goal of this section is to provide a roadmap for frequency quality improvement. Therefore, it is useful to find a relationship between power demand and the necessary reserves for frequency control.

In this study, for simplicity, the necessary amount of reserves is considered to be equal to the amount of load fluctuation.[15] Therefore, the mission for this section can also be set as finding the relationship between power demand and load fluctuation.

Estimation of the load fluctuation requires statistical analysis of a great amount of past data. The JICA survey team, however, doesn't have enough time to collect and analyze the data in Bangladesh, and it is also very difficult to find good correlation factors among the data because many factors may influence the load fluctuation such as total demand, weekdays/holidays, time zone, power system condition, and so on.

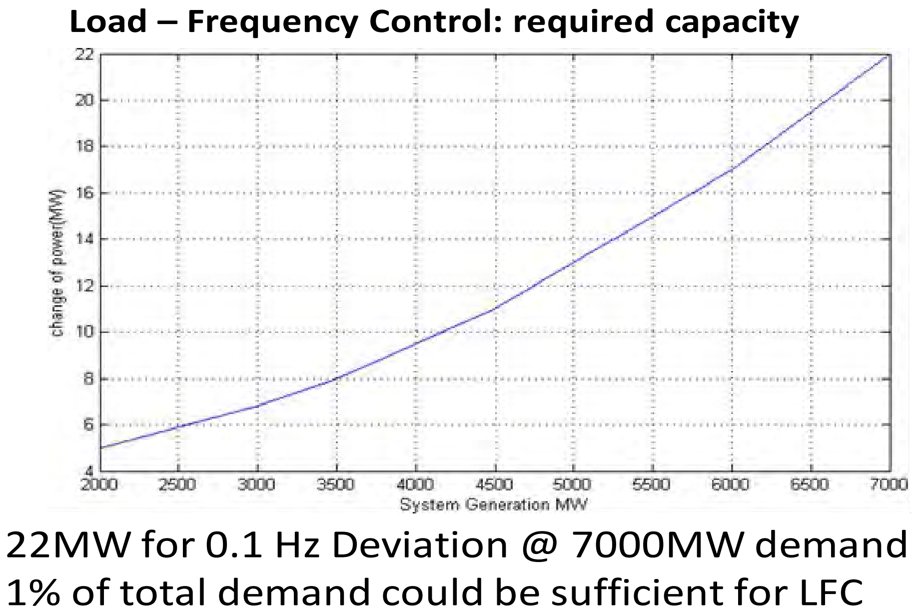
Therefore, the JICA survey team will try to apply the proportional expression between the load fluctuation and power demand obtained via analyses of load fluctuation in Japan, and to obtain a proportionality constant by using the data from 3 cases of frequency control practice and the frequency fluctuation chart at the time of generator or load tripping fault provided by NLDC.

[15] The frequency fluctuation can be theoretically canceled out by regulating the reserves in a simultaneous and commensurate manner in response to the load fluctuation. In fact, it is impossible to make the output from reserves follow the load fluctuation with pinpoint accuracy. Therefore, some frequency deviation is practically allowed (50+/-0.2Hz in TEPCO) due to the control delay. Thanks to this allowable frequency deviation, the necessary amount of reserves is less than the amount of load fluctuation. In this study, however, the JICA survey team set the calculation conditions to be more severe.

The data concerning the frequency control provided by NLDC

Case 1: Load-frequency chart in NLDC

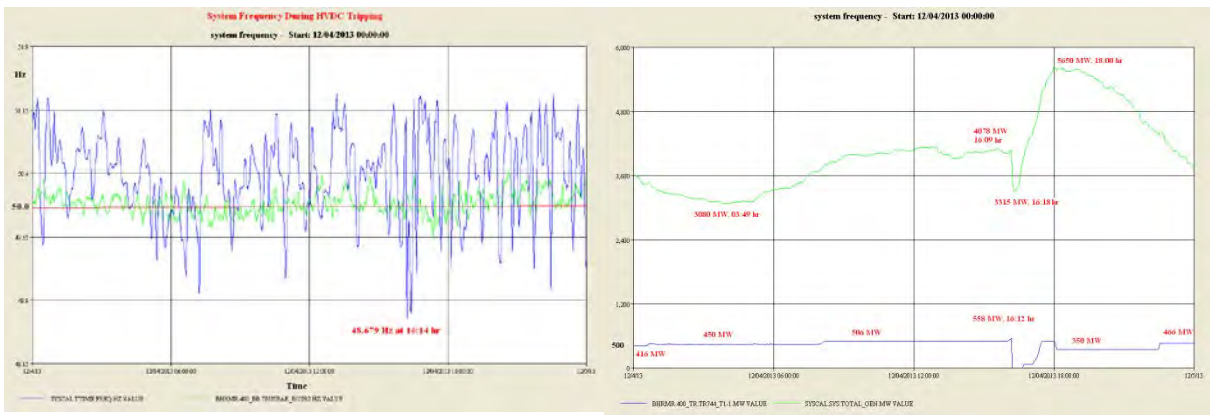
NLDC prepares a chart as shown in Figure 16-14, which indicates the necessary amount of reserves to improve frequency fluctuation by 0.1Hz at a given power demand. For example, the necessary reserves to improve frequency fluctuation by 0.1Hz are 22MW when the power demand is 7,000MW.



Source: NLDC

Figure 16-14 The Necessary Reserve to Improve 0.1[Hz] of Frequency Fluctuation

Case 2: HVDC international tie-line tripping fault (occurred on Dec. 4th 2013)



Source: JICA Survey Team

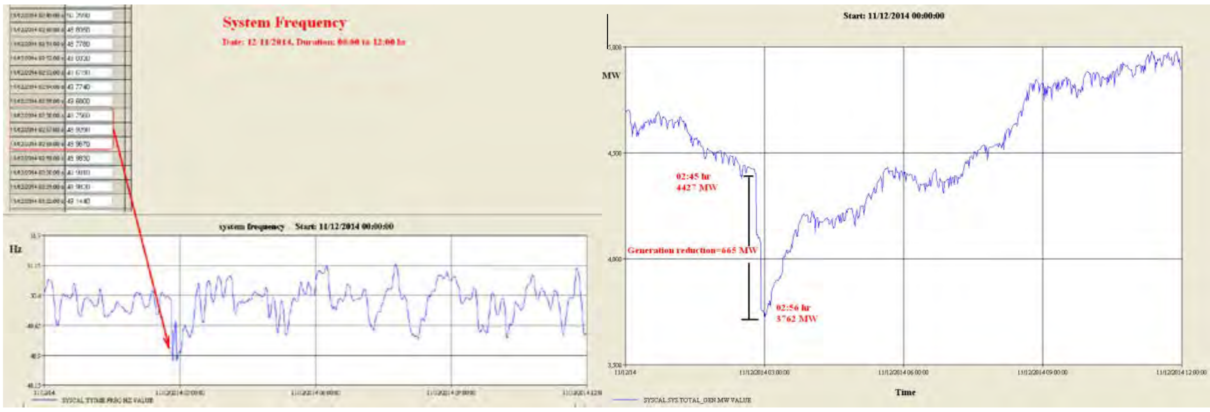
Figure 16-15 Impact of Tripping HVDC Link (System Frequency & Generation Records)

Date & Time	Frequency Hz	Load MW	Generation MW	HVDC Import MW
12/04/2013 16:10:00 s	50.934	3739.832	4060.916	549
12/04/2013 16:11:00 s	51.056	3725.427	4066.471	554
12/04/2013 16:12:00 s	51.06	3715.312	4071.837	558
12/04/2013 16:13:00 s	49.181	3512.534	3638.304	0
12/04/2013 16:14:00 s	48.679	3361.106	3527.44	0
12/04/2013 16:15:00 s	48.702	3183.347	3420.231	0

From the data above, the JICA survey team can estimate that import power of 558MW from India was suddenly interrupted due to a trip of the HVDC international tie-line. As a result, the total supply decreased sharply from 4,072MW to 3,638MW. At the same time, load shedding by Under Frequency Relay (UFR) seemed to occur and demand decreased from 3,715MW to 3,512MW.

From this consideration, it can be calculated that the frequency was lowered by 0.1Hz due to the supply shortage of about 12.3MW, under the total demand of 3,715MW.

Case 3: Tripping fault at a few units of the generator in Ashuganj area (occurred on Nov. 12th 2014)



Source: JICA Survey Team

Figure 16-16 Impact of Tripping Generators on the System Frequency

Since the data for load fluctuation has not been provided, the JICA survey team considered that only generator tripping occurred and load-shedding did not occur. In addition, in the right figure, although NLDC reported that total generation decreased from 4,427MW to 3,762MW in one event, there are obviously two generator trip events, determined by observing the chart closely. From this observation, at the first frequency drop, demand is considered to have decreased to only about 4,240MW.
In this data, there is no information on the demand, but the JICA survey team considers that total generation output was almost equal to the total demand because the frequency immediately before the fault was about 50.2 [Hz], which indicates that the demand and supply had been almost balanced.

Based on the considerations above, it can be calculated that the frequency was lowered by 0.1Hz due to the supply shortage of about 12.8MW, under the total demand of 4,427MW.

Trial calculations of necessary reserves for frequency control (load fluctuation)

From the results of the 3 cases, the JICA survey team will make a trial calculation of the relationship between demand and load fluctuation.

According to the technical report from the Committee of Experts in the Institute of Electrical Engineers of Japan (technical report No. 869, IEEJ), there is a result in statistical analysis where the standard deviation of load fluctuation (σ) is proportional to the square root of the power demand (P). Here, the JICA survey team simply assumed that the load fluctuation (ΔP), in other words, the necessary reserves (=ΔP), is also proportional to the square root of the total demand (P). i.e.:

$\Delta P = \alpha * \sqrt{P}$ [MW]

Assuming that the quantity of reserves consumed and the degree of frequency improved (for example; 0.1 [Hz]) are in proportion to each other, the equation above can be converted into the following equation relationship between demand and the amount of necessary reserve for improving 0.1[Hz]. i.e.:

$\Delta P = \alpha * \sqrt{P}$ [MW/0.1Hz]

Here, the results of Cases 1, 2, 3 – relationship between the total power demand and necessary reserves to improve frequency by 0.1Hz – are substituted into the equation. Then, the proportionality constant α can be determined as follows:

$\Delta P = 0.263*\sqrt{P}$ [MW/0.1Hz] : Case 1
$\Delta P = 0.201*\sqrt{P}$ [MW/0.1Hz] : Case 2
$\Delta P = 0.193*\sqrt{P}$ [MW/0.1Hz] : Case 3

Though the calculation results of constant α vary widely from 0.193 to 0.263, hereinafter, the study team uses the equation of case 1 because, in that, the amount of load fluctuation (necessary reserve) becomes the largest.[16]

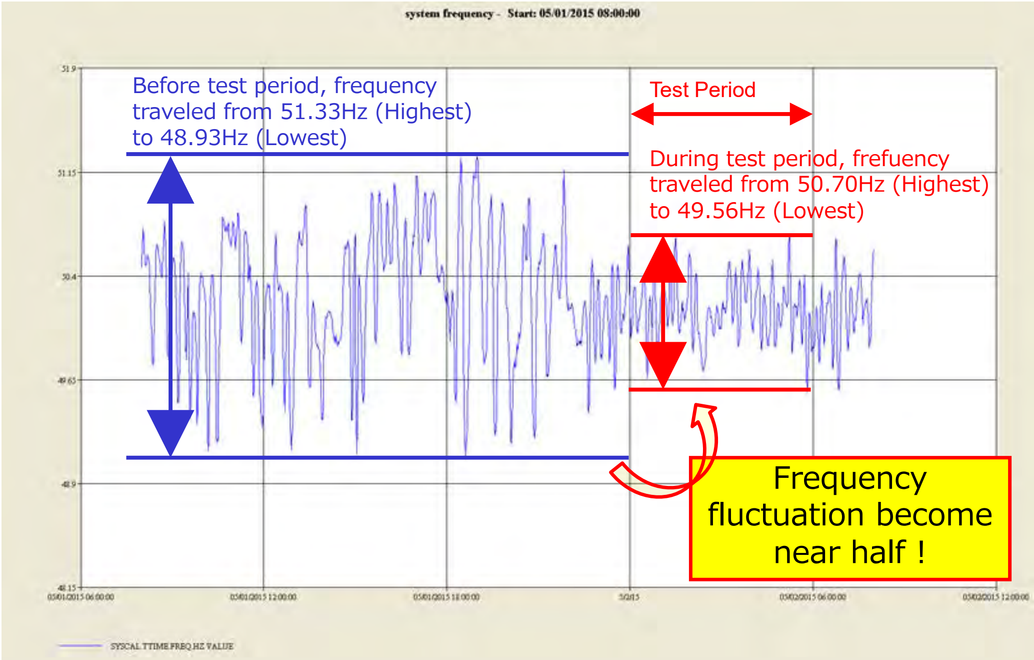
In terms of solitary information that can verify the derived equation, there are useful results from the frequency control test that was carried out in the Khulna power station in May 2015. An outline of this test is shown in Table 16-18.
According to the explanation from NLDC, in this test, they examined the effects of frequency improvements by realizing the action of FGMO by repeating the telephone instructions to the power station during the test time. Assuming that the power demand during the test time was around 5,000MW on average, the necessary reserve to improve frequency quality by 0.1Hz can be calculated at about 18.6MW from the equation. On the other hand, the frequency fluctuation decreased from about ±1.2 [Hz] to ±0.55 [Hz] due to using the gas turbine machine as reserves. From these facts, about 121MW from the rated output of 158MW was used for reserves. Though there are, unfortunately, no records of generator output that can support this estimation it is not improbable.

Table 16-18 Outline of Frequency Control Test in Khulna Power Station

Date	May 2nd, 2015 (SAT.) 0:00 – 6:00 AM (for 6 hours)
Site	Khulna Power Station (Rated output: 158MW×1 unit, Gas-Turbine, fuel: HSLO: High-sulfur light oil)
Conditions	Realizing simulated FGMO by repeating the telephone instructions from NLDC shift engineers to Khulna power station.
Total demand	5,870MW (at 0:00 AM) - 4,500MW (at 6:00 AM)
Effectiveness	Before/After the test: 51.33Hz - 48.93Hz (+2.66% -- -2.14%) During the test: 50.70Hz - 49.56Hz (+1.40Hz -- -0.88%)

Source: JICA Survey Team

16 This equation is not consistent with the characteristics of the graph as shown in Figure 16-14. This figure shows the lower convex curve where the rate of increase in the amount of necessary reserve rises as demand increases, but the above relational equations are clearly the upper convex curve to demand. However, qualitatively, it is considered that a load that fluctuates randomly is connected more to the power system as demand increases. If there are many random elements, since the whole variation is suppressed and smoothed, the upper convex curve is believed to be close to actual conditions.

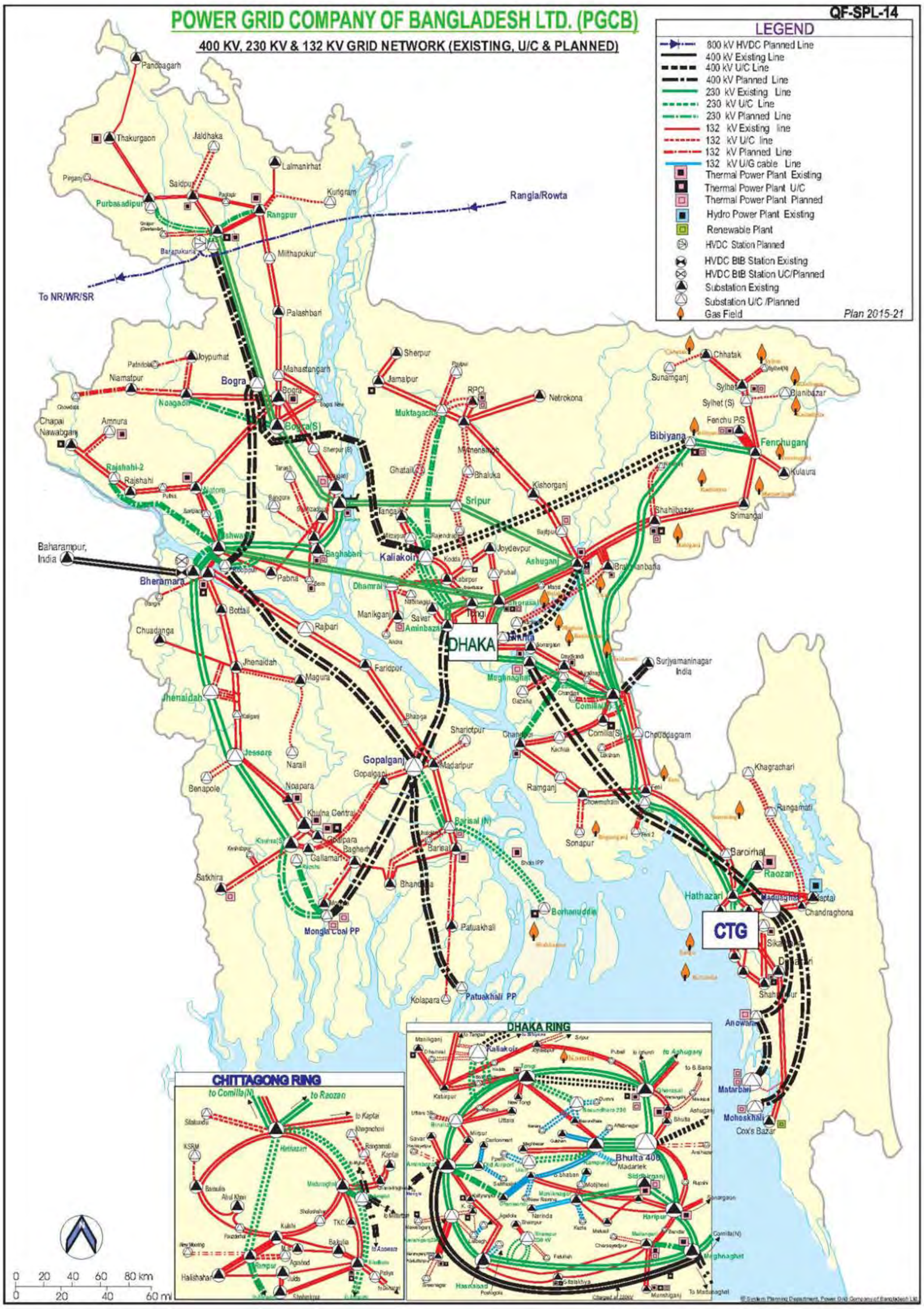


Source: JICA Survey Team

Figure 16-17 Frequency Fluctuation Record during Test Operation in Khulna Power Station

(b) N-1 Case (Emergency Conditions)

The case which may cause great frequency fluctuations due to a single apparatus fault is generation tripping or load tripping. As per the power system diagram shown inFigure 16-18, since almost all the 400kV, 230kV and 132kV transmission facilities in Bangladesh consist of double-circuit transmission lines and are operated by a meshed configuration, it can be said that there are no cases in which frequency fluctuates greatly due to an N-1 fault in the AC system.



Source: JICA Survey Team

Figure 16-18 Power System Diagram of Bangladesh

It should be considered, but rather in the following cases:

- Single generation tripping of maximum capacity
- Import power cut-off due to single apparatus fault such as HVDC transmission line or Back to Back (BTB)

Specific amounts and factors regarding supply tripping that should be considered in future years' development of the power system are shown as follows:

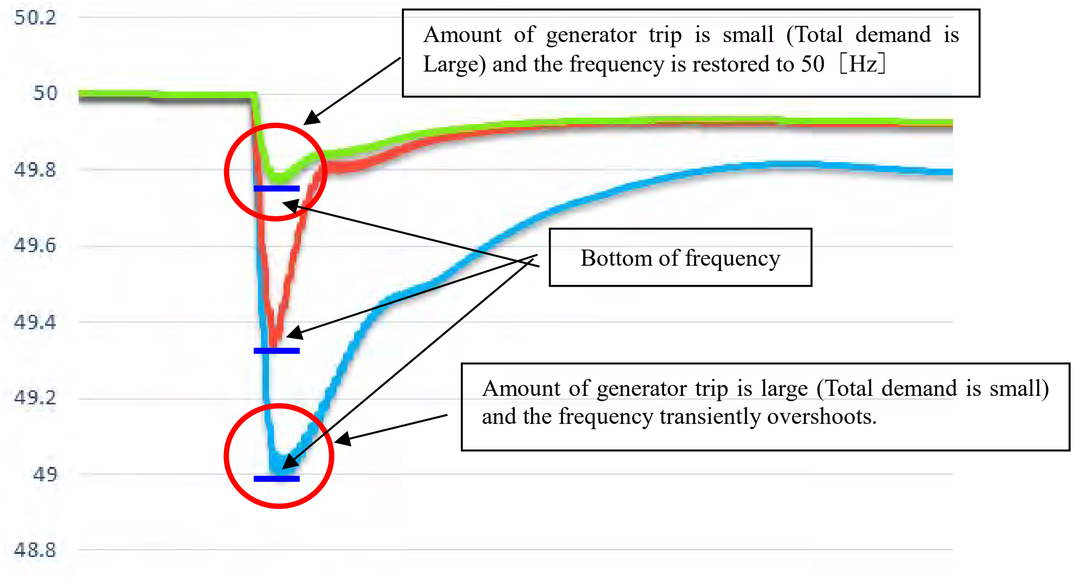
Table 16-19 Supply Tripping Amount and Factors That Should Be Considered in Each Year

Year	Supply tripping amounts	Factors
2015~2024	500MW	Single apparatus fault of HVDC 500MW
2024~2041	1180MW	Single unit tripping of Rooppur nuclear power plants

Source: JICA Survey Team

In this study, the JICA survey team will check the adequacy of reserves for each year by comparing with these supply tripping amounts.

The important thing is that it is not always perfect even if there is a sufficient amount of reserves as shown in the above table. As shown in Figure 16-19, if the reserve is secured as shown in the table, it is possible to finally recover to normal frequency. However, immediately after the generator tripping, the frequency transiently decreases rapidly, since the output of generators provided as reserves cannot keep up with the sudden loss of supply. The greater the ratio of the generator capacity among the total supply power becomes, the more severe this tendency becomes.



Source: JICA Survey Team

Figure 16-19 Time-shift Illustration of Frequency Fluctuation at the Time of Generation Tripping

Therefore, for example, if frequency overshoots below the permissible under-frequency range of the generator due to the tripping of a large capacity generator in the low demand season or time zone, other generators are simultaneously tripped (i.e. reference Figure 16-7). This leads to a further frequency decrease. Then, the power system will collapse and a so-called cascading outage occurs. In the worst case, there is a possibility that the whole power system will experience a black out.

Bangladesh has already experienced a black out due to the cut-off of about 500MW of imported power from India via the HVDC international tie-line, in November 2014.

In order to avoid cases like this, adequate capacity of automatic load shedding by UFR is provided as a back-up scheme. Besides, in the above-mentioned IAEA guideline, in order to avoid load shedding that exceeds the permissible range, one nuclear generator capacity in the low demand period is recommended to be selected to be less than 10% of the total demand.

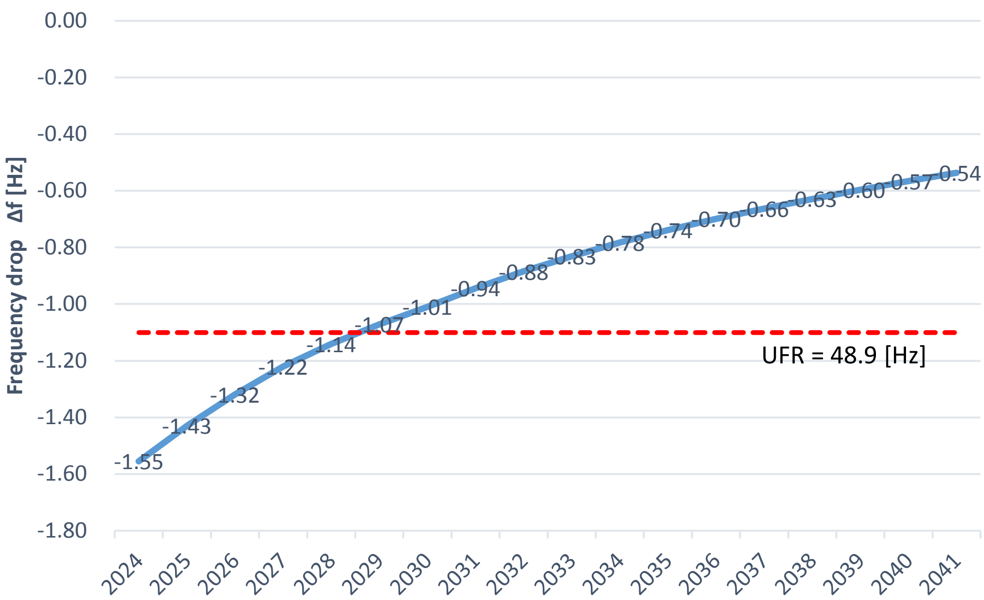
Fig. 16-20 shows the trend of frequency deviation (Δ f) when a sudden trip of Rooppur nuclear power unit (1180MW) occurs under the minimum demand conditions each year after 2024. The bottom of frequency is as shown in Fig. 16-19. The calculation formula of the frequency drop is as follows:

A mathematical relation:

$$\frac{\Delta f}{50}\ [\%/Hz] \times K\ [\%MW/\%Hz] = -\frac{1{,}180}{P}\ [\%MW]$$

where,

K : k-factor of the = 5.0 [%MW/%Hz] (a standard value in TEPCO)
P : Minimum demand each year



Source: JICA Survey Team

Figure 16-20 Trend of Bottom of Frequency Immediately after a Sudden Trip of Rooppur Unit

As shown in the graph above, frequency overshoots below the UFR settings, 48.9Hz, due to the trip of the Rooppur unit in a low demand season or time zone that leads to load shedding until 2028. However, it should be allowed in order to avoid a cascading outage and blackout.

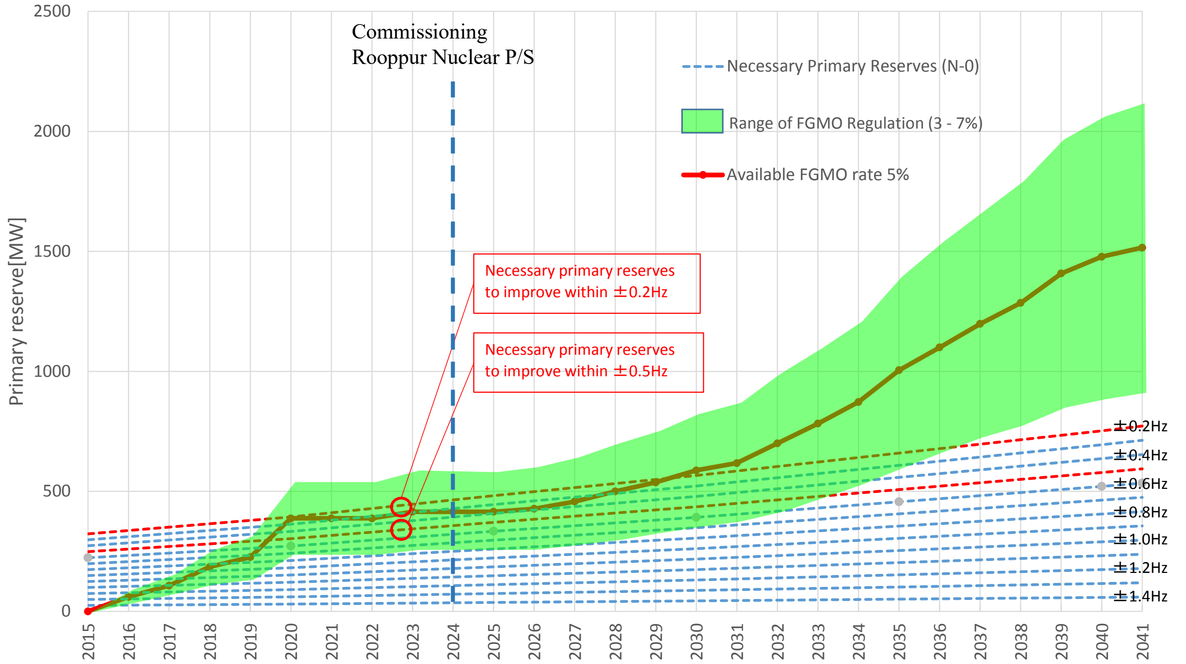
(3) Verification of Adequacy of Reserves

Figure 16-21 and Figure 16-22 show the balance of available primary reserves and necessary reserves for improving frequency fluctuation in units of 0.1Hz, from the study results of section 16.5.2 (1) and 16.5.2 (2). Here, prerequisite conditions are as follows:

- The available reserves are colored green, based on the case of 100% and 80% operation rate in

Table 16-17.

- The necessary reserves are calculated based on the equation $\Delta P = 0.263 \times \sqrt{P}$ (MW/0.1Hz), to improve frequency quality from the current situation (assuming +/-1.5Hz) to certain values in +/-0.1Hz segments. Then they are drawn in dashed lines from +/-1.4Hz-quality (+/-0.1Hz improvement) to +/-0.2Hz-quality (+/-1.3Hz improvement).
- When the green range is on dashed lines, it is the balance point between available and necessary reserve. Therefore, the range indicates the trend of frequency quality improvement.



Source: JICA Survey Team

Figure 16-21 The Comparison of Securing the Amount of Necessary Reserve and Available Reserve (The rate of operational generator: 100%)

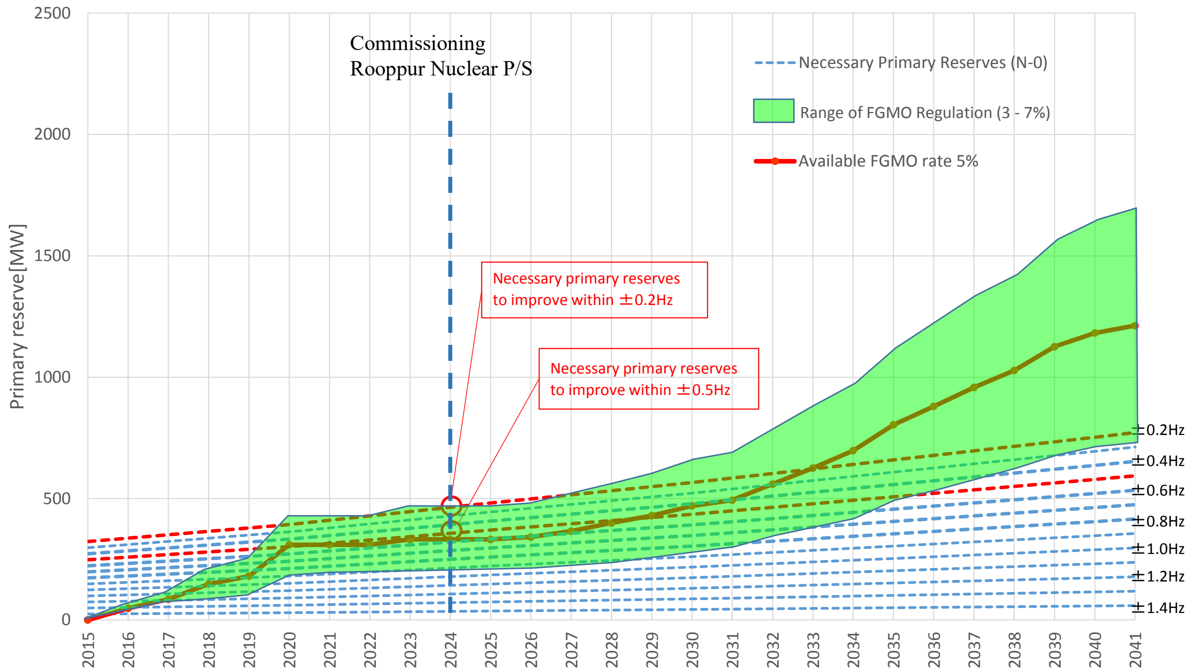


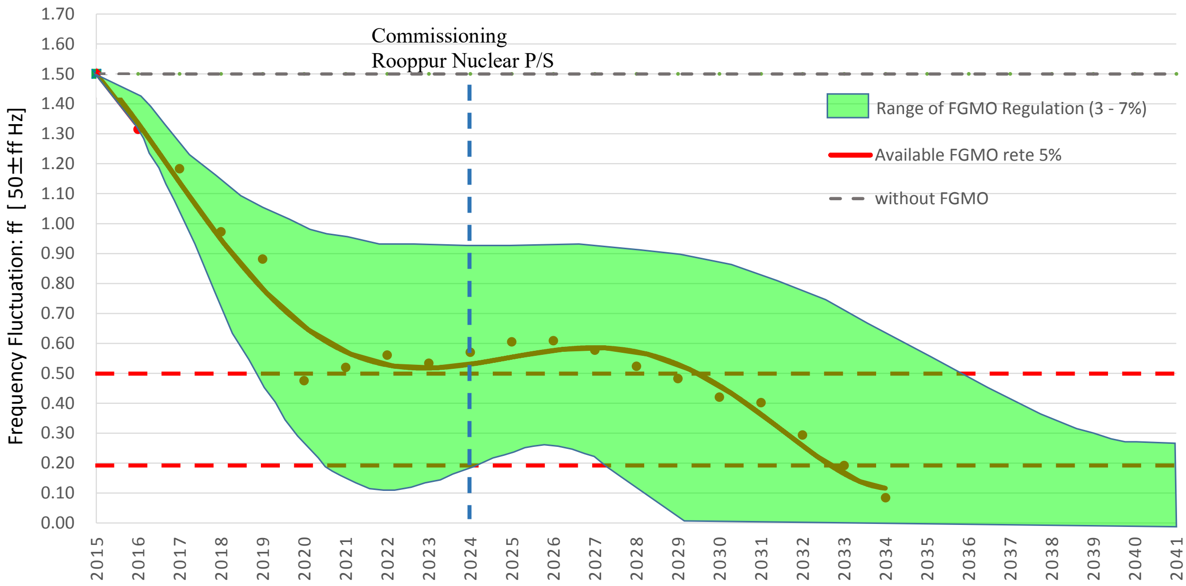
Figure 16-22 The Comparison of Securing the Amount of Necessary Reserve and Available Reserve (The rate of operational generator: 80%)

Source: JICA Survey Team

As shown in Figure 16-21, in ideal conditions, where the rate of the operational generator is 100%, it is expected to be improved to within ±0.2 [Hz], which is equivalent to the frequency quality of TEPCO in 2037 at the latest. However, in reality, maintenance outages of the generation plant are inevitable, and unplanned maintenance outages should also be taken into account as risks. Figure 16-22 shows the 80% operational-rate case (maintenance outage + unplanned maintenance outage: 20%).
If the rate of the operational generator is 80%, there is a possibility that the frequency will deviate from the target range of ± 0.2Hz even in 2041. However, as mentioned above, it can be said that there are no big challenges at 80% operational-rate, because it contains a considerable margin upon a trial calculation.

(4) Roadmap for frequency quality improvement

Figure 16-23 shows the future trend of frequency quality improvement when the current frequency fluctuation is assumed to be ± 1.5Hz, based on the study of the demand-supply balance of reserves, shown in Figure 16-22. Here, the plots shown in Figure 16-23 are calculated values for each year, and the curves are quadratic approximate curves obtained from the plots.



Source: JICA Survey Team

Figure 16-23 Future Roadmap of Improving Frequency Quality

According to Figure 16-22 and Figure 16-23, the following are points to note:

Frequency control in normal conditions

- If the effective amount of FGMO is 5% of total demand as an average value, it is possible that the frequency fluctuation can be controlled to within ±0.5Hz until the commitment of the Rooppur nuclear generation plant at 2024.
- A risk that the effective amount of FGMO is less than 5% cannot be denied. However, as mentioned above, it is considered that the risk can be ignored because it contains a considerable margin upon the accumulation of necessary primary reserve.
- It is sufficiently possible to secure the reserve in order to improve the frequency quality to within ±0.2Hz by 2041.

Frequency control in abnormal conditions

- After the first commitment of a Rooppur nuclear generation unit in 2024, the frequency drop becomes remarkable due to the trip of that unit. As a result, a cascading trip of other generators

occurs and there is a risk of blackout.
Therefore, the steady accumulation of primary reserve is essential. Also, in order to avoid a total blackout, the amount of load shedding by UFR should be secured sufficiently for the time being.

Therefore, it is a major challenge for the time being to improve the frequency quality to a level where a nuclear power plant can be in stable operation. Therefore, the important points for this are as follows:

Institution design, Apparatus design

- Framework to foster economic incentives such as purchase of reserves at a reasonable price and grants of compensation
- Incorporating FGMO and LFC functions into design specifications as an interconnection requirement for new generators and implementing the functional tests before commitment. The FGMO is implemented immediately after commitment.
- Coal-fired thermal power is planned to provide the primary reserve from 50% of them at present. If there is an intention to avoid load shedding by UFR as much as possible, so that the primary reserve is provided by all of the coal-fired thermal power plants for the time being, it is essential for all new generators to incorporate the FGMO and LFC functions into the design specification.

Operation and maintenance of conventional apparatus

- Since conventional generators are also expected to contribute as a further reserve, rehabilitation of generators except for those already incorporated into the reserve is essential, and this aims to secure several hundred MW of reserve.
- In particular, after the commissioning of nuclear power, in order to secure the reserve in the low demand season, maintenance outage planning should be taken adequately into consideration in the weekly, day before, day demand and supply planning.
- The effect of frequency drop due to the trip of a Rooppur nuclear power unit is big for the time being. Thus, in order to avoid a total blackout, it is acceptable to secure the amount of load shedding by UFR which is the rated output of a Rooppur nuclear power unit.

Also, in this study the following points should be noted.

- The trial calculation of the amount of necessary supply reserve is inferred from records of load variation in Japan.
- The trial calculation of the amount of available supply reserve is inferred from the current power development planning. Because a theoretical calculation of effective amount with FGMO is impossible, it is only an inference in the light of the Japanese experience.

Therefore, from now on, on the basis of such records for FGMO, which has been scheduled to be carried out in Bangladesh since the end of January 2016, we must verify its effect. And then it is necessary to refine the roadmap for the frequency quality improvement further.

16.6 Actual Condition of EMS/SCADA System in NLDC for Load Frequency Control (LFC)

As long as the current operation rules allow the current frequency deviation (±1.0Hz), instruction by phone is still acceptable. However, in order to improve the quality toward the level of developed countries (±0.05Hz~0.2Hz), utilization of automatic control will be essential, so the urgent enhancement of FGMO by each generation unit and LFC by SCADA/EMS in NLDC is strongly desired.

16.6.1 Installed functions in NLDC system

At present, there is a French (Areba)–built SCADA/EMS in NLDC, which has the function of LFC within it, but it has not been connected to generators owned by IPPs, nor has it had its data set to work well.

Table 16-20 Functions of SCADA/EMS and Current Status of Usage

Functions	Outline	Current Problem
SCADA Functions (Monitoring of the power system)	Monitor status change of power system by receiving supervisory and telemetry (hereinafter TM) data from RTU. When detected status changes and there is a deviation in TM values, it will inform the operator through the operation display. Following are monitored: - Frequency - Voltage - Power Flow - Post-fault Analysis	Information display failure on the system monitoring panel is recognized. Reasons as follows: - Failures existing in tele-communication between NLDC and substations. Failure occurs at substations including high voltage substations, substation apparatus such as Trd, IED, RTU, power supply equipment installed at the substations. - Intermittent tele-communication between NLDC and other companies - Online information supply excluded from contract - Substation facilities mainly owned by PGCB; however, do have substations owned by other company. - PGCB owns some power plants as well.
Load Frequency Control (LFC)	Maintain primary frequency regulation capacity. LFC function controls power output of generators based on frequency deviation, and maintains frequency within adequate range. Frequency control is accomplished through generator governor response (primary frequency regulation) and LFC.	Current problems includes the following: - Grid Code and Power Purchase Agreement (hereinafter PPA) arrangements are not suitable for LFC and Automatic Generation Control (hereinafter AGC) - No disclosure of Generation Parameters. Despite above, no complaints from customers about the frequency variation are received, since 60% of the customers are not using electronic products (even if used, only fan or lighting) Poor power quality is not a problem with motivation to solve it, and there is no penalty for PGCB for providing such electricity.
Voltage and Reactive power control (VQC)	This function sends a reactive power signal to generators to regulate voltage targeted to this function. Reactive power signal originates from operators' key input value.	Voltage condition of each region is as below: - West, and North: In poor condition due to long transmission line, and lack of generators. Deployment of line voltage regulator, static tap changer, shifting to higher voltage may be a solution. - South: Generally in good condition. Voltage is high at night, and low in daytime. - East: In good condition due to existence of large generator. High voltage is maintained. Shunt reactor deployment is recommended when in high voltage. (Unsure whether exists.)
State Estimation, Network Security Analysis, and System Optimization	Real time contingency analysis for N-1 Security Real time monitoring of P-V curve and Voltage Stability	Problems regarding the state estimation include the following; - There are places in results where the estimated value (pink) and measured value (green) are quite different. - Measured values not delivered in timely manner, and data update not completed in time. Regulation condition was poor. No regulated interface existed between EMS and SCADA system.
Economic Dispatch Control (EDC)	Economic Dispatch Control (EDC) calculates economic dispatch output schedule for each generator of different efficiency to control its power output depending on the change in power demand. EDC is the short-term determination of the optimal output of a number of electricity generation facilities, to meet the system load, at the lowest possible cost, while serving power to the public in a robust and reliable manner. Scheduling/Real-Time Dispatching.	- EDC function was unused. - Generators operate in accordance with power generation planning at the power plants, hence NLDC is not involved in power generation plan.
Demand Forecast and Generation Scheduling	The Demand Forecast Function calculates total demand from weather forecast information and the past record data, and allocates the most economical generation schedule for each generator via Generation Scheduling Function. The demand forecast function predicts the gross demand for the next day by using multiple regression analyses based on previous data, past weather conditions, type of day (day of the week, singular point, etc.), and weather forecast information	In Japan, dispatching systems receive weather information from the Japan Meteorological Agency. Weather forecast is important information because electricity demand differs significantly with even a 1 degree Celsius difference in maximum temperature. The Demand Forecast Function calculates total demand from weather forecast information and the past recorded data, and allocates the most economical generation schedule for each generator via Generation Scheduling Demand. Lack of long term demand forecast program is a problem, and is needed. Desk calculation would be fine, if actual data analysis is possible.
Recording,	Event recording shall be displayed on monitor	The operating staff creates the daily report by hand, and it does not

Functions	Outline	Current Problem
Archiving	when an event occurs. Also, the recorded data shall be able to be referred to (displayed) on monitor. Post-Fault Diagnosis Web Server for other Customer/administrative Services	utilize the record data which the system has collected Failure history is preserved NLDC system is not connected to the outside world. Only within the NLDC.
Maintenance of database	Database modification for addition/deletion of power system components.	Dedicated maintenance team is present. DB for the new substation and outgoing Matabari are also being handled by the same team.
Configuration n Control	Real-time Monitoring of SCADA/EMS network status	Configuring component devices in the system configuration screen and confirmation of RTU state is possible. RTU status screen: Green is healthy, purple is disconnected (which also includes future reserve). As preparation for power failure at NLDC, backup power supply such as a diesel engine and UPS are available.

Source: JICA Survey Team

16.6.2 Logic diagram of load frequency control in CLDO system in TEPCO

In order to implement LFC via the system in NLDC, operation data setting for each generator is required as indicated in Table 16-20.
Unfortunately, the relevant documents regarding the specification and necessary items for LFC have not been provided, so it is difficult to start the practical work toward the realization of LFC.

(1) Necessary minimum data for LFC in TEPCO (for reference)

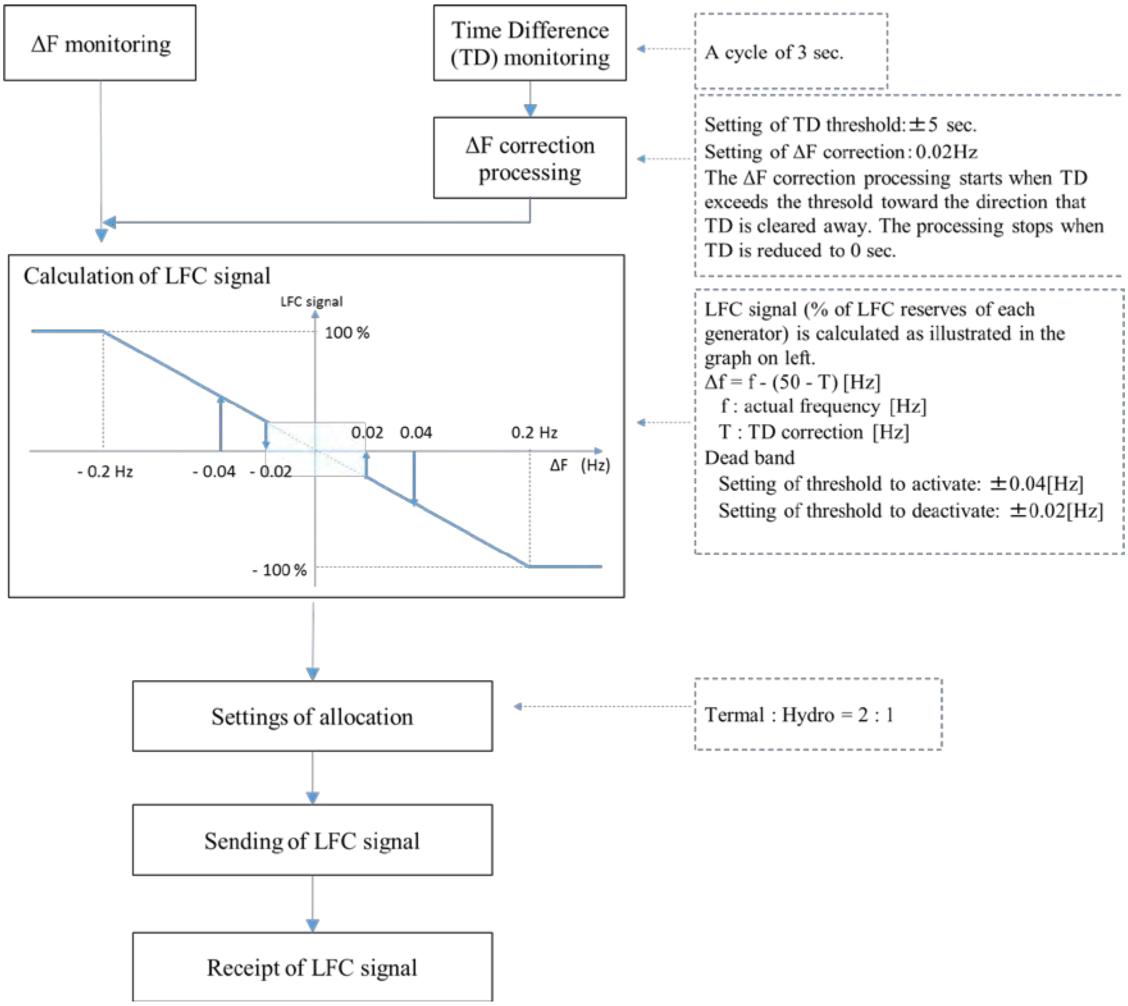
Source: JICA Survey Team

Figure 16-24 illustrates the processing flow diagram for LFC in TEPCO. As shown in this figure, the LFC process is relatively simple due to its independence from EDC (Economic Dispatching Control). According to the diagram, data settings for following items may be enough to operate frequency control and time difference correction:

Telemetry Data
- Current frequency (deviation from 50Hz)
- Current time difference
- Current status of LFC mode (whether the generation unit can respond to the LFC signal or not)
- Current status of operation (In/Out of service), current output
- Current status of remaining margin in response to the up/down signal by LFC.

Internal Data
- Target frequency [Hz] = 50Hz
- TD Threshold (Threshold time to start time difference correction) [sec.]
- ΔF Correction (Frequency correction when starting the time difference correction) [Hz]
- Dead band of LFC [Hz]
- Allocation settings to the generators [%]
- Limiter settings of LFC signal [%]

In the case of the NLDC system in Bangladesh, there may be a possibility of realizing LFC by beginning with a simple and small scale trial, similar to TEPCO's system.



Source: JICA Survey Team

Figure 16-24 Flow Diagram for LFC in TEPCO

16.6.3 Early Applicableness of Load Frequency Control by NLDC System

The JICA survey team conducted a survey by questionnaire with the existing generating stations. Thanks to enormous efforts and cooperation by BPDB, the following 7 power stations kindly gave us their responses. According to the results of survey, there are no useful data or documents, including LFC flow diagrams, except for one station:

- Barapukuria Coal Power Plant
- Bheramara Power Plant
- Haripur 100MW Power Station
- Sylhet 150MW Combined Cycle Power Plant
- Rangpur 20MW Gas Turbine Power Station
- Saidpur 20MW Gas Turbine Power Station
- Dohazari-Kailiaish 100MW Peaking Power Station

Therefore, there is no choice except to target the newly installed generating units for LFC. It is essential to take the function into consideration when preparing the specifications or designing, and to agree to cooperate among NLDC, Generators and manufacturers to provide and perform data O&M.

It will take several years to set the project on its way, and it is still uncertain whether it will catch up with the development and commencement of nuclear power generation in 2024.

16.6.4 Solution - Early Applicableness of FGMO

On the other hand, FGMO has high potential for prompt and wide expansion because:

- Obligation for equipment and operation of Free-Governor Mode has already been stipulated in Grid Code.
- FGMO by some gas-turbine generators has already been agreed and started execution. (Refer to 16.5.2 (3))
- FGMO can be realized for each generating unit alone. It does not need to be controlled by a central system such as SCADA/EMS in NLDC and to have communication channels developed or improved on a large scale.

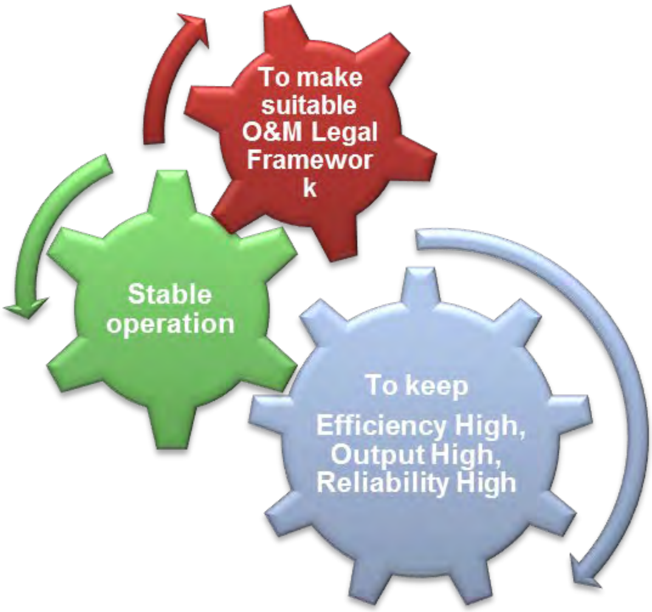
The remaining challenge is to enforce obedience to the rules and to monitor and regulate generators in order to perform FGMO from the commencement of operation.

Chapter 17 O&M Legal Framework

17.1 Introduction

17.1.1 Purpose of this study

The purpose of this study is to suggest the establishment of the suitable legal framework for Bangladesh.

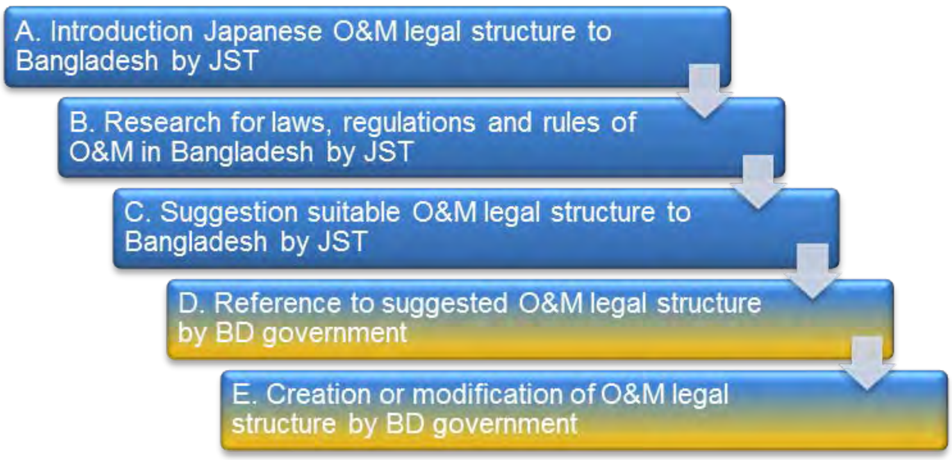


Source: JICA Survey Team

Figure 17-1 Purpose of O&M Legal Framework

17.1.2 Solutions procedure

This solutions procedure is as follows. A, B and C are done by WG, and D and E are done by the Bangladesh government. JST means JICA Survey Team.

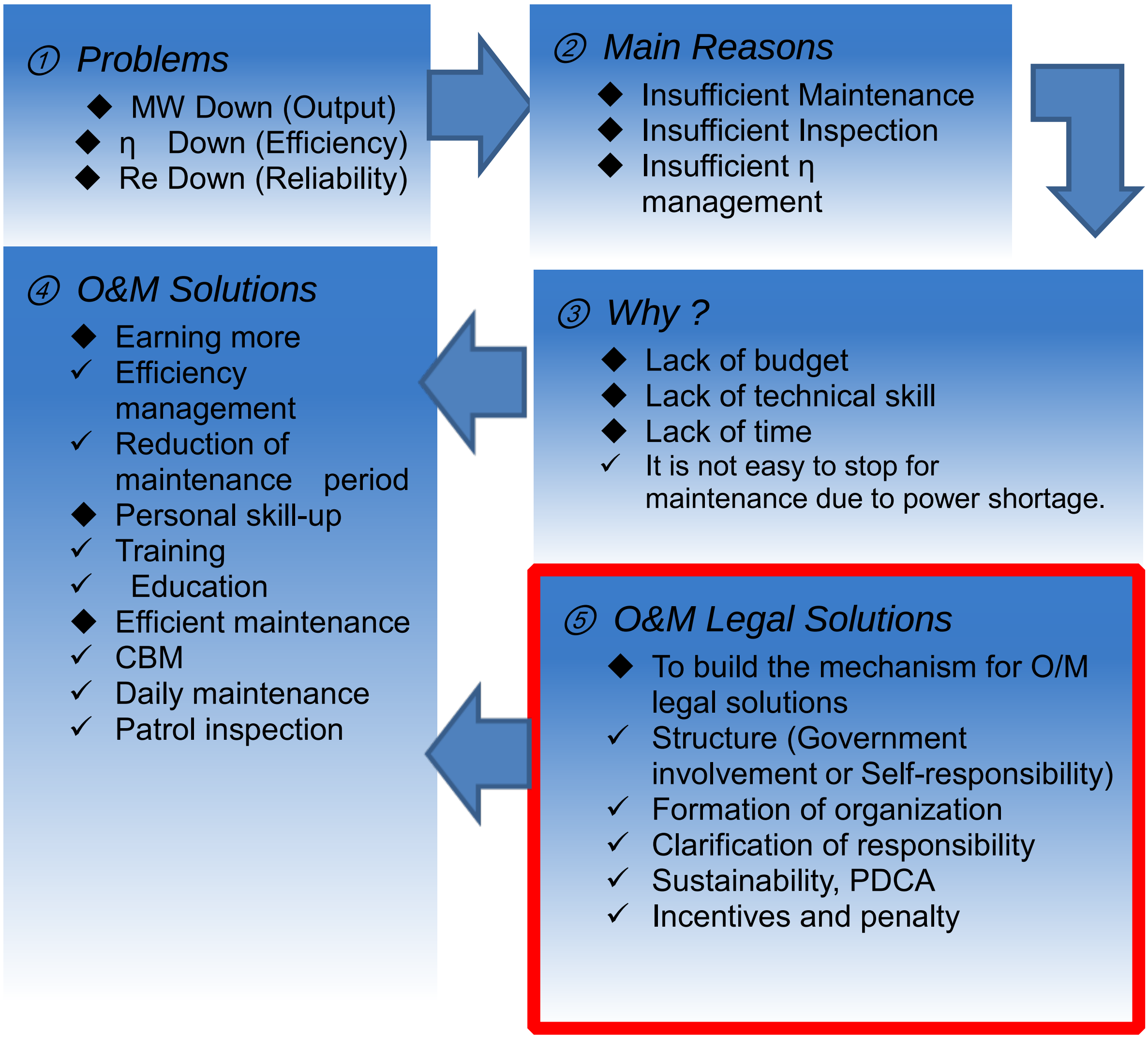


Source: JICA Survey Team

Figure 17-2 O&M Legal Solutions Procedure

17.1.3 Cause and effect diagram

Cause and effect diagram for Bangladesh is as below. The red square is this study's solutions for suitable O&M in Bangladesh.



Source: JICA Survey Team

Figure 17-3 Problems and O&M Legal Solutions

17.1.4 Scheme of O&M legal framework

The O&M Legal Framework contains 2 kinds of schemes. One is concrete measures and the other is philosophical approaches.
There are a lot of measures for stable operation, as per the below figure, and many approaches should be considered by the legal framework.

Source: JICA Survey Team

Figure 17-4 Concrete Measures

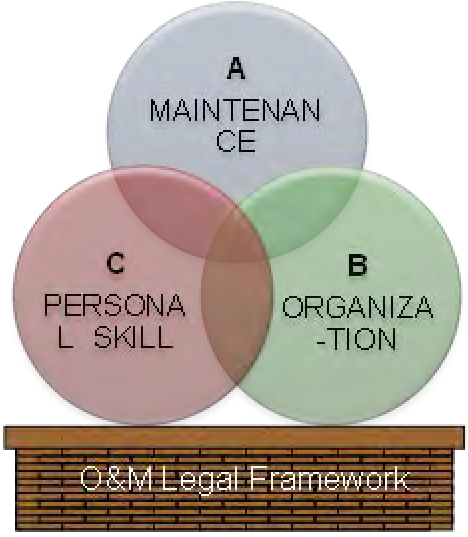
Source: JICA Survey Team

Figure 17-5 Philosophical Approach

17.1.5 Key factors for stable operation

The O&M Legal Framework should support key factors for stable operation.
The key factors for O&M are these three measures:

- MAINTENANCE
- ORGANIZATION
- PERSONAL SKILL



Source: JICA Survey Team

Figure 17-6 Key Factors for O&M

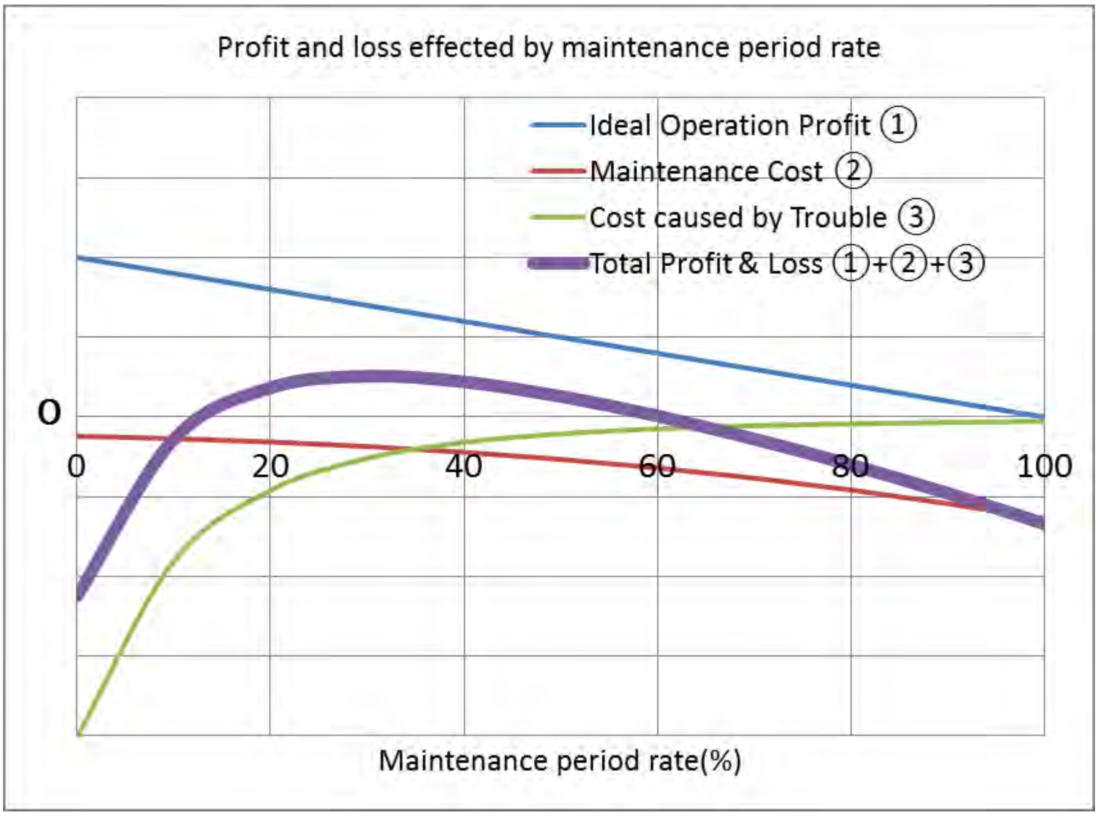
Source: JICA Survey Team

Figure 17-7 Details of Key Factors for O&M

17.1.6 General economic concept of O&M

(1) Maintenance period rate

Suitable maintenance will enable stable operation and stable operation will produce economic benefit. Maintenance Period Rate explains operational benefit easily.
**Maintenance Period Rate (%) = Maintenance days/All days
MPR 0% = No maintenance, Operation always if no trouble
MPR 100% = Maintenance always. NO operation
The following figure shows operational profit/loss against maintenance period rate. It is easy to understand that suitable maintenance produces economic benefit for P/P.



Source: JICA Survey Team

Figure 17-8 Profit and Loss Affected by Maintenance Period Rate

- Too low an MPR produces a big loss
  - Long unplanned stop, with no earnings
  - Huge cost for repair needed
- O&M legal solutions should be built to encourage suitable maintenance opportunities

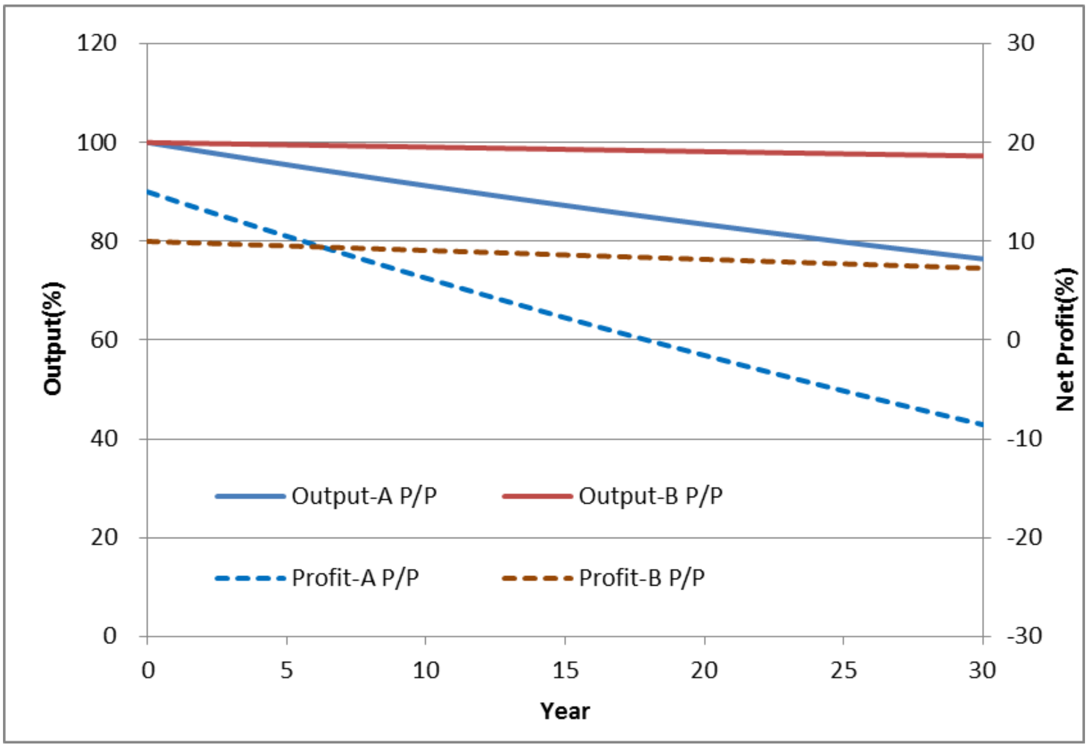
(2) Output and profit

The maintenance/inspection cost is much cheaper than operational gross profit but insufficient maintenance causes output-decrease and efficiency-decrease. The output-decrease and efficiency-decrease influence gross profit directly and cause a huge negative impact.
Two P/P, A and B, are assumed as insufficient maintenance and sufficient maintenance with some conditions. The following figure shows operational profit/loss against operation years. It is easy to understand that suitable maintenance produces economic benefit for P/P.

Table 17-1 Conditions

	A P/P	B P/P
Output(MW)	100% at COD to 77% at 30y	100% at COD to 97% at 30y
Gross Profit①	100% at COD to 77% at 30y	100% at COD to 97% at 30y
Fuel Cost②	70% at COD to 70% at 30y	70% at COD to 70% at 30y
Fixed cost③	10% at COD to 10% at 30y	10% at COD to 10% at 30y
Maintenance Cost④	5% at COD to 5% at 30y	10% at COD to 10% at 30y
Net Profit①-②-③-④	Calculated	Calculated

Source: JICA Survey Team



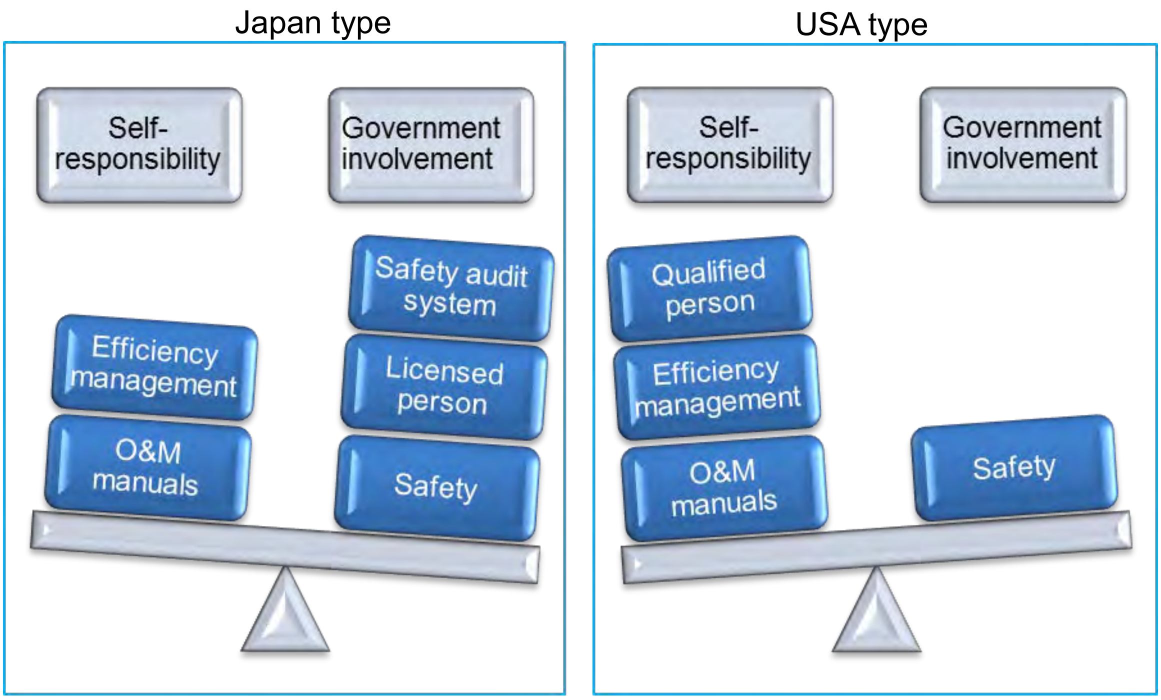
Source: JICA Survey Team

Figure 17-9 Output and Profit

17.2 Japanese O&M Legal Framework

17.2.1 General concept for regulations of O&M

The government should take into consideration how much government involvement is suitable to regulate the power sector. Too much regulation will make private sector vitality decrease and too little regulation will make the private sector uncontrollable. Japan is famous for strict government involvement in the private sector and the trend of current regulation is deregulation, but government involvement still remains.



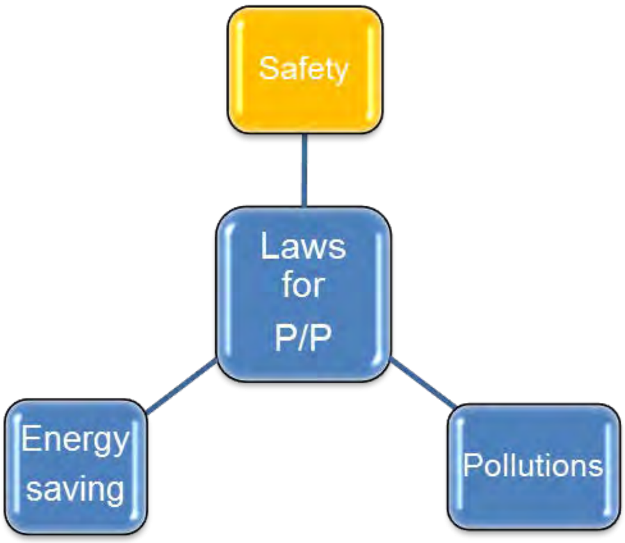
Source: JICA Survey Team

Figure 17-10 Government Involvement or Self-responsibility

17.2.2 Japanese government's main requirements for P/P

The main concepts of the Japanese O&M legal framework are as follows:

- Self-responsibility controlled by government
  - Minimum government involvement
- To meet with government requirements
  - Government regulates
    - Safety (technical standards, etc.)
    - Energy saving
    - Pollutions
  - Government doesn't regulate
    - Output (MW)
    - Efficiency (%)
- To meet with manuals decided by P/P
  - P/P makes manuals and follows the manuals
    - Maintenance manual
    - Patrol inspection manual



Source: JICA Survey Team

Figure 17-11 Legal Framework in Japan

17.2.3 Main regulations for P/P

The regulations for Japanese P/P can be divided three categories such as safety, Energy saving and Pollution. The details of regulations are as follows.

- Safety
  - Electricity Business Act   Act No. 170 of July 11, 1964
    The purpose of this Act is to protect the interests of electricity users and achieve the sound development of Electricity Businesses by realizing appropriate and reasonable management of Electricity Businesses, and to assure public safety and promote environmental preservation by regulating the construction, maintenance and operation of Electric Facilities.

  - Electricians Act   Act No. 139 of 1960

  - High Pressure Gas Safety Act   Act No. 204 of June 7, 1951
    The purpose of this Act is to regulate the production, storage, sale, transportation and other matters related to the handling of high pressure gases, their consumption as well as the manufacture and handling of their containers and to encourage voluntary activities by private businesses and the High Pressure Gas Safety Institute of Japan for the safety of high pressure gases with the aim of securing public safety by preventing accidents and disasters caused by high pressure gases.

  - Electrical Appliances and Materials Safety Act (Tentative translation)   Act No. 234 of November 16, 1961
    The purpose of this Act is to regulate the manufacture, sale, etc. of Electrical Appliances and Materials and to foster voluntary activities by private businesses to ensure the safety of Electrical Appliances and Materials, so as to prevent hazards and damages resulting therefrom.

  - Industrial Safety and Health Act   Act No. 57 of June 8, 1972
    The purpose of this Act is to secure, in conjunction with the Labor Standards Act (Act No. 49 of 1947), the safety and health of workers in workplaces, as well as to facilitate the establishment of a comfortable working environment, by promoting comprehensive and systematic countermeasures concerning the prevention of industrial accidents, such as taking measures for the establishment of standards for hazard prevention, clarifying the safety and health management responsibility and the promotion of voluntary activities with a view to preventing industrial accidents

  - Act on Ensuring Fair Electric Business Practices   Act No. 96 of May 23, 1970

  - Fire Service Act   Act No. 186 of July 24, 1948
    The purpose of this Act is to prevent, guard against, and suppress fires in order to protect the lives, bodies and property of citizens from fires, and to reduce the damage arising from fires or disasters such as earthquakes, thereby maintaining peace and order and contributing to the promotion of social and public welfare.
    Chapter III Hazardous Materials
    Hazardous materials of the designated quantity or a larger quantity shall not be stored at facilities other than a storage facility (including a storage facility for storing or handling hazardous materials by means of a tank mounted on a vehicle (hereinafter referred to as a "mobile tank storage facility"); the same shall apply hereinafter), nor shall they be handled at facilities other than a manufacturing facility, storage facility and handling facility; provided, however, that this shall not apply where the designated quantity or a larger quantity of hazardous materials are stored or handled temporarily for not more than ten days with the

approval of the competent fire chief or fire station chief.

- Energy saving
  - Act on the Rational Use of Energy Act No. 49 of June 22, 1979
    The purpose of this Act is, with the aim to contribute to securing the effective utilization of fuel resources according to the economic and social environment concerning energy in and outside Japan, to take the measures required for the rational use of energy with regard to factories, etc., transportation, buildings, and machinery and equipment as well as other necessary measures, etc. for comprehensively promoting the rational use of energy, thereby contributing to the sound development of the national economy.

- Pollution
  - Basic Environment Law Act No. 91 of Nov. 10, 1993
    The purpose of this law is to comprehensively and systematically promote policies for environmental conservation to ensure healthy and cultured living for both the present and future generations of the nation as well as to contribute to the welfare of mankind, through articulating the basic principles, clarifying the responsibilities of the State, local governments, corporations and citizens, and prescribing the basic policy considerations for environmental conservation.

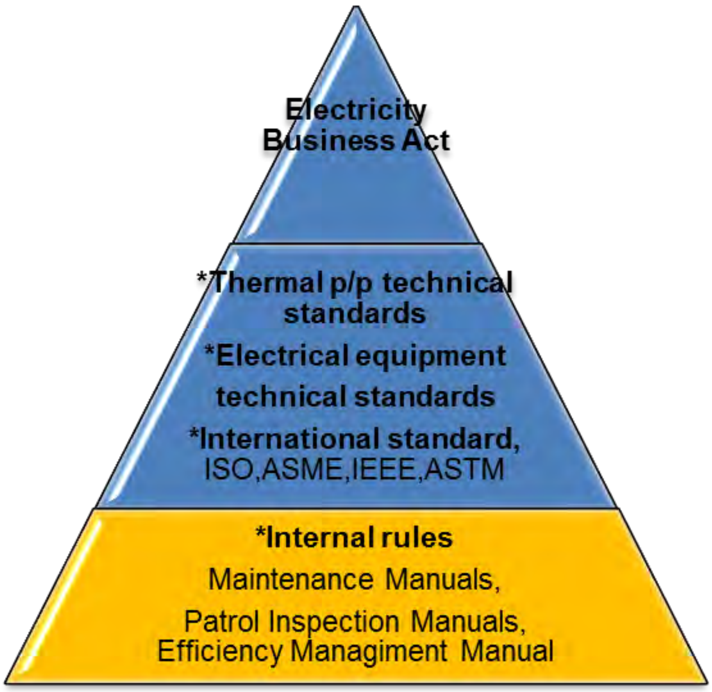
  - Air Pollution Control Act Act No. 97 of June 10, 1968
    The purposes of this Act are to protect the health of citizens and to protect the living environment from air pollution by, among other things, controlling emissions, etc. of Soot and Smoke, Volatile Organic Compounds, and Particulates associated with the business activities of factories and workplaces and with the demolition, etc. of buildings, etc., by promoting the implementation of measures against hazardous air pollutants and by setting maximum permissible limits for automobile exhaust; and to protect victims where air pollution has caused harm to human health by providing for the liability of business operators for damages.

  - Water Pollution Control Act Act No. 138 of 1970
    The purposes of this Act is to prevent the water pollution (including form of deterioration of the condition of water other than the deterioration of water quality; the same applies hereinafter) in the Public Water Areas and in the underground water by regulating effluent discharged by factories and workplaces into the Public Water Areas and infiltration of water through the underground, thereby to protect human health and to preserve the living environment and to protect sufferers by setting forth stipulations regarding the responsibilities of the business operators of factories or workplaces to compensate the damage in cases where human health is damaged by polluted water or waste liquid discharged from factories and workplaces.

  - Noise Regulation Act Act No. 98 of 1968
    The purpose of this Law is to preserve living environment and contribute to protection of the people's health by regulating noise generated by the operation of factories and other types of work sites as well as construction work affecting a considerable area, and by setting maximum permissible levels of motor vehicle noise.

17.2.4 Laws, regulations and rules concerning inspection & maintenance

The Japanese O&M legal framework is like a pyramid, as per the below figure. The blue portion is defined by the government or public organizations and the yellow portion is defined by P/P.
The Electricity Business Act contains two major parts, 1) Business and 2) Safety. The safety laws are the minimum requirement for safety but they are very strict. Therefore, P/P maintains a high quality of operation.
The Japanese government requests that P/P define the safety regulations, which consist of many manuals, by themselves and that P/P should observe the safety regulations.



Source: JICA Survey Team

Figure 17-12 O&M Legal Framework in Japan

The below table shows the individual regulations described in pyramid but the international rules are excluded.

Table 17-2 Safety Rules Related Electricity Business Act

Law	*Electricity Business Act
Cabinet order	*Electricity Business Act Enforcement Order
Ordinance	*Ministerial Ordinance for the Enforcement of the Electricity Business Act Electrical reporting rules
Ministerial ordinance	*Ministerial Ordinance for Establishing Technical Standards for Thermal Power Generation Equipment: *Ministerial Ordinance for Establishing Technical Standards for Electrical Equipment: Ordinance on the qualifications of the chief engineer based on provisions of the Electricity Business Act
Notice	*Interpretation of technical standards for Thermal Power Generation Equipment *Notice defining the details of the technical standards for Thermal Power Generation Equipment *Interpretation of technical standards for Electrical Equipment *Technical elements required to meet the technical standards ordinance based on Electricity Business Act *Q & A relates to chief engineer system *Interpretation of welding inspection in thermal power plant based on the Electricity Business Act Enforcement Regulations etc.

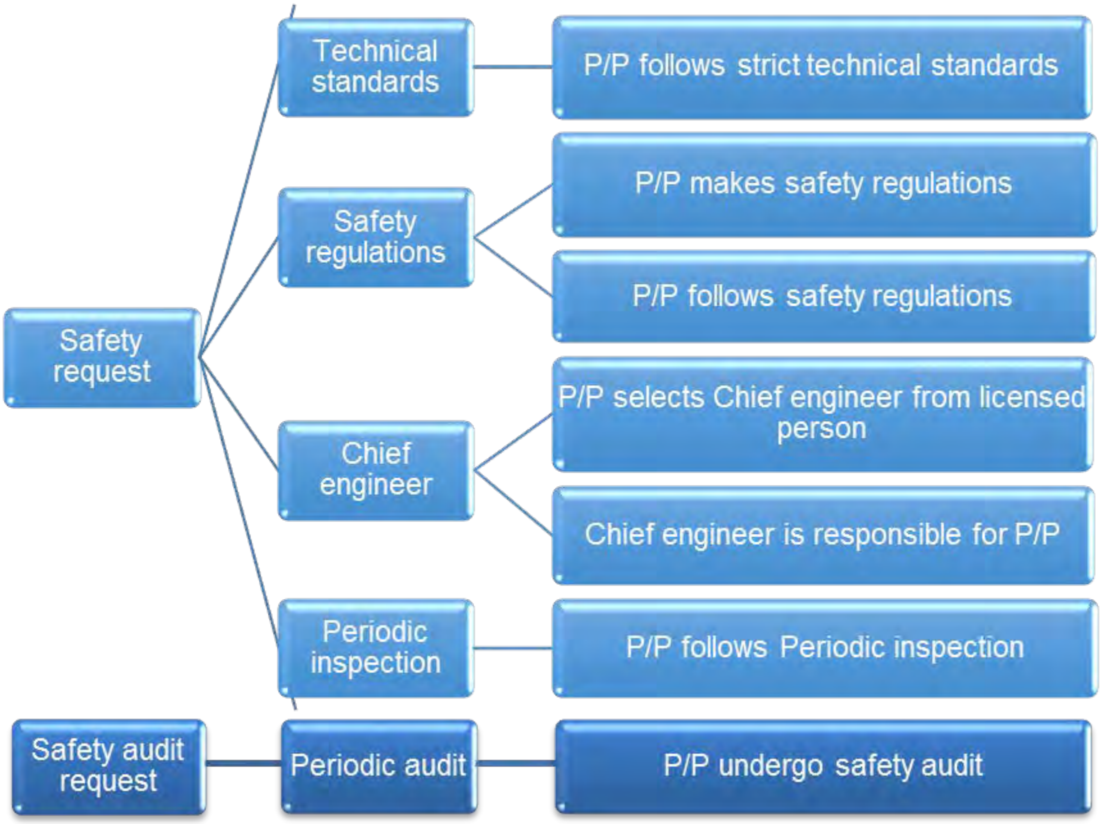
Source: JICA Survey Team

17.2.5 Safety requirements in Electricity Business Act

Safety requirements in the Electricity Business Act number five items, as per the below figures.

Source: JICA Survey Team

Figure 17-13 Government Safety Requirements for P/P (1)



Source: JICA Survey Team

Figure 17-14 Government Safety Requirements for P/P (2)

17.2.6 Details of safety requirements in Electricity Business Act

The actual text regarding safety requirements in the Electricity Business Act is as follows.

- (Technical Standards)

Article 39 (1) A person who installs Electric Facilities shall maintain the Electric Facilities to ensure that they conform to the technical standards established by an Ordinance of the Competent Ministry.

- (Safety Regulations)

Article 42 (1) A person who installs Electric Facilities shall, in order to ensure safety of the construction, maintenance and operation of the Electric Facilities, pursuant to the provision of an Ordinance of the Competent Ministry, establish safety regulations for each organization in charge of the Electric Facilities, the safety of which should be secured uniformly, and notify the Competent Minister of the regulations before the commencement of the use of the Electric Facilities by the organization (in the case of facilities requiring self-inspection set forth in Article 51, paragraph (1) or operator's inspection set forth in Article 52, paragraph (1), before the commencement of the construction of the facilities).

- (Chief Engineer)

Article 43 (1) A person who installs Electric Facilities shall, pursuant to the provision of an Ordinance of the Competent Ministry, appoint one or more chief engineers from among persons who have a chief engineer's license in order to cause him/her to supervise the safety of the construction, maintenance, and operation of the facilities.

- (Periodic Safety Management Inspection)

Article 55 (1) A person who installs Specific Electric Facilities (which means boilers, turbines and other Electric Facilities for electricity generation, which are specified by an Ordinance of the Competent Ministry and have some parts under a pressure higher than that specified under the preceding Article, as well as nuclear reactors for electricity generation and auxiliary equipment thereof, which are specified by an Ordinance of the Competent Ministry; hereinafter the same shall apply) shall, pursuant to the provision of an Ordinance of the Competent Ministry, conduct an operator's inspection of the Specific Electric Facilities at periodic intervals, record the inspection results, and preserve such records.

- (Safety Audit)

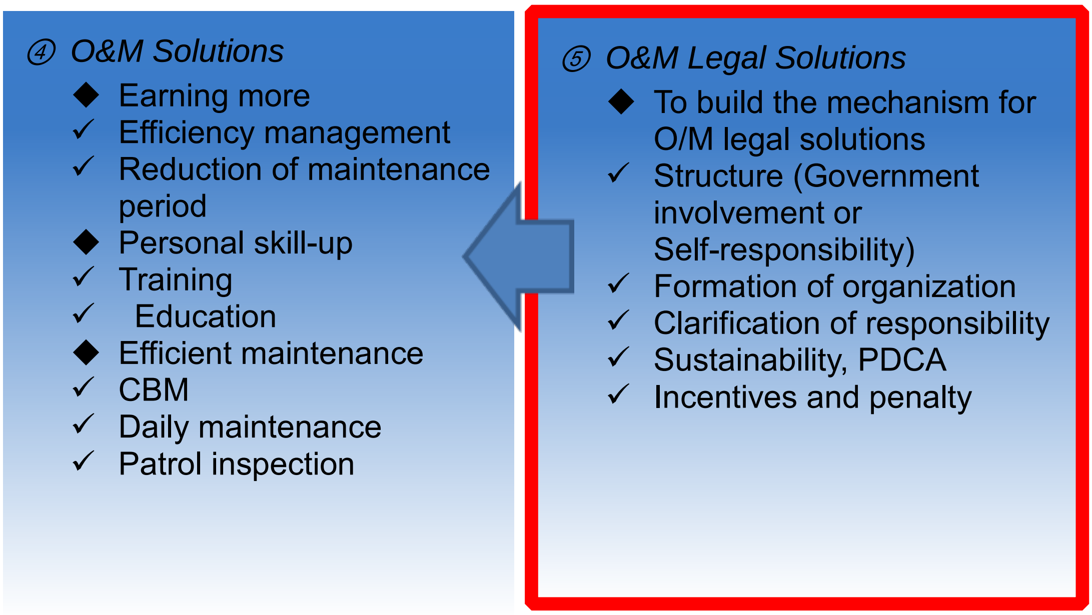
Article 55 (4) A person who installs Specific Electric Facilities subject to a Periodic Operator's Inspection shall, within the period specified by an Ordinance of the Ministry of Economy, Trade and Industry, submit the system for conducting a Periodic Operator's Inspection to undergo examination by the Minister of Economy, Trade and Industry in the case of other persons.

17.2.7 Safety regulations content defined in the Electricity Business Act

The Japanese Electricity Act imposes upon P/P the making of safety regulations, and the content defined by the government is as follows.

① *Safety structure*
② *Duty and organization*
③ *Duty scope and rights of Chief Engineer*
④ *Safety education*
⑤ *Safety PDCA*
⑥ *Writing, modification and preserving of Documents*
⑦ *Documents status for safety regulations*
⑧ *Record*
⑨ *Patrol, check and inspection*
⑩ *Operation*
⑪ *Management for items and service*
⑫ *Safety for long no-operation*
⑬ *Measures for Disaster*
⑭ *Regular improvement for safety regulations*
⑮ *Important items for safety*

Every P/P decides the original safety regulation, submits the safety regulation to the government, and follows the safety regulation.
The above content involves not only O&M legal solutions but also O&M solutions as described in 17.1.3 , as per the below figure; therefore, this safety regulation is a key point of the O&M legal framework in Japan.

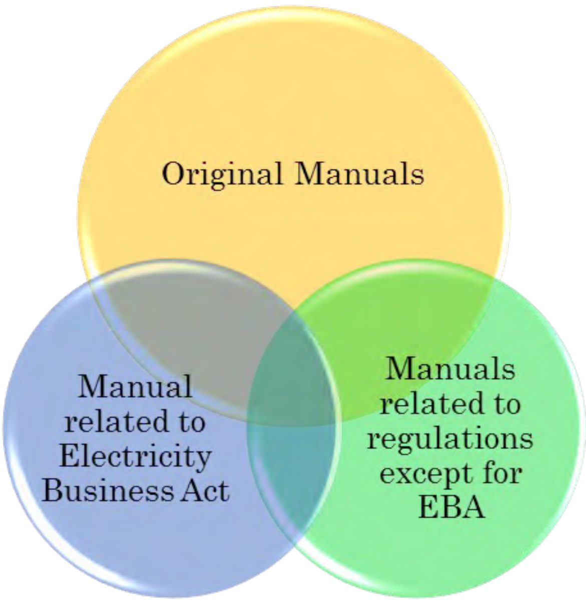


Source: JICA Survey Team

Figure 17-15 Problems and O&M Legal Solutions (excerpt)

17.2.8 Internal rules

Every P/P makes many internal manuals for O&M to achieve stable operation. The internal rules can divided three categories, such as 1) related to Electricy Business Act, 2) related to regulations which is except for Electricy Business Act, and 3) original manuals. Most of internal manuals consist of original manuals in general.



Source: JICA Survey Team

Figure 17-16 Internal Manuals in P/P

Typical original manuals in p/p are as follows.

- Inspection Manuals
  - Boiler
  - Turbine
  - Electrical
  - I&C
    - Interval (1 year, 2 years, 4 years, 8 years)
    - Inspection items

- Daily Patrol Inspection Manual
  - Patrol Route
  - Inspection items
  - Points of check (Vibration, Temperature, Pressure, Level, Noise, etc.)

- Operation Manual
  - Emergency
  - Operation against Trouble manual
    - Boiler
    - Turbine
    - Electrical
    - I&C

- Efficiency Management Manual
  - Method of Efficiency calculation

    - ✧ Gas firing P/P
    - ✧ Coal firing P/P
  - ➢ Management against Efficiency down

- Education and Training Manual
  - ➢ Safety
  - ➢ Operation
    - ✧ Emergency
    - ✧ Continuous monitoring
  - ➢ Maintenance
    - ✧ Boiler
    - ✧ Turbine
    - ✧ Electrical
    - ✧ I&C
  - ➢ Original license system

17.2.9 Licensed and qualified persons in power plant

Japanese has a license system, defined by laws, which makes the quality of work high.

- Power plant
  - ➢ Boiler &Turbine supervisor (Boiler &Turbine chief engineer)
  - ➢ Electrical supervisor (Electrical chief engineer)
  - ➢ Energy saving supervisor (Energy Management Control Officer)
  - ➢ High pressure tank supervisor
  - ➢ Pollution prevention supervisor
  - ➢ Dangerous materials supervisor
  - ➢ etc.
- Subcontractors
  - ➢ Welder
  - ➢ Electrical technician
  - ➢ Scaffolding worker
  - ➢ Slinging worker
  - ➢ etc.

The method of license acquisition depends on each license system, as an example, the following is the Chief Engineering License.

(Chief Engineering License)
Article 44 (1) The types of chief engineering license are as follows.
(i) First-Class Chief Electricity Engineering License;
(ii) Second-Class Chief Electricity Engineering License;
(iii) Third-Class Chief Electricity Engineering License;
(vi) First-Class Chief Boiler/Turbine Engineering License;
(vii) Second-Class Chief Boiler/Turbine Engineering License.
(2) A chief engineering license is granted by the Minister of Economy, Trade and Industry to persons who fall under any of the following:
(i) a person who holds the academic record or qualification and work experience specified by Ordinance of the Ministry of Economy, Trade and Industry for each type of chief engineering license;
(ii) with respect to the types of chief engineering licenses listed in items (i) to (iii) of the preceding paragraph, a person who has passed an examination for a chief electricity engineering license.

17.2.10 Notification and reports system

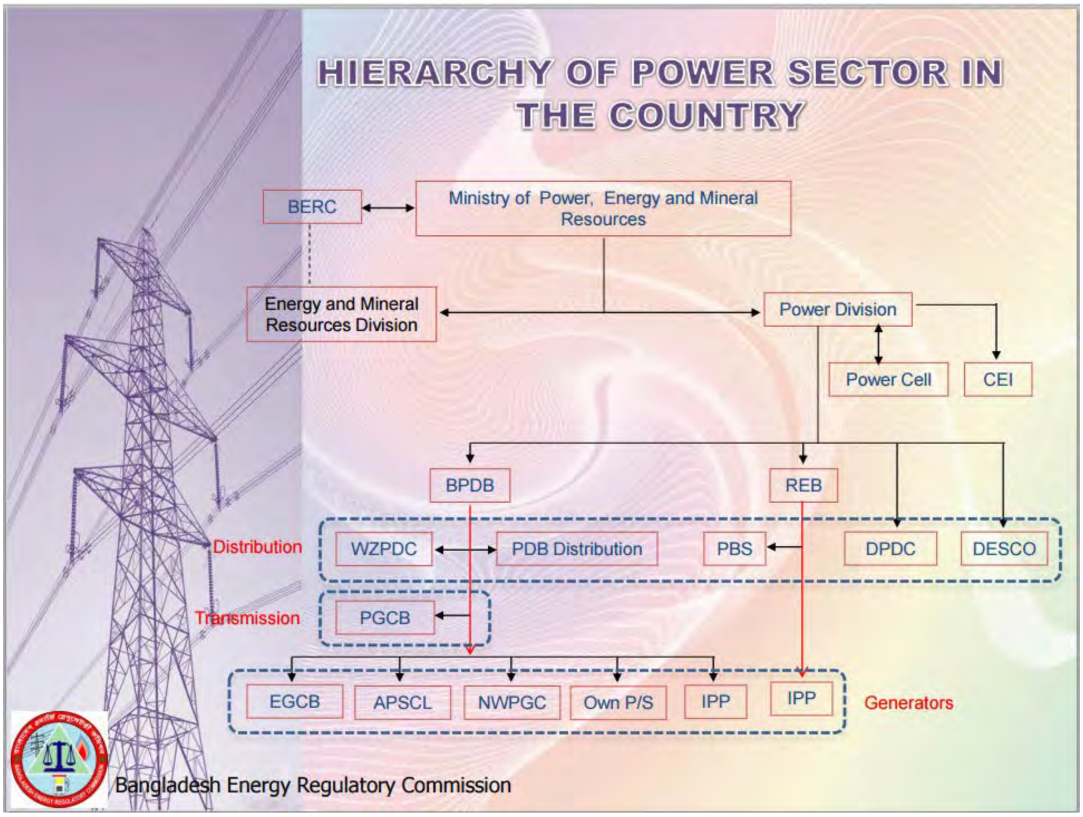
The Japanese Electricity Act has notification and reports system about O&M as below.

- Changes of Electric Facilities, etc.
- Safety Regulations
- Chief Engineer
- Plan of the construction project
- Collection of Reports
  - Periodic report
  - Report on accident
    - Fatal accident
    - Electrical fire accident
    - Accident to the public
    - Disruptive accident
    - Power supply trouble due to the accident
    - Secondary accident to the other company
  - Pollution prevention

17.3 Bangladesh O&M Legal Framework

17.3.1 Hierarchy of power sector

The organization of Bangladesh power sector is as follows.



Source:
http://www.sari-energy.org/PageFiles/What_We_Do/activities/Cross_Border_Energy_Trade_Feb_2013/Presentations/Bangladesh.pdf
Accessed: 9/6/2015

Figure 17-17 Hierarchy of Power Section in Bangladesh

17.3.2 Laws and acts in Bangladesh

There are some laws and acts regarding the power sector in Bangladesh, two of them as Electricity Act 1910 and Bangladesh Energy Regulatory Commission Act, 2003 are most important regulations about O&M in P/P.

17.3.3 Electricity Act 1910

Electricity Act 1910 has been made minor change several times and currently it is carried on making a substantial revision for the first time in 100 years. The significantly revised draft version in Bengali has been published on the internet and that web site is accepted the public opinions.
The enforcement date of the Act is undecided so far and the following is the latest version of the Act.

Table 17-3 Electricity Act 1910

PART I PRELIMINARY
1. Short title, extent and commencement
2. Definitions
PART II SUPPLY OF ENERGY
Licenses
3. Grant of Licenses
4. Revocation or amendment of licenses
5. Provisions where license of licensee, not being a local authority, is revoked
6. Provisions where license of local authority is revoked
7. Purchase of undertaking
8. Provisions where no purchase and license revoked with consent of licensee
9. Licensee not to purchase, or associate himself with other licensed undertakings or transfer his undertakings
10. General power for Government to vary terms of purchase
11. Annual accounts of licensee
Works
12. Provisions as to the opening and breaking up of streets, railways and tramways
13. Notice of new works
14. Alteration of pipes or wires
15. Laying of electric supply-lines or other works near sewers, pipes or other electric supply-lines or works
16. Streets, railways, tramways, sewers, drains or tunnels broken up to be reinstated without delay
17. Notice to telegraph authority
18. Aerial lines
19. Compensation for damage
Supply

PART III
SUPPLY, TRANSMISSION AND USE OF ENERGY BY NON-LICENSEES

PART IV
GENERAL

Protective Clauses

Administration and Rules

Criminal Offences and Procedure

Source: http://bdlaws.minlaw.gov.bd/pdf_part.php?id=93
Accessed: 9/6/2015

17.3.4 Bangladesh Energy Regulatory Commission Act 2003

Bangladesh Gazette, Extraordinary, July 24, 2003

BANGLADESH GAZETTE

Extraordinary
Published by the Authority

Published: Thursday, July 24, 2003
Amended: Thursday, February 17, 2005

S.R.O.No- 228/Law/2003— The Government, in exercise of the powers conferred by section 65 of the Bangladesh Energy Regulatory Commission Act, 2003, is pleased to publish the following English translation of the Act, to be called the Authentic English Text of the Act, and it shall be effective from the date on which the Act comes into force under sub-section (2) of section 1 of the Act.

Act No 13 of 2003
An Act to make provisions for the establishment of an independent and impartial regulatory commission for the energy sector

WHEREAS it is expedient to make provisions for the establishment of an independent and impartial regulatory commission to create an atmosphere conducive to private investment in the generation of electricity, and transmission, transportation and marketing of gas resources and petroleum products, to ensure transparency in the management, operation and tariff determination in these sectors; to protect consumers' interest and to promote the creation of a competitive market;

It is hereby enacted as follows —

CHAPTER - 1
Preliminary

1. Short title and commencement—

(1) This Act shall be called the Bangladesh Energy Regulatory Commission Act, 2003.

(2) It shall come into force on such date as the Government may, by Gazette notification, appoint.

Figure 17-18 Bangladesh Energy Regulatory Commission Act 2003 (Front)

Source: http://www.berc.org.bd/images/stories/pdf/law/berc_act_2003_English.pdf
Accessed: 9/6/2015

17.3.5 Bangladesh Energy Regulatory Commission Act, 2003.(excerpt)

- *CHAPTER – 1 Preliminary*
- *CHAPTER – 2 Establishment of the Commission*
- *CHAPTER – 3 Financial matters of the Commission*
- *CHAPTER – 4 Functions, Powers and Proceedings of the Commission*
  - *22. Functions of the Commission—*

    (a) to determine efficiency and standard of the machinery and appliances of the institutions using energy and to ensure through energy audit the verification, monitoring and analysis of the energyand the economy use and enhancement of the efficiency of the use of energy;

    (b) to ensure efficient use, quality services, determine tariff and safety enhancements of electricity generation and transmission marketing, supply, storage and distribution of energy;

    (c) to issue, cancel, amend and determine conditions of licences, exemption of licences and to determine the conditions to be followed by such exempted persons;

    (d) to approve schemes on the basis of overall program of the licencee and to take decision in this regard taking into consideration the load forecast and financial status;

    (e) to collect, review, maintain and publish statistics of energy;

    (f) to frame codes and standards and make enforcement of those compulsory with a view to ensuring quality of service;

    (g) to develop uniform methods of accounting for all licencees;

    (h) to encourage the creation of a congenial atmosphere to promote competition amongst the licencees;

    (i) to extend co-operation and advice to the Government, if necessary, regarding electricity generation, transmission, marketing, supply distribution and storage of energy;

    (j) to resolve disputes between the licencees, and between licencees and consumers, and refer those to arbitration if considered necessary;

    (k) to ensure appropriate remedy for consumer disputes, dishonest business practices or monopoly;

    (l) to ensure control of environmental standards of energy under existing laws; and

    (m)to perform any incidental functions if considered appropriate by the Commission for the fulfillment of the objectives of this Act for electricity generation and energy transmission, marketing, supply, storage, efficient use, quality of services, tariff fixation and safety improvement.
  - *23. Investigation power—*

    (1) Commission shall have all those powers for the purposes of an investigation or proceedings, which are exercised by a Civil Court at the time of trial under the Code of Civil Procedure, such as: –

    (a) to summon a witness and ensure his presence and examination of the witness on oath;

    (b) to detect and present any important document which may be submitted as a document or evidence;

    (c) to collect evidence through an affidavit;

    (d) to call for public record from any court or office;

    (e) to adjourn hearing;

    (f) to ensure presence and absence of the parties; and

    (g) to review the Commission's decisions, directives or orders.
- *CHAPTER – 5 Relationship between the Government and the Commission*
- *CHAPTER – 6 License*
  - *27. Licence—*
  - *28. Issuance of licence by the Commission—*
  - *31. General duties and powers of the licencee.*

    (1) Every licencee shall make arrangement for the efficient, co-ordinated, cost-effective production, transmission and supply of energy.

(2) Every licencee shall maintain international standards and working methods at the time of discharging his duties relating to energy operation, maintenance and safety.

- *CHAPTER – 7 Tariff*
- *CHAPTER – 8 Commission's power to issue order and implement its decision*
- *CHAPTER – 9 Flow of Information*
- *CHAPTER – 10 Arbitration - Settlement and Appeal*
- *CHAPTER – 11 Offence and Penalty*
- *CHAPTER – 12 Receipt of Complaint of Consumer and disposal*
- *CHAPTER – 13 Miscellaneous*
- *CHAPTER – 14 Transitional Provision*

17.4 Comparison between Bangladesh and Japan

Next table shows that comparison between Bangladesh and Japan about main provisions of O&M regulations.

Table 17-4 Comparison between Bangladesh and Japan

	JAPAN	Bangladesh
Business Licenses	*Electricity Business Act* ***(Business Licenses)*** *Article 3 (1) A person who intends to conduct Electricity Business (excluding Specified-Scale Electricity Business; hereinafter the same applies in this Chapter (except for Article 5, item (vii) and Article 17, paragraph (1))) must obtain a license from the Minister of Economy, Trade and Industry.* *(2) The license set forth in the preceding paragraph is granted by business category, for each of General Electricity Business, Wholesale Electricity Business, or Specified Electricity Business respectively.* ***(Application for a License)*** *Article 4 (1) A person who intends to obtain a license under paragraph (1) of the preceding Article must submit a written application to the Minister of Economy, Trade and Industry, stating:* *(i) the name and address of the applicant, as well as the name of the representative if the applicant is a corporation;* *(ii) the service area, the General Electricity Utilities to which electricity is to be supplied or the service points;* *(iii) the following particulars concerning the Electric Facilities to be used for Electricity Business;* *(a) regarding Electric Facilities for the generation of electricity, the site where they are to be installed, the type of motive power, frequency, and output capacity;* *(b) regarding Electric Facilities for the transformation of electricity, the site where they are to be installed, frequency, and output capacity;* *(c) regarding Electric Facilities for the transmission of electricity, the site where they are to be installed, the electric system, installation means, number of circuits, frequency, and voltage;* *(d) regarding Electric Facilities for the distribution of electricity, the electric system,*	*Electricity Act 1910* ***Grant of Licenses*** *3. (1) The Government may, on application made in the prescribed form and on payment of the prescribed fee (if any), grant to any person a license to supply energy in any specified area, and also to lay down or place electric supply-lines for the conveyance and transmission of energy,-* *(a) where the energy to be supplied is to be generated out-side such area from a generating station situated outside such area to the boundary of such area, or* *(b) where energy is to be conveyed or transmitted from any place in such area to any other place therein, across an intervening area not included therein, across such area.* *BERC Act 2003* *CHAPTER – 6* ***Licence*** *27. Licence—* *(1) No person shall engage himself in the following business unless he is empowered by a licence or exempted from having it under this Act or any other Act, such as:-* *(a) power generation;* *(b) energy transmission;* *(c) energy distribution and marketing;* *(d) energy supply; and* *(e) energy storage.* *28. Issuance of licence by the Commission—* *Licence may be issued to any person for the following purposes in a procedure prescribed by the Commission, such as:-* *(a) for power generation;* *(b) for energy transmission;* *(c) for distribution and marketing of*

	JAPAN	Bangladesh
	frequency, and voltage. *(2) The written application set forth in the preceding paragraph must be accompanied by a business plan, estimate of business income and expenditure, and other documents specified by Ordinance of the Ministry of Economy, Trade and Industry.*	*energy;* *(d) for supply of energy; and* *(e) for storage of energy.*

	JAPAN	Bangladesh
Supervision for Safety	*Electricity Business Act* ***(Purpose)*** *Article 1 The purpose of this Act is to protect the interests of electricity users and achieve the sound development of Electricity Businesses by realizing appropriate and reasonable management of Electricity Businesses, and to assure public safety and promote environmental preservation by regulating the construction, maintenance and operation of Electric Facilities.* ***(Order for Improvement of Operational Procedure)*** *Article 30 The Minister of Economy, Trade and Industry may, when a General Electricity Utility or Specified Electricity Utility fails to make the necessary repairs or take other measures immediately to eliminate any stoppage to the electricity supply arising from an accident or he/she finds that the interest of electricity users is adversely affected because the General Electricity Utility's or Specified Electricity Utility's operational procedure for supplying electricity is inappropriate, order the General Electricity Utility or Specified Electricity Utility to improve the operational procedure.*	*Electricity Act 1910* ***Prohibition of connection with earth, and power for Government to interfere in certain cases of default*** *34. (1) No person shall, in the generation, transmission, supply or use of energy, permit any part of his electric supply-lines to be connected with earth except so far as may be prescribed in this behalf or may be specially sanctioned by the Government.* *(2) If at any time it is established to the satisfaction of the Government-* *(a) that any part of an electric supply-line is connected with earth contrary to the provisions of sub-section (1), or* *(b) that any electric supply-lines or other works for the generation, transmission, supply or use of energy are attended with danger to the public safety or to human life or injuriously affect any telegraph-line, or* *(c) that any electric supply-lines or other works are defective so as not to be in accordance with the provisions of this Act or of any rule thereunder,* *the Government may, by order in writing, specify the matter complained of and require the owner or user of such electric supply-lines or other works to remedy it in such manner as shall be specified in the order, and may also in like manner forbid the use of any electric supply-line or works until the order is complied with or for such time as is specified in the order.*

	JAPAN	Bangladesh
On-site Inspections	*Electricity Business Act* ***(On-site Inspections)*** *Article 107 (2) In addition to the on-site inspection prescribed in the preceding paragraph, the Minister of Economy, Trade and Industry may, to the extent necessary for the enforcement of this Act, have officials of the Ministry of Economy, Trade and Industry enter the business office or other office or other workplace of an Electricity Utility, and inspect the status of the services or accounting or the Electric Facilities, books, documents, and any other articles of the Electricity Utility.*	*BERC Act 2013* ***23. Investigation power—*** *(1) Commission shall have all those powers for the purposes of an investigation or proceedings, which are exercised by a Civil Court at the time of trial under the Code of Civil Procedure, such as: –* *(a) to summon a witness and ensure his presence and examination of the witness on oath;* *(b) to detect and present any important document which may be submitted as a document or evidence;* *(c) to collect evidence through an affidavit;* *(d) to call for public record from any court or office;* *(e) to adjourn hearing;* *(f) to ensure presence and absence of the parties; and* *(g) to review the Commission's decisions, directives or orders.*

	JAPAN	Bangladesh
Technical Standards	*Electricity Business Act* ***Conformity with Technical Standards*** *Article 39 (1) A person equipped with Electric Facilities for Business Use must maintain the Electric Facilities for Business Use to ensure that they conform to the technical standards established by Ordinance of the Competent Ministry.* *(2) The Ordinance of the Competent Ministry set forth in the preceding paragraph must be formulated in accordance with the following:* *(i) Electric Facilities for Business Use do not cause bodily harm nor cause damage to objects;* *(ii) Electric Facilities for Business Use do not cause electric nor magnetic interference*	***There is no technical standard established by government agencies.*** *Bangladesh Gazette, Extraordinary, July 24, 2003* ***31. General duties and powers of the licensee. –*** *(2)Every licensee shall maintain international standards and working methods at the time of discharging his duties relating to energy operation, maintenance and safety.*

	JAPAN	Bangladesh
	with the functioning of other electric equipment or objects; *(iii) damage to Electric Facilities for Business Use does not significantly hinder the supply of electricity by a General Electric Utility;* *(iv) if Electric Facilities for Business Use are used for General Electricity Business, damage to the Electric Facilities for Business Use does not significantly hinder the supply of electricity pertaining to General Electricity Business.* ***Order for Conformity with Technical Standards*** *Article 40 The competent minister may, when finding that Electric Facilities for Business Use do not conform to the technical standards established by Ordinance of the Competent Ministry under paragraph (1) of the preceding Article, order the person equipped with the Electric Facilities for Business Use to repair or alter the Electric Facilities for Business Use to ensure conformity to the technical standards, or order the person to relocate the facilities or suspend the use of them, or restrict the person from using the facilities.*	

	JAPAN	Bangladesh
Safety Regulations	*Electricity Business Act* ***Independent Safety Measures*** *(Safety Regulations)* *Article 42 (1) A person equipped with Electric Facilities for Business Use must, in order to ensure safety of the construction, maintenance and operation of the Electric Facilities for Business Use, pursuant to the provisions of Ordinance of the Competent Ministry, establish safety regulations for each organization in charge of the Electric Facilities for Business Use, the safety of*	***There is no safety regulation.***

	which should be secured uniformly, and notify the competent minister of the regulations before commencement of the use of the Electric Facilities for Business Use by the organization (in the case of facilities requiring self-inspection set forth in Article 51, paragraph (1) or operator's inspection set forth in Article 52, paragraph (1), before the commencement of the construction of the facilities). *(2) A person equipped with Electric Facilities for Business Use must, when having revised the safety regulations, notify the competent minister of the revised particulars without delay.* *(3) The competent minister may, when finding it necessary in order to ensure safety of the construction, maintenance, and operation of Electric Facilities for Business Use, order the person equipped with the Electric Facilities for Business Use to revise the safety regulations.* *(4) A person equipped with Electric Facilities for Business Use and employees thereof must observe the safety regulations.*	

	JAPAN	Bangladesh
Chief Engineer	*Electricity Business Act* ***Independent Safety Measures*** ***(Chief Engineer)*** *Article 43 (1) A person equipped with Electric Facilities for Business Use must, pursuant to the provisions of Ordinance of the Competent Ministry, appoint one or more chief engineers from among persons who have a chief engineering license in order to have said chief engineer supervise the safety of the construction, maintenance, and operation of the*	***There is no obligation to appoint chief engineers.***

	JAPAN	Bangladesh
	facilities. *(2) Notwithstanding the provisions of the preceding paragraph, a person equipped with Electric Facilities for Private Use may, when permitted by the competent minister, appoint a person who does not have a chief engineering license as a chief engineer.* *(3) A person equipped with Electric Facilities for Business Use must, when having appointed a chief engineer (excluding, however, cases of an appointment permitted under the preceding paragraph), notify the competent minister to that effect without delay. The same applies when such person has dismissed the chief engineer.* *(4) The chief engineer must perform the duty of supervising the safety of the construction, maintenance, and operation of Electric Facilities for Business Use in good faith.* *(5) People who are engaged in the construction, maintenance or operation of Electric Facilities for Business Use must follow the instructions given by the chief engineer to ensure the safety thereof.*	

	JAPAN	Bangladesh
Chief Engineering License	*Electricity Business Act* ***Independent Safety Measures*** ***(Chief Engineering License)*** *Article 44 (1) The types of chief engineering license are as follows.* *(i) First-Class Chief Electricity Engineering License;* *(ii) Second-Class Chief Electricity*	***There is no chief engineering license system.***

	JAPAN	Bangladesh
	Engineering License; *(iii) Third-Class Chief Electricity Engineering License;* *(iv) First-Class Chief Dam/Waterway Engineering License;* *(v) Second-Class Chief Dam/Waterway Engineering License;* *(vi) First-Class Chief Boiler/Turbine Engineering License;* *(vii) Second-Class Chief Boiler/Turbine Engineering License.* *(2) A chief engineering license is granted by the Minister of Economy, Trade and Industry to persons who fall under any of the following:* *(i) a person who holds the academic record or qualification and work experience specified by Ordinance of the Ministry of Economy, Trade and Industry for each type of chief engineering license;* *(ii) with respect to the types of chief engineering licenses listed in items (i) to (iii) of the preceding paragraph, a person who has passed an examination for a chief electricity engineering license.* *(3) The Minister of Economy, Trade and Industry may choose not to grant a chief engineering license to persons who fall under any of the following:* *(i) a person who was ordered to return their chief engineering license pursuant to the following paragraph, before the elapsing of a period of one year since the person was thus ordered;* *(ii) a person who was sentenced to a fine or more severe punishment for violation of this Act or any order issued under this Act, before the elapsing of a period of two years since the person served out the sentence or ceased to be subject to the sentence.* *(4) If a person who has a chief engineering license has violated this Act or any order issued under this Act, the Minister of Economy, Trade and Industry may order that person to return their chief*	

	JAPAN	Bangladesh
	engineering license. *(5) The scope of the construction, maintenance and operation of the Electric Facilities for Business Use for which a person who has a chief engineering license is in charge of safety supervision as well as the procedural particulars concerning the grant of a chief engineering license are specified by Ordinance of the Ministry of Economy, Trade and Industry.*	

	JAPAN	Bangladesh
Periodic inspection	*Electricity Business Act* ***(Periodic Safety Management Inspections)*** *Article 55 (1) A person equipped with Specific Electric Facilities (which means boilers, turbines and other Electric Facilities for electricity generation, which are specified by Ordinance of the Competent Ministry and have some parts exposed to pressures higher than those specified under the preceding Article, as well as nuclear reactors for electricity generation and auxiliary equipment thereof, which are specified by Ordinance of the Competent Ministry; hereinafter the same applies) must, pursuant to the provisions of Ordinance of the Competent Ministry, conduct an operator's inspection of the Specific Electric Facilities at periodic intervals, record the inspection results, and keep such records on file.* *(2) In the inspection set forth in the preceding paragraph (hereinafter referred to as a "Periodic Operator's Inspection"), it is necessary to confirm that the Specific Electric Facilities conform to the technical standards established by Ordinance of the Competent Ministry under Article 39, paragraph (1).*	***There is no obligation of Periodic Inspection***.

	JAPAN	Bangladesh
Safety audit	*Electricity Business Act* *Article 55 (4) A person equipped with*	***There is no safety audit system***

	Specific Electric Facilities subject to a Periodic Operator's Inspection must, within the period specified by Ordinance of the Competent Ministry (if notification has been given under Article 51, paragraph (7) as applied mutatis mutandis pursuant to paragraph (6), the period specified by Ordinance of the Competent Ministry depending on the past evaluation of the Periodic Operator's Inspection to which the notification pertained), submit the system for conducting a Periodic Operator's Inspection to undergo examination by a person registered by the Minister of Economy, Trade and Industry if that person installs Specific Electric Facilities other than Specific Electric Facilities for electricity generation by means of nuclear power, which are specified by Ordinance of the Ministry of Economy, Trade and Industry, or examination by the Minister of Economy, Trade and Industry in the case of other persons. *(5) The examination set forth in the preceding paragraph is conducted, in accordance with the principle of ensuring safety management for Specific Electric Facilities, with respect to the organization in charge of a Periodic Operator's Inspection, inspection means, process control, and other particulars specified by Ordinance of the Competent Ministry.*	

Source: JICA Survey Team

17.5 Suggestions

The JICA Survey Team suggests that the Bangladesh government take into consideration the following items in their regulations.

17.5.1 Review of research

This chapter consists from physical matters to philosophical matters, it is not easy to understand the flow of research method. Therefore the research items are reviewed again as follows.

- Introduction
  - Purpose of this study
  - Solutions procedure
  - Cause and effect diagram
  - Scheme of O&M legal framework
  - Key factors for stable operation

- General economic concept of O&M

- Japanese O&M Legal Framework
  - General concept for regulations of O&M
  - Japanese government's main requirements for P/P
  - Main regulations for P/P
  - Laws, regulations and rules concerning inspection & maintenance
  - Safety requirements in Electricity Business Act
  - Details of safety requirements in Electricity Business Act
  - Safety regulations content defined in the Electricity Business Act
  - Internal rules
  - Licensed and qualified persons in power plant
  - Notification and reports system

- Bangladesh O&M Legal Framework
  - Hierarchy of power sector
  - Laws and Acts in Bangladesh
  - Electricity Act 1910
  - Bangladesh Energy Regulatory Commission Act 2003

- Comparison between Bangladesh and Japan

17.5.2 Suggested O&M legal items

Based on the survey results of O&M Legal Framework, we found five important provisions in the Electricity Business Act of Japan were not institutionalized in Bangladesh, and we believe that these five provisions will contribute to the stable operation of the power plant in Bangladesh.

- Periodic inspection
  - Purpose
    - To avoid postponement of the inspection due to budget shortage or tight electricity demand, etc. by securing periodic inspection.
    - To prevent serious accidents by conducting the periodic inspection.
  - Action
    - Authorities decide the intervals and inspection items of periodic inspection.
    - Generators have to conduct the periodic inspection.

- Safety audit
  - Purpose
    - To audit whether periodic inspections are implemented properly or not.
    - If there is a defect in the periodic inspection, auditors instruct to correct it.
  - Action
    - Authorities decide items of safety audit
    - Generators receive priodically safety audit by authority periodically

- Chief engineer
  - Purpose
    - To clarify the responsibility of the technical matters
    - To carry out the technical management under chief engineer
  - Action
    - Authorities order generators to stipulate the responsibility of chief engineer
    - Generators select chief engineer among licensed person

- Safety regulations
  - Purpose
    - ✧ To establish self-management system by making safety regulations
    - ✧ To establish PDCA cycle of operation independently
  - Action
    - ✧ Authorities order generators to set up safety regulations
    - ✧ Generators follow their safety regulations

- Technical standards
  - Purpose
    - ✧ To prevent from accidents and disasters caused by technical issues
    - ✧ To reduce the forced maintenance works
  - Action
    - ✧ Authorities make national technical standards
    - ✧ Generators follows the national technical standards

17.5.3 Recommended schedule of regulations

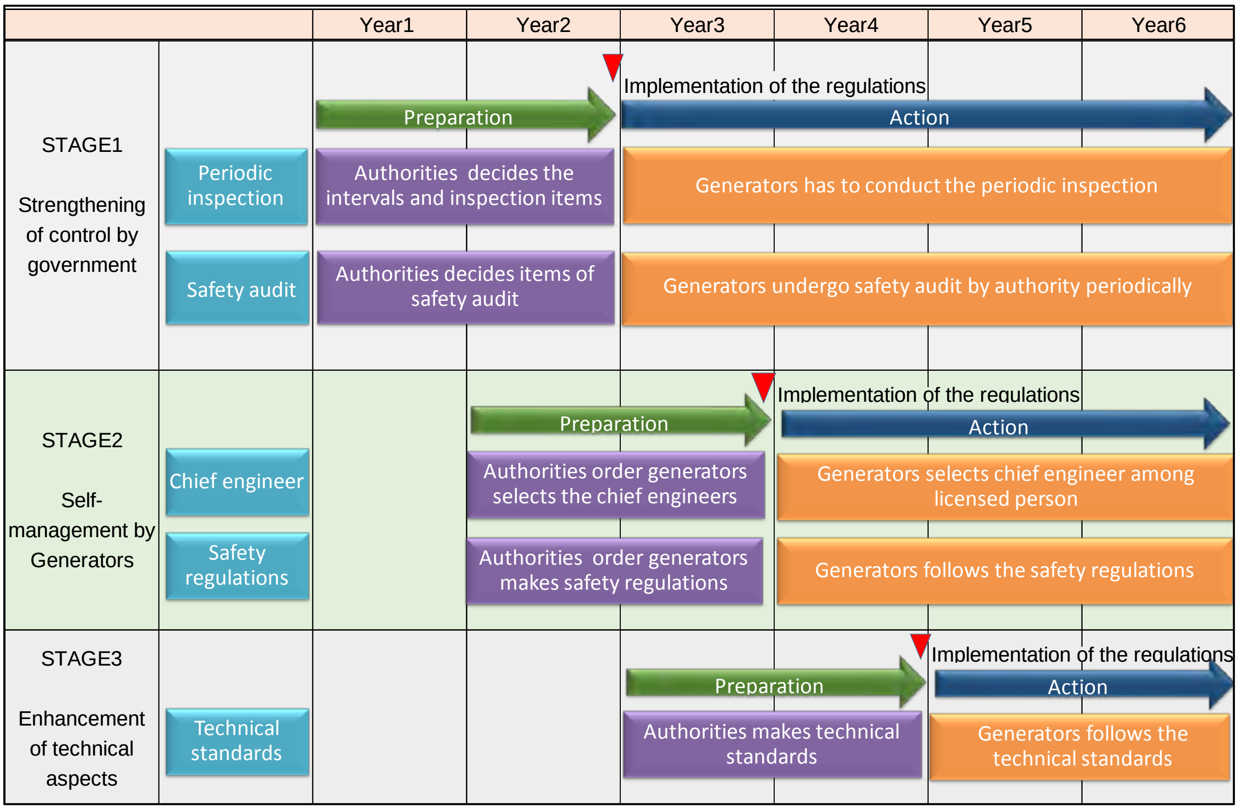
Suggested O&M legal items mentioned above can be divided into three classes as mentioned below, and these classes are recommended to achieve step by step.

1) Strengthening of control by government
   - ✓ Periodic inspection
   - ✓ Safety audit

2) Self-management by Generators
   - ✓ Chief engineer
   - ✓ Safety regulations

3) Enhancement of technical aspects
   - ✓ Technical standards

When the preparation time until implementation of regulation is set to 2 years and start time of every class has 1 year difference, the schedule becomes as follows. Because this recommended schedule is just a sample, Bangladesh government is expected to set up a reasonable schedule for the authorities and generators in consideration of power sector's situation.



Source: JICA Survey Team

Figure 17-19 Recommended Schedule

Chapter 18 Thermal Power Operations and Maintenance

18.1 Outline

The JICA team carried out a survey on the current status of Operation and Maintenance at the power facilities in Bangladesh. The findings were sorted out from the viewpoints of organizational resources such as human capital, facility, finance, and information. Our proposals include solutions for each of the organizational challenges.
Rehabilitation and conversion to combined cycle are proposed as countermeasures against facility deterioration. Implementation of information management is advised for a best practice of O&M contributing to maintenance and budget planning. In human development, new training facilities with practical training programs are suggested.

18.2 Basic Survey for Bangladesh Thermal Power

18.2.1 Equipment

The existing power stations and those planned for construction are as follows.

Data source : PGCB Daily Gen, Petro Bangla Daily, Summit power, GTCL Daily, TGTDCL, PGCL, BCMCL, BPDB AR 11-12, Project list 2014

Serial Number of PGCB	Plant name	Configuration	Original installed capacity (MW)	Derated capacity at 2015/01 (MW)	Generation Capacity 2012-2013 (MW)	Sector	Producer (Source: PGCB)	Commercial Operation Date
1a	Ghorasal Power Station ST-1	55 MW ST: Unit-1	55	85	55	Public	BPDB	1976
1a	Ghorasal Power Station ST-2	55 MW ST: Unit-2	55		30	Public	BPDB	1976
1b	Ghorasal Power Station ST-3	210 MW ST: Unit-3	210	170	180	Public	BPDB	1986/9/14
[illegible]	ST-3 repowering plan	add 206MW GT				Public	BPDB	
1c	Ghorasal Power Station ST-4	210 MW ST: Unit-4	210	180	180	Public	BPDB	1989/3/18
1d	Ghorasal Power Station ST-5	210 MW ST (Unit-5)	210	190	190	Public	BPDB	1994/9/15
1e	Ghorasal Power Station ST-6	210 MW ST , Unit-6	210	190	190	Public	BPDB	1999/1/31
[illegible]	ST-6 repowering plan	add 206MW GT						
2	Ghorashal 100 MW QRPP (Aggreko)	128x0.85MW	100	100	100	Private	QRPP 3yrs: Aggreko	2010/8/23
3	Ghorashal 45 MW QRPP (Aggreko)	50x0.85	45	45	45	Private	QRPP 3yrs: Aggreko	2010/8/10
4	Ghorashal MAX Power 78MW	4x19.6MW	78	78	78	Private	RPP: Max power	2011/5/27
5	Ghorasal(Regent) 108MW	108MW (34*3.15MW)	108	108				
6	Haripur GT-1	BPDB 33MW / PGCB 32 MW	33		20	Public	SBU, BPDB	1987
6	Haripur GT-2	BPDB 33MW / PGCB 32 MW	32	60	20	Public	SBU, BPDB	1987
6	Haripur GT-3	BPDB 33MW / PGCB 32 MW	32		20	Public	SBU, BPDB	1987
7	Haripur 412MW CCPP	412MW (1on1)	412	412		Private	IPP	2014/March7
8	Haripur NEPC (HFO) 110MW	110MW (8x15MW)	110	110	85	Private	IPP	1999
9	Haripur Power CCPP 360MW , AES	360MW (GT:235MW+ST:115MW)	360	360	360	Private	IPP	2001/5/21
10	Meghnaghat CCPP , AES	450MW (GT:150MW*2+ST:150MW)	450	450	450	Private	IPP	2002/11/26
11	Meghnaghat/Meghnagat IEL (100MW)	100MW QRPP (5 Yrs) IEL, 12x8.9MW	100	100	100	Private	IEL	2011/5/8
[illegible]	Meghnaghat CCPP(Summit power) 203MW	203MW (2*110MW) , SC GT	203	203		Private		
[illegible]	Meghnaghat 300-450 MW CCPP Unit-2 (315MW)	(ST:115MW to N,o12) , GT203MW				Private	N/A	2014
13	Madanganj/Modanganj (Summit) 102MW	102MW (6x17.08MW)	102	100	100	Private	QRPP 3yrs Summit power	2011/4/5
14	Keraniganj (Powerpac) 100MW QRPP	100 MW (3x14.4MW)	100	100	100	Private	RPP 5years, Power pack	2012/3/27
15	Narshingdi/Narsindi (REB Doreen)	22MW (8x2.9MW)	22	22	22	Private	SIPP, REB, Doreen Generation and systems	2008/12/21
16a	Siddhirgonj Power Station (ST) 210MW	210 MW Steam Turbine	210	150	150	Public	BPDB	2004/9/3
16b	Siddhirgonj Power Station (GT-1 & GT2) 210MW	BPDB 2*120MW / PGB 210MW (2x105 MW) G/T	210	210	210	Public	EGCB	#1:2011/12/1, #2:2012/2/5
17	Siddhirgonj (Desh) 96MW QRPP	96MW (96x1.2MW)	100	98	96	Private	QRPP 3yrs, Desh energy	2011/2/17
18	Siddhirganj / Siddhorganj (Dutch-Bangla) 100 MW	100MW (12x8.9MW)	100	100	100	Private	RPP 5years Dutch Bangla power	2011/7/21
19	Pagla (DPA Power QRPP) 50MW	50MW (158x0.34MW) DPA Power	50	50	50	Private	QRPP 3yrs	2010/11/24
20	Gangnagar , (Narayanganj) 100MW PP (Orion)	102MW	102	102		Private	IPP	2014/6/3
21	Summit Power Ltd (Dhaka) (disaggregated follows)	6*3.67MW+2*6.97MW*14*8.73MW	146	146	146	Private	SIPP, REB	2006/12/16
retired	Madisabdi 35 MW REB	N/A	N/A	N/A	N/A	Private	REB, Summit power	
retired	Ashulia 45 MW REB	N/A	N/A	N/A	N/A	Private	REB, Summit power	
retired	Maona 33 MW SIPP	N/A	N/A	N/A	N/A	Private	REB, Summit power	2008
retired	Rupganj 33 MW SIPP	N/A	N/A	N/A	N/A	Private	REB, Summit power	2009/6/5
22	Gazipur 50MW (RPCL)	52MW (6*8.5MW)	52	52	52	Public	IPP, RPCL	2012/7/1
23	Tongi Power Station (105MW)	105MW Gas Turbine	105	105	105	Public	BPDB	2005/3/28
Dhaka area								
24a	Raujan,Chittagong Power Station ST: Unit-1, 210MW	210 MW S/T	210	180	180	Public	BPDB	1993/3/28
24b	Raujan,Chittagong Power Station ST: Unit-2, 210MW	210 MW S/T	210	180	180	Public	BPDB	1997/9/21
25	Raozan/ Raujan 25 MW PP (RPCL)		25	25	25	Public	RPCL	2013/5/3
[illegible]	Baraka-Patanga/Patenga 50MW(Barakafulia)		50	50		Private	IPP	
[illegible]	Chittagong Energy pack		no data			Private	IPP	
28	Karnafuli Hydro Power Station	40MW: Unit-1	40	230	30	Public	BPDB	1962
28	Karnafuli Hydro Power Station	40MW: Unit-2	40		40	Public	BPDB	1962
28	Karnafuli Hydro Power Station	50MW: Unit-3	50		50	Public	BPDB	1982
28	Karnafuli Hydro Power Station	50 MW: Unit-4	50		50	Public	BPDB	1988
28	Karnafuli Hydro Power Station	50 MW: Unit-5	50		50	Public	BPDB	1988
29a	Chittagong Sikalbaha ST (60MW)	60MW	60	40	40	Public	BPDB	1984
29b	Sikalbaha Peaking GT (150MW)	150MW	150	150	150	Public	BPDB	2010/8/18
30	Sikalbaha (Energis)	35MW	no data	35		Private	RPP	
[illegible]	Shikalbaha RPP 55MW	55 MW (4x12.5MW+2x11.9MW+1x3MW)	55		51	Private	RPP 3yrs	2010/6/5
31	Hathazari 100MW peaking PP	100MW (11x8.9MW) Peaking PP	98	98	100	Public	BPDB	2011/12/23
32	Sangu, Dohazari-Kalaish 100MW peaking	102MW (6x17MW)	102	102	100	Public	BPDB	2011/12/30 or 2012/1/1
33	Juldah/Julda (Acorn) 100MW(8*13.45MW)	100MW (8x13.45MW)	100	100	100	Private	RPP 5years, Acorn Infra.Service	2012/3/26
34	Barabkunda/Barobkundo SIPP 22MW	22MW (8x2.90MW)	22	22	22	Private	SIPP, PDB	2009/5/23
35	Malancha, Ctg EPZ (United) 36MW	36MW (5*6.73MW+3*9.34MW ?)	36		30	Private		
Chittagong area								
36a	Ashugonj Power Station Unit-1,-2 , 64MW*2	128MW (64MW*2)	128	92	55	Public	APSCL	1970
36b	Ashugonj Power Station Unit-3, 150MW	150MW ST	150	145	140	Public	APSCL	1986
36c	Ashugonj Power Station Unit-4, 150MW	150MW ST	150	175	150	Public	APSCL	1987
36d	Ashugonj Power Station Unit-5, 150MW	150MW ST	150	144	140	Public	APSCL	1988
36e	Ashugonj GT-2 (56MW)	56MW	56	40	40	Public	APSCL	1986
36f	Ashuganj/ashugonj Engines 50MW	53MW (16x3.35MW)	53	45	51	Public	APSCL	2011/4/30
37	Ashugonj RPP (Precision) 55MW	55MW (15x4MW)	56	55	55	Private	RPP 3yrs.	2010/7/4
38	Ashuganj Aggekko 95MW	95MW (96x1.1MW) ←増出力(80MW;82*1.1MW)	95	95	80	Private	RPP 3years, Aggreko	2011/1/31←
39	Ashuganj United Power 53MW (14*4MW)	53MW (14x4MW)	53	53	53	Private	RPP 3years, United Ashugonj power	2011/6/12
40	Ashuganj (Midland) 51MW	51MW (6*9.34MW)	51	51		Private		2011/12/6
41	Brahmanbaria (Aggreko) 85MW	85MW (86*1.1MW) ←増出力(70MW;72*1.1M)	85	85	70	Private	QRPP 3yrs, Aggreko	2011/6/30←
42	Titas Daudkandi/Doudkandi 50MW peakingPP	52MW (6x8.92MW)	52	52	52	Public	BPDB	2011/10/29
43	Chandpur CCPP 150MW	163MW (GT:106MW, ST:57MW)	163	163	163	Public	BPDB	2012/GT mar/ST:2012/7/1
44	Feni (Doreen) 22MW	22MW (8X 2.94MW) , Feni	22	22	22	Private	SIPP, BPDB	2009/2/16
45	Feni Mohipal (Doreen) 11MW	11MW (4*2.9MW)	11	11	11	Private	SIPP, REB, Dreen Generation and systems	2009/4/22
46	Jangalia, Summit, 33MW(4*8.73MW)	33 MW (4x8.73MW)	33	33	33	Private	SIPP, BPDB, Summit power	2009/5/13
[illegible]	Lakdhanvi 52MW	52MW	52	52		Private	IPP	
48	Summit power, Comilla 25MW	25MW (3*3.67MW+2*6.97MW)	25	25	25	Private	SIPP, REB	
Comilla area								

Serial Number of PGCB	Plant name	Configuration	Original installed capacity (MW)	Derated capacity at 2015/01 (MW)	Generation Capacity 2012-2013 (MW)	Sector	Producer (Source: PGCB)	Commercial Operation Date
49	RPCL CCPP (Mymensingh CCPP) 210MW	210MW (4*35MW+70MW)	210	202	197	Private	IPP	1999/11/20
50	Tangail (Doreen) 22MW	22MW (8*2.9MWor 2.5MW?)	22	22	22	Private	SIPP, BPDB	2008/11/12
Mymensingh area								
51a	Fenchugonj Comb. Cycle (CCPP-1) 97MW	DPDB 97MW (GT:2x32MW, ST:33MW)	97	80	90	Public	BPDB	1994-95
51b	Fenchugonj Comb. Cycle (CCPP-2) 104MW	GT:2x35MW, ST:35MW	104	90	104	Public	BPDB	2011/10/26
52	Fenchugonj/Fenchuganj (Barakatullah) 51 MW	51MW (19*2.9MW)	51	51	51	Private	RPP 15yrs	2009/10/18
53	Fenchuganj Energyprima 44MW	44MW (12*3.3MW + 5*2MW)	44	44	44	Private	RPP, energy prima	2012/2/15
54	Hobiganj (Confidence-EP) 11MW	11MW(4*2.9MW)	11	11	11	Private	SIPP, REB	2009/1/10
retired	Shahjibazar Power Unit-5,6 ,38MW	38 MW	38	N/A	0	Public	BPDB	
55	Shahjibazar GT: Unit- 8,9 , 70MW	BPDB/PGCB 70MW (2*35MW)	70	66	66	Public	BPDB	2000
ECNEC Approved	Shahibazar conversion 105MW	ST35MW 増設計画	N/A					2017/june
56	Shahjibazar (Shahibazar, Sahzinazar) 86MW	86MW (32x2.90MW)	86	86	86	Private	RPP 15yrs	2009/2/9
57	Shahjibazar (, Sahzinazar) , Energyprima) 50MW	50MW (27x2.0MW)	50	50	50	Private	RPP 3yrs	2008
58	Sylhet 150 MW	BPDB 150MW / PGCB 142MW	150	142	142	Public	BPDB	2012/3/28
modernization	Sylhet conversion 150MW→225MW	add 75MW	N/A			Public	BPDB	2017/jan
59	Sylhet 20MW GT	20MW	20	20	20	Public	BPDB	1986
60	Sylhet (Energyprima), Kumargoan, 48MW	48MW (29x1.95MW)	48	50	50	Private	RPP 3yrs	2008
61	Shahjahanulla/ Shajahanulah power Com 25MW	3*9.34MW	25	25				2013/11/1
62	Sylhet (Desh) , Kumargao/kumkargoan , 10MW	10MW (6*1.95MW)	10	10	10	Private	RPP 15yrs	2009/3/15
Shlhet area								
63	Bheramara GT Unit-1, -2,-3 , 60MW	60MW (3*20MW) GT	60	46	16	Public	BPDB	1976/76/80
64	Bheramara (Quantum) 105MW	BPDB 110MW/ PGCB:105MW (12x8.5MW+2x6MW+2x13MW)	105	105	105	Private	RPP 3yrs	2010/12/31
65	Bheramara HVDC Interconnector 500MW (直流送電)	500MW	500	500				2013/11/1
66a	Khulna ST 110MW	110 MW Steam Turbine	110	55	55	Public	BPDB	1984
66b (ritered in 2013)	Khulna ST 60MW	60 MW Steam Turbine	60	N/A	30	Public	BPDB	1973
67	Khulna (KPCL-1) 110MW	110MW (19x6.5MW)	110	110	110	Private	IPP	1998
68	Khulna (KPCL-2) ,Summit power , 115MW	115MW (7x17MW) , QRPP (5 Yrs)	115	115	115	Private	IPP,KPCL	2011/6/1
69	Faridpur 50MW peaking	54MW (8*6.89MW), Peaking PP	54	54	54	Public	BPDB	2011/11/4
70	Khulna 150MW GT	158MW(GT)	158	158		Public	NWPGCL	2013/9/23
(70b contructed)	Khulna 150MW GT → 225MW (ST75MW,CCPP)	75MW(ST)	N/A			Public		2015/dec
retired	Khulna RPP(Aggreko) 40MW	40MW (50x0.80MW)	40	N/A	40	Private	RPP 3yrs	2008
74	Khulna Aggreko 55MW	55 MW (71*0.85MW)	55	55	55	Private	QRPP 3yrs	2010/8/10
71	Gopalganj/Gopalgonj/ Gopanlgonj 100MW peaking PP	109MW (16*6.98MW)	109	109	109	Public	BPDB	2011/9/29 or 2011/11/16?
72	Noapara/ Nowapara (Quantam) 105MW	101MW (5x9.9MW+6x9.5MW+2x9.2MW)	105	101	101	Private	RPP 5years,Quantum power system	2011/8/26
73	Noapara/ Nowapara (Khanjahan Ali) 40MW(5*8.5MW)	40MW (5*8.5MW), QRPP (5 Yrs)	40	40	40	Private	RPP, khan Jahan Ali	2011/5/28
Khulna area								
75	Barisal GT : Unit-1 20MW	20 MW Gas Turbine	20	30	16	Public	BPDB	1984
75	Barisal GT : Unit-2 20MW	20 MW Gas Turbine	20		16	Public	BPDB	1987
76	Bhola (Venture) 33MW	34.5 MW	33	33	33	Private	RPP 3yrs	2009/7/12
Barisal area								
77a	Baghabari GT 71MW	71MW Gas Turbine	71	71	71	Public	SBU, BPDB	1991
77b	Baghabari GT 100MW	100MW Gas Turbine	100	100	100	Public	SBU, BPDB	2001
ECNEC approved	Baghabari 100MW conversion → 150MW	add 50MW → 150MW	N/A					2017/June
78	Baghabari 50MW peaking PP	52MW (6*8.9MW)	52	52	52	Public	BPDB	2011/8/29
79 (retired in 2013)	Westmont GT, Baghabari	2x45MW	90	N/A	70	Private	IPP	1999
80	Bera Peaking 70MW	71MW (9*8.29MW)	71	71	71	Public	BPDB	2011/10/28
81	Amnura 50MW, Sinha Power	50MW (7*7.79MW),	50	50	50	Private	RPP 5years, Sinha power	2012/1/13
82	Katakhali, Rajshahi (Northern) 50 MW	50MW (6*8.92MW)	50	50	50	Private	RPP, NPSL	2012/5/23
83	Katakhali 50MW Peaking PP	50MW (6*8.7MW)	50	50		Public	BPDB	2012/12/1
84: COD	Sirajganj/Sirajigonj CCPP (150→225MW完工) NWPGCL	210MW (GT:150MW. ST:75MW)	210	210		Public	NWPGCL	GT 2012/9/1→2014/May?
85	Santahar 50MW peaking	50MW (6*8.7MW)	50	50		Public	BPDB	2012/12/1
86	Bogra (GBB) 22MW	22MW (6*4MW)	22	22	22	Private	RPP 15yrs	2008
87	Bogra Energyprima 20MW	20MW (5*3.3MW+5*2MW)	20	20	20	Private	RPP 3yrs, energy prima	2011
88	Ullapara (Summit) 11MW	11MW (4*2.9MW)	11	11	11	Private	SIPP, REB, Summit power	2009/3/2
89(COD)	Natore 52MW / Raj Lanka /Rajshahi	52MW (6*8.92MW)	52	52				2014/1/24
Rajshahi area								
90	Barapukuria ST : Unit-1,2 , 250MW	2x125MW	250	200	200	Public	BPDB	2006
91	RangpurGT 20MW	20MW Gas Turbine	20	20	20	Public	BPDB	1988
92	Syedpur/Saidpur GT 20MW	20MW Gas Turbine	20	20	20	Public	BPDB	1987
93	Thakurgaon (RZ) 47MW	BPDB:55MW / PGCB:47MW(20x1.5MW+21x1.1MW)	47	40	47	Private	RPP 3yrs	2010/8/2
Rangpur area								

Source: JICA Survey Team

Figure 18-1 List of Existing Power Plants

Serial Number of *PGCB*	Plant name	Configuration	Original installed capacity (MW)	Derated capacity at 2015/01 (MW)	Generation Capacity *2012-2013 (MW)*	Sector	Producer *(Source: PGCB)*	Commercial Operation Date
test run	Ghorasal/ Ghorashal, Narsingdi/Narsindl 100 MW PP	108MW	108			Private	IPP	2014/july→
under construction	Munshiganj (Kathpotti) 50 MW PP	53MW	53			Private	IPP	2014/sep →
under construction	Chittagong (Patenga/potiya) 100 MW PP	108MW	108			Private	IPP	2014/oct→
under construction	Bhola 225 MW CCPP : SC GT 125MW ←150MW ?	GT 125MW ←150MW ?	150			Public	BPDB	2014/Nov→
under construction	Ashuganj 225MW CCPP : SC GT Umit 150MW	GT 150MW	150			Public	APSCL	2014/dec→
under construction	Ashuganj 225MW CCPP : SC ST Unit 75MW	ST 75MW	75			Public	APSCL	2015/June
under construction	Bibiana #2 341MW CCPP(Summit) : SC GT Unit	222MW(GT)	222			Private	BPDB	2015/jan
under construction	Kodda, Gazipur 150 MW PP	150MW	150			Public(BPDB-RPCL)	BPDB	2015/Feb
under construction	Jangalila, Comilla, 52MW peaking	52MW	52					2015/mar
under construction	Ashuganj (South) 450 MW CCPP	373MW (CCGT)	373			Public	APSCL	2015/June
contructed	Co'xbazar 60MW PP	60MW	60			Private		2015/June
under construction	Ashuganj 195MW Modular PP	195MW	195			Public	APSCL	2015/June
under construction	Siddhirganj 335MW CCPP : GT 200MW	200MW GT	200			Public(EGCB)	EGCB	2015/June
under construction	Siddhirganj 335MW CCPP : ST 135MW	135MW ST	135			Public	EGCB	2016/march
under construction	Biblana #2 341MW CCPP : SC ST Unit	119MW(ST)	119			Private	BPDB	2015/july
under construction	Bhola 225 MW CCPP : SC ST 70MW	ST 70MW	70			Public	IPP	2015/aug
contructed	Keraniganj 100MW PP (re-locate from khulna)	100MW	100			Private	IPP	2016/jan
under construction	Narayanganj 53MW	53MW	53			Private	REB	2016/jan
contructed	Manikganj 55MW PP	55MW	55			Private	REB	2016/march
Approved by Purchase Committee	Fenchuganj 50 MW PP	50MW	50			Private	IPP	2016/march
LOI	Munshiganj (Kathpotti) 50 MW PP	50MW	50			Private	IPP	2016/june
under construction	Bosila, Keraniganj, 108MW CCPP(CLC power)	108MW(GT)	108			Private	IPP	2016/june
under construction	Nababganj/ Nababgonj 55MW PP	55MW	55			Private	REB	2016/june
PPA	Kusiara 163MW CCPP	163MW	163			Private	IPP	2016/june
contructed	Chapai nababganj 104MW PP	104MW	104			Public	BPDB	2016/june
ender	Kaptai Solar 8MW	8MW	8			Public	BPDB	2016/june
Tender	Hatiya hybrid (Diesel Generator/solar) 7MW	7MW	7			Public	BPDB	2016/june
Approved by Purchase Committee	Sorishabari 3MW solar	3MW	3			Private	IPP	2016/june
contructed	Shahjibazar CCPP : GT216MW	GT 216MW	216			Public	BPDB	2016/june
contructed	Shahjibazar CCPP : ST 116MW	ST 116MW	116			Public	BPDB	2017/march
NOA	Sikalbaha 225 MW CCPP : GT	150MW(GT)	150			Public	BPDB	2016/sep
NOA	Sikalbaha 225 MW CCPP : ST	75MW(ST)	75			Public	BPDB	2017/june
NOA	Sirajganj #2, 225MW CCPP : SC GT	150MW	150			Public	NWPGCL	2016/sep
NOA	Sirajganj #2, 225MW CCPP : SC ST	70MW	70			Public	NWPGCL	2017/june
PPA	Sirajganj 367MW CCPP : SC GT	249MW GT	249			Private	IPP	2016/sep
LOI	Sirajganj 367MW CCPP : SC ST	118MW ST	118			Private	IPP	2017/june
PQ&RFP evaluation	Dhorola 30MW solar park	30MW	30			Private	IPP	2016/dec
under evaluation	Bibiana south 383MW CCPP ,SC GT	GT 252MW	252			Public	BPDB	2017/jan
under evaluation	Bibiana south 383MW CCPP ,SC ST	ST 131MW : conbined 383MW	131			Public	BPDB	2018/jan
contructed	Ashuganj (North) CCPP 381MW	381MW	381			Public	APSCL	2017/jan
2014→2017	Ghorasai 363MW CCPP : SC GT Unit 254MW	254MW GT	254			Public	BPDB	2017/march
2015→2018	Ghorasai 363MW CCPP : SC ST Unit 109MW	109MW ST	109			Public	BPDB	2018/jan
2015→2017	Bheramara 414MW CCPP : SC GT Unit 260MW	260MW GT	260			Public	NWPGCL	2017/march
contructed	Bibiana #3 CCPP 400MW GT:274MW	274MW GT	274			Public	BPDB	2017/march
contructed	Bibiana #3 CCPP 400MW ST:126MW	126MW ST	126			Public	BPDB	2018/jan
contructed	Barapukuria 275MW, Unit 3	274MW ST	274			Public	BPDB	2018/jan
contructed	Maowa, Munshlganj 522MW coal fored pp(Orion)	522MW	522			Private	IPP	2018/jan
contructed	Khulna 630 MW Coal fired pp (Orion)	630MW	630			Private	IPP	2018/jan
N/A	International Grid Connection	500MW	500					2018/dec
LOI	Chittagong 282MW Coal fired PP (Import coal)	282MW	282			Private	IPP	2019/march
LOI	Dhaka 282MW Coal fired PP (import coal)	282MW	282			Private	IPP	2019/march
PPA	BIFPCL, Rampal, Coal fired PP 1,320MW	1,320MW	1320			Public	BIFPCL	2019/June
	Chittagong 1000MW CCPP(LNG)	1,000MW	1000			Public	BPDB	2019/Dec
LOI	Chittagong 612MW Coal fired PP S.alam group (Import coal)	612MW	612			Private	IPP	2020/Jan
LOI	Dhaka 635MW coal fired pp (Orion)	635MW	635			Private	IPP	2020/Jan
preliminary	LNG based 1,000MW CCPP	1,000MW	1000			Public	BPDB	2020/June
FS	Moheskhali 1,200MW coal fired PP (JV Huadian/ECA)	1,200MW	1200			Public	BIFPCL	2021/June
LOI	Chittagong 612MW Coal fired PP S.alam group (Import coal)	612MW	612			Private	IPP	2021/Jan
FS finish	Matarbari 1,200MW coal fired PP	1,200MW	1200			Public	CPGCL	2021/Dec
	BPDB and CHHKLChina JV ,Chittagong,Co'x Bazar	1,320MW	1,320			Public	BCFPCL	
	Patuakhali , Barisal Patuakhali	!,320MW	1,320			Public	CMC-NWPGCL	
	Moheskhali PP ,Chittagong,Co'x Bazar	!,320MW	1,320			Public	-	
	1,320MW PP with South Korea (West Generation Power Compa	1.320MW	1,320			Public	WGPC	
	Chittagong-Anowara PP , Chittagong, Anowara	1,320MW	1,320			Public	-	
	Munshiganj 600-800MW PP	800MW	800			Public	-	
	Ashuganj Coal- based pp , Barisal	1,320MW	1,320			Public	APSCL	
	Barapukuria 300MW financed by ECA, Rangpur,Dinajpur	300MW	300			Public	BPDB	
	Bashkhali 600MW, chittagong (Bangladesh Machine Tools Factor	600MW	600			Private	BMTFL	
	Mirersorai Chittagong 150MW Commercial pp (Chittagong powe	150MW	150			Private	BSRM	

Source: JICA Survey Team

Figure 18-2 List of Planned Power Plants

(1) O&M target site selection

To ascertain the O&M situation in Bangladesh as a whole, the JICA survey team carried out screening with the following selection criteria. The team also considered the rehabilitation target site and combined cycle power generation remodeling plan target site.

(2) Screening criteria and grounds

(a) BPDB owned

Grounds: BPDB is the largest generation public company in Bangladesh, and thus, cooperation can be expected for the JICA survey team investigation

(b) Operation period: more than 10 years, less than 30 years

Grounds: 10 years of experience in O&M is preferable.
A unit older than 30 years may have large-scale malfunctions regardless of the application of the remodeling plan, therefore, 10-20 year long stable operation may not be expected after the completion of the remodeling works.

(c) Larger than 100MW

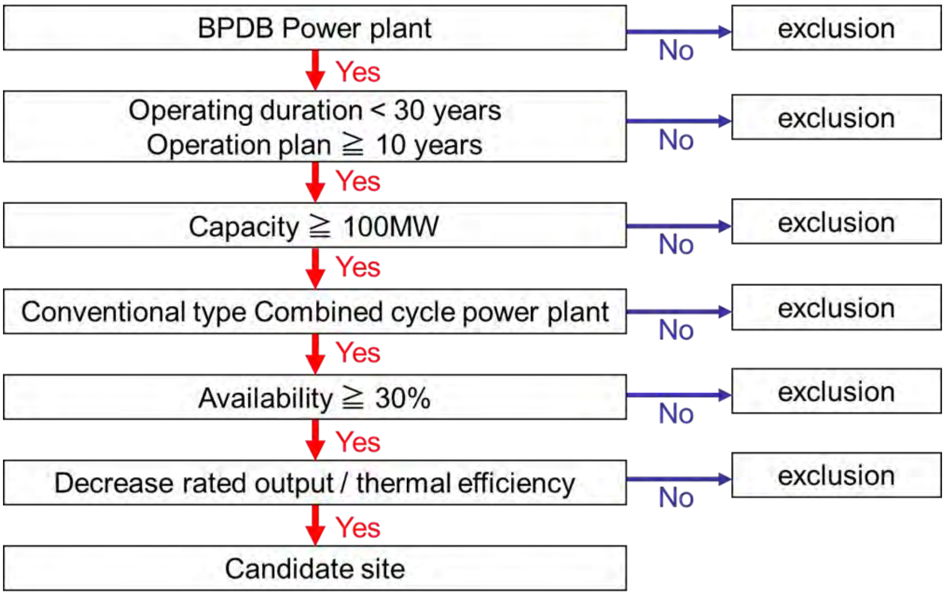
Grounds: There is little to expect from the rehabilitation effect on a small power unit.

(d) Availability more than 30%

Grounds: This means the plant is very useful, and will continue to be vital in the future.

(e) Lowered output or efficiency

Grounds: A large expect can be expected.



Source: JICA Survey Team

Figure 18-3 Site Selection

After site selection, the JICA survey team submits the target site list and discusses it with working group members. Finally, the target site list is decided.

BPDB Annual Report 2012-2013

Name of powerplant	For		COD (Year)	Type	Fuel	Installed	Derated	Plant factor	Efficiency (NET)	
	O&M	C/C				(MW)	(MW)	(%)	(%)	
Rauzan #1		○	1993	ST	Gas	210	180	23.94	27.98	*1
Rauzan #2		○	1997	ST	Gas	210	180	15.80	28.89	*1
Ashuganji #3、#4、#5	○	○	1987/87/88	ST	Gas	450	430	88.56	33.88	
Siddhirganj	○	○	2004	ST	Gas	210	150	56.98	30.32	
Barapukuria #1,#2	○		2009/2009	ST	Coal	250(125*2)	200	75.37	27.56	
Chandpur	○		2012	CC	Gas	163	163	49.68	37.27	
Haripur GT1,GT2,GT3		○	1987	GT	Gas	32*3	60	53.33	21.16	
Ghorasal #3,#4	○	○	1987/89	ST	Gas	420(210*2)	360	69.53	31.09	
Ghorasal #5,#6	○	○	1995/99	ST	Gas	420(210*2)	380	33.72	28.76	
Tongi		○	2005	GT	Gas	105	105	38.38	25.93	
Baghabari		○	2001	GT	Gas	100	100	87.52	28.29	
Shahjibazar		○	2000	GT	Gas	70(35*2)	66	76.36	25.53	
Fenchuganj	○		2011	CC	Gas	104	104	49.08	30.06	
Sylhet		○	2012	GT	Gas	150	142	51.96	29.16	

*1) Rauzan power station 1)lack of gas causes low availability
2)large scale of its generation capacity
Because of above reasons, Rauzan power plant also listed in candidate plants list.

Source: JICA Survey Team

Figure 18-4 Target Site List

After site investigation, the JICA survey team writes down the next section.

18.3 Actual O&M Situation

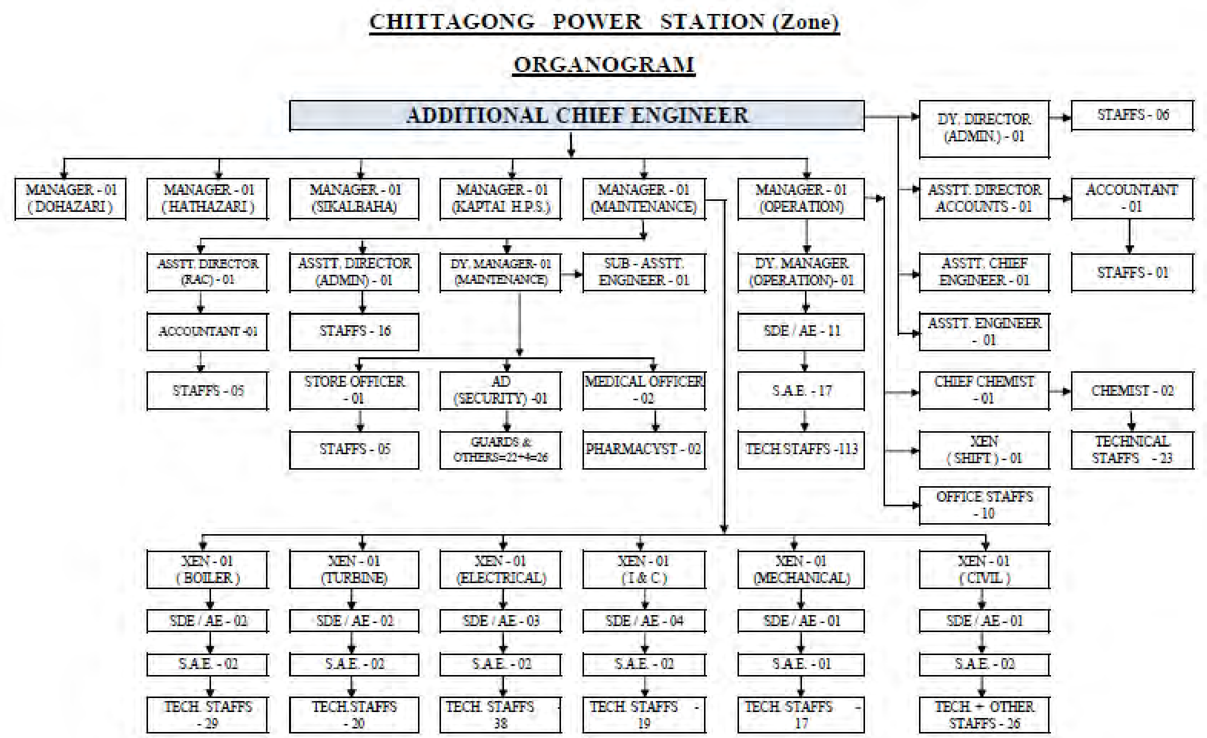
18.3.1 Power station situation

(1) Rauzan thermal power station (main fuel : natural gas)

Basic information	:	COD unit 1: 1993, unit 2: 1997
Capacity (COD)	:	210MW, 210MW
Capacity (Now)	:	180MW, 120MW

Organization chart:

Source: Rauzan thermal power station



Source: Rauzan thermal power station

Figure 18-5 Rauzan Organization Chart

Table 18-1 Rauzan Thermal Power Station

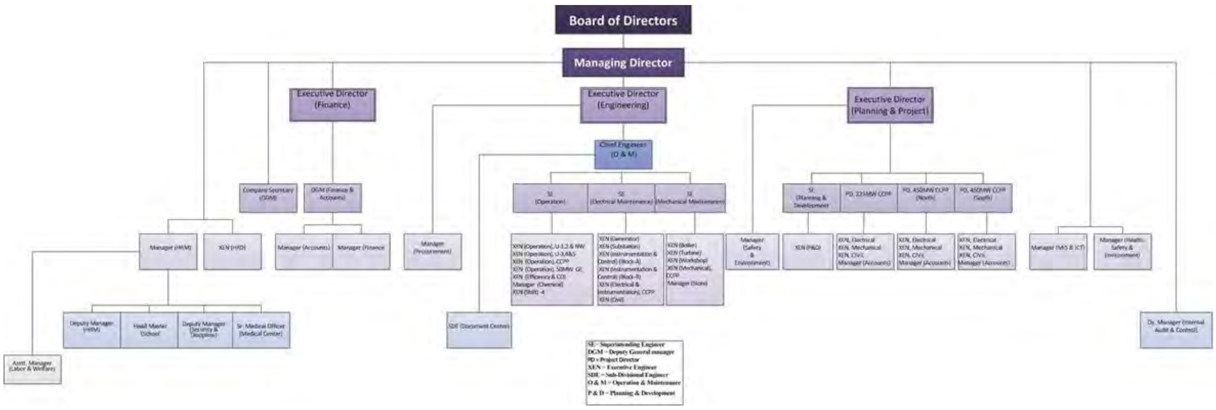
Maintenance plan	Unidentified
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Cannot get shutdown permission because of lack of power supply
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	Manufacture
Safety for equipment	Firefighting system
Safety for staff	Has safety rules *there is a human accident data book
Efficiency management	Monthly average efficiency calculated by SAE
Fuel analysis	No analysis
Environmental regulation	Unidentified
Organization for operation	13 staff/shift (10 operators for 2 units, shift-leader, shift sub-leader, supervisor), 3 shifts
Patrol for site	Unidentified
Plant condition report	Operator checks and records every 2 hours
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*No root cause analysis for unit 2 explosion and there are also no countermeasures *Does not reach rated output
Capacity limitation	Yes
Future plan	Unit 2 has a plan for large scale repair at next outage by Chinese manufacturer
Peculiar information	These plants can operate until facility replacement parts disappear
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	They have not received enough gas, but they believe gas will be supplied

Source: JICA Survey Team

(2) Ashuganj thermal power station (main fuel : natural gas) units 3, 4 and 5

Basic information	:	COD unit 3: 1986, unit 4: 1987, unit 5: 1988
Capacity (COD)	:	150MW, 150MW, 150MW
Capacity (Now)	:	135MW, 129MW, 134MW

Organization chart:



Source: Ashuganj thermal power station

Figure 18-6 Ashuganj Organization Chart

Table 18-2 Ashuganj Thermal Power Station

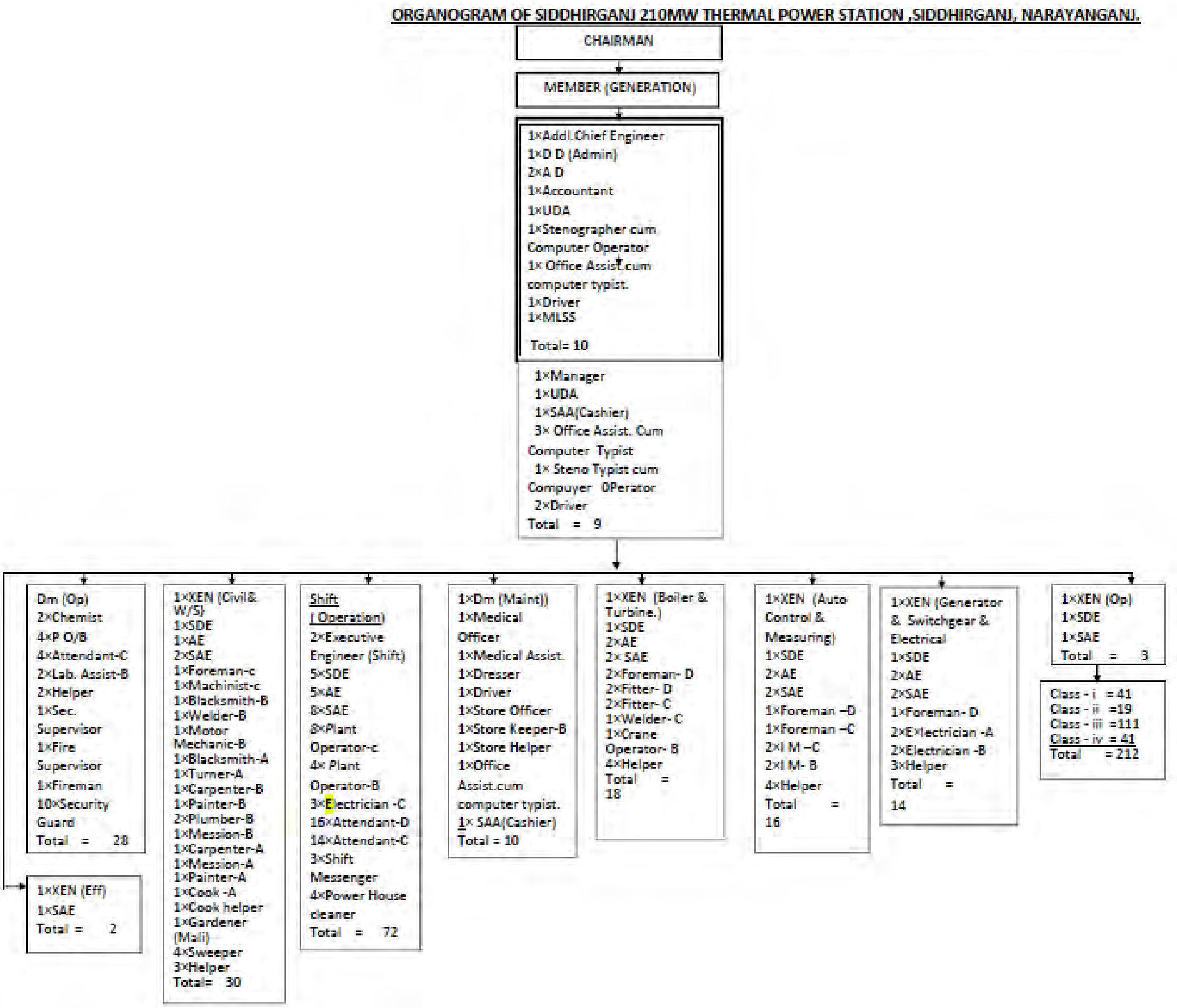
Maintenance plan	Chief engineer
Maintenance plan basic idea	Few days' short stop maintenance and every 3 months maintenance
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Cannot get shutdown permission from Power div
Manufacture support for daily	Unidentified
Daily maintenance	Maintenance staff
Major inspection	Unidentified
Safety for equipment	Firefighting system
Safety for staff	Health and safety section was established in 2013. *in emergency, contact hospital and head office (*there is no communication chart)
Efficiency management	Monthly average efficiency calculated by efficiency section
Fuel analysis	No analysis
Environmental regulation	No (there is no emission monitor)
Organization for operation	6 staff / shift, 4 groups, 3 shifts
Patrol for site	Every 2 hours
Plant condition report	Operation group makes operation log sheet. It includes unit start up/shut down events and trip events
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*Does not reach rated output *High pressure heater tube leak
Capacity limitation	Yes
Future plan	Combined cycle power generation remodeling plan sequentially
Peculiar information	None
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	No

Source: JICA Survey Team

(3) Siddhirganj thermal power station (main fuel : natural gas)

Basic information	:	COD 2004
Capacity (COD)	:	210MW
Capacity (Now)	:	150MW

Organization chart:



Source: Siddhirganj thermal power station

Figure 18-7 Siddhirganj Organization Chart

Table 18-3 Siddhirganj Thermal Power Station

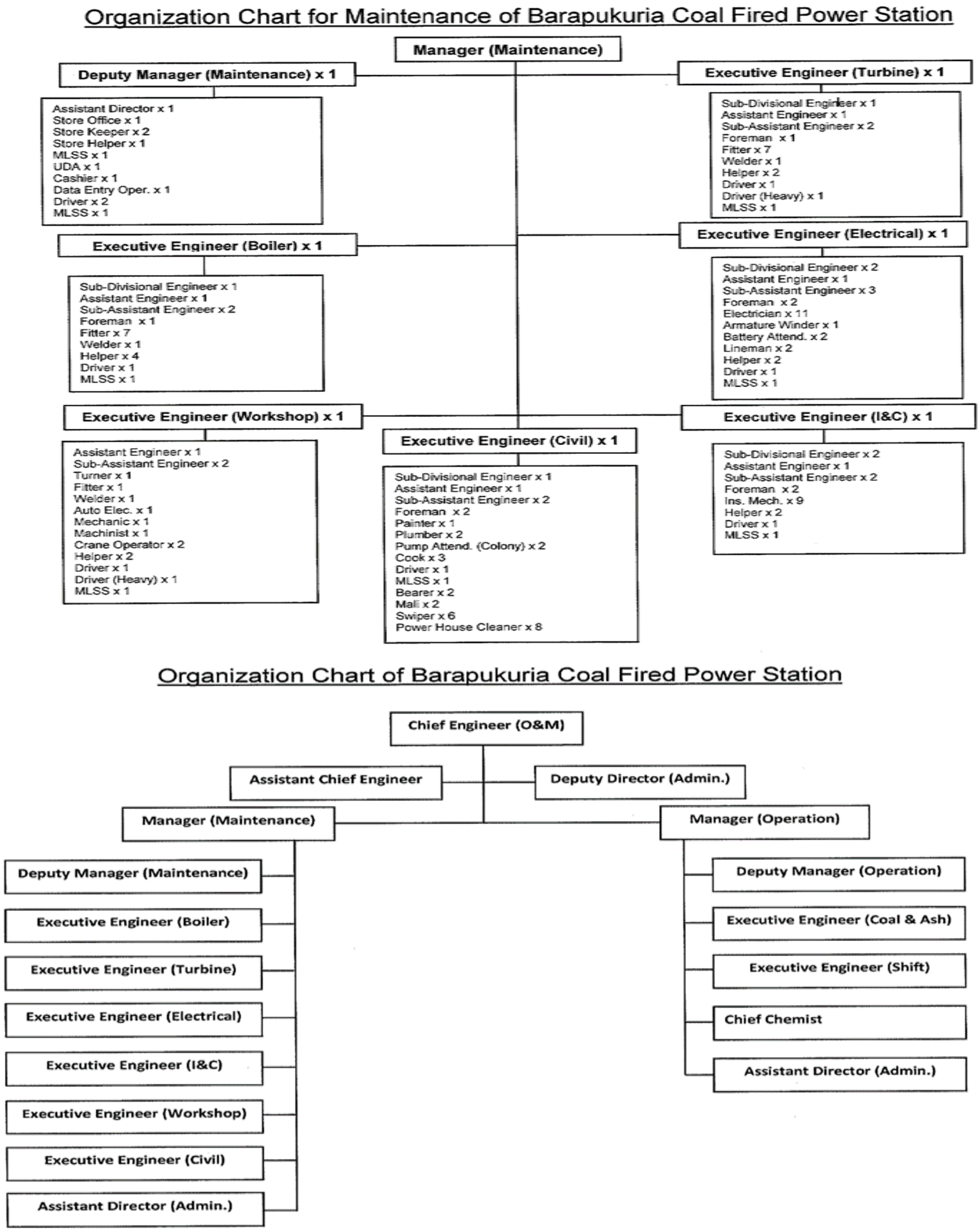
Maintenance plan	Unidentified
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Unidentified
Reason to disturb it	Unidentified
Manufacture support for daily	Yes (Russian company)
Daily maintenance	Maintenance staff *there is a workshop
Major inspection	Unidentified
Safety for equipment	Firefighting system
Safety for staff	No record
Efficiency management	Monthly average efficiency only
Fuel analysis	No analysis
Environmental regulation	Unidentified
Organization for operation	9 staff/shift (operator *4, Engineer *5) 4 groups/3 shifts Others:11 staff for local (day shift)
Patrol for site	Once/shift
Plant condition report	Operation group makes operation log sheet every hour. *auxiliary equipment switch over test (there is a monthly schedule)
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output
Capacity limitation	Yes - 150MW (Generator has trouble)
Future plan	None
Peculiar information	Unidentified
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	Uneasy *the generation output is 110MW degree because of shortage of gas supply

Source: JICA Survey Team

(4) Barapukuria thermal power station (main fuel : Coal)

Basic information : COD 2005
Capacity (COD) : 250MW (125MW*2)
Capacity (COD) : 180MW

Organization chart:



Source: Barapukuria thermal power station

Figure 18-8 Barapukuria Organization Chart

Table 18-4 Barapukuria Thermal Power Station

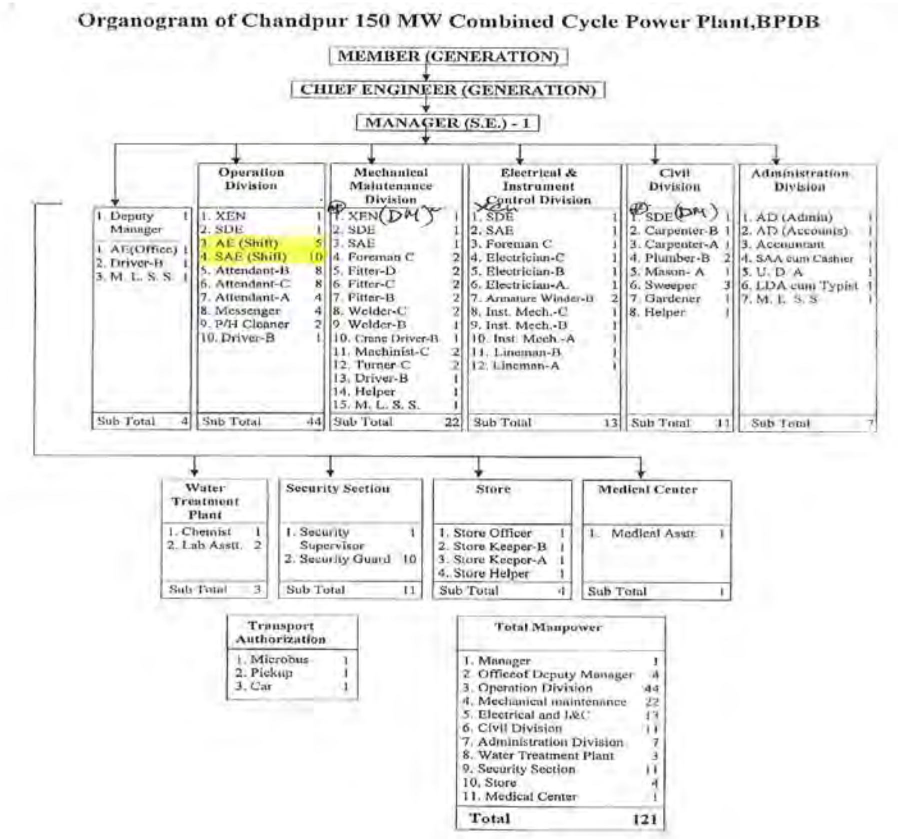
Maintenance plan	Executive engineer, approved by manager
Maintenance plan basic idea	Boiler inspection every 2.5 months, major inspection every 4 years *They have a 3 year maintenance plan
Feasibility of maintenance plan	*Boiler minor inspection will be held as scheduled *major maintenance has never been carried out since COD.
Reason to disturb it	BPDB: budget issue Power Div: shutdown permission issue
Manufacture support for daily	Unidentified
Daily maintenance	Maintenance staff *they have spare parts based on 10 years' experience
Major inspection	Main equipment (boiler, turbine): manufacture other portions: maintenance staff
Safety for equipment	Firefighting system
Safety for staff	BPDB guideline only *there are no individual rules, and no safety section in power station. *if a person is injured, they submit a report to BPDB head office
Efficiency management	Monthly average efficiency only *No performance test
Fuel consumption	2,400ton/day for 2 units
Fuel analysis	*they do analysis every day, but if heat value is not over/under 6,100kcal/kg +/-10%, then they use 6,100kcal/kg, the same as the construction period value.
Environmental regulation	Nox: 150ppm、Sox: 277ppm
Organization for operation	4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	*Operation group makes operation log sheet. *auxiliary equipment switch over test
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *because coal includes small stones, it breaks coal mill equipment
Capacity limitation	180MW (because mill cannot operate at rated speed)
Future plan	None
Peculiar information	Bituminous coal (6,100kcal/kg +/-10%) They cannot inspect boiler equipment by themselves
Staff issues	Unidentified
Training system	OJT and using BPDB training center

Source: JICA Survey Team

(5) Chandpur thermal power station (main fuel : natural gas)

Basic information	:	COD 2012
Capacity (COD)	:	163MW
Capacity (Now)	:	163MW

Organization chart:



Source: Chandpur thermal power station

Figure 18-9 Chandpur Organization Chart

Table 18-5 Chandpur Thermal Power Station

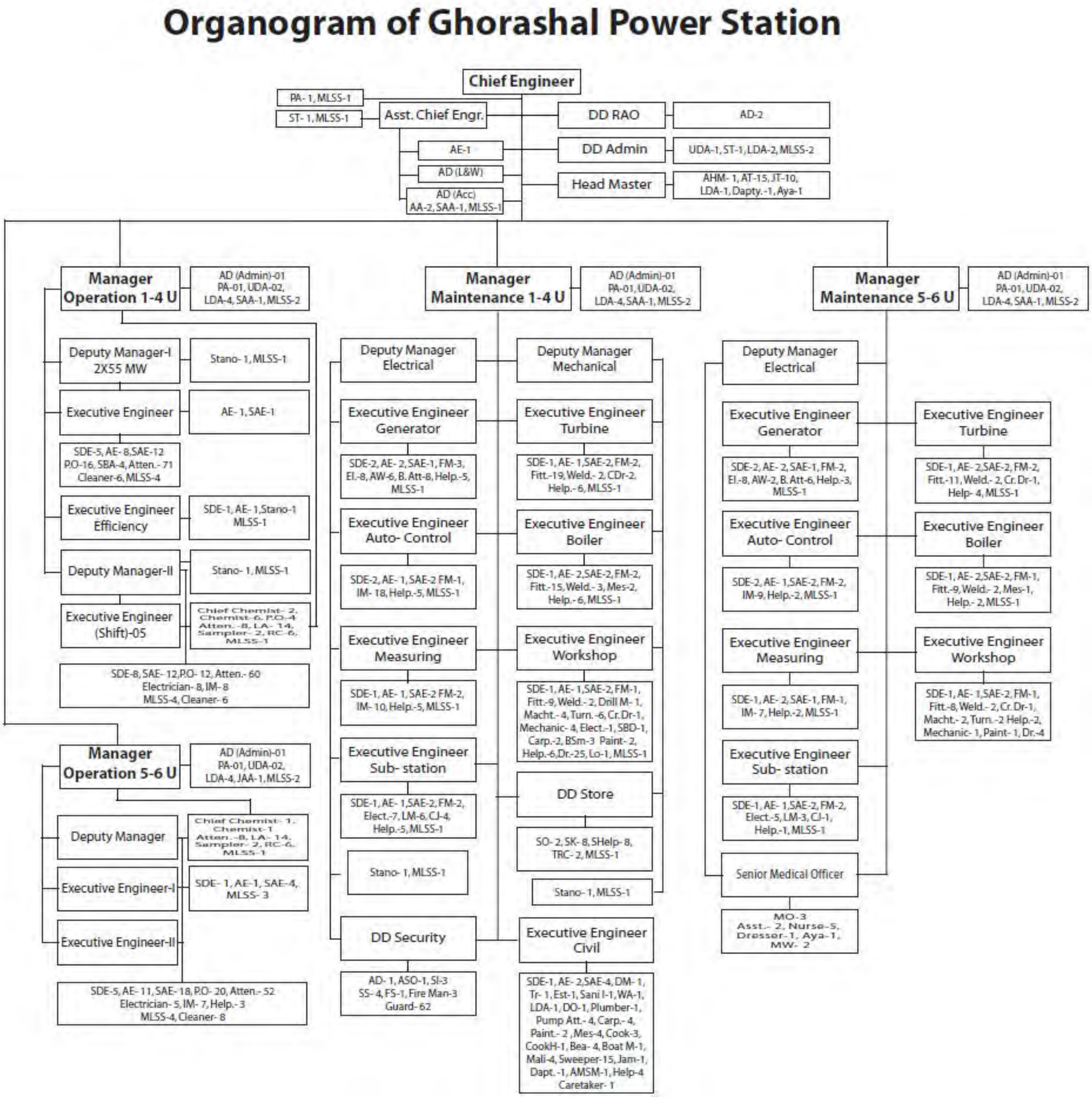
Maintenance plan	Executive - electrical engineer, - operator, - mechanical engineer -> plant manager Finally, BPDB approves
Maintenance plan basic idea	No original maintenance plan *just finished warranty period
Feasibility of maintenance plan	Ignorance *because, during construction period, they have priority over other plants
Reason to disturb it	-
Manufacture support for daily	None *they consider making a contract with manufacture
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff + overseas expert company (Indian engineering) *Indian engineering company cooperates with Tongi thermal power station
Safety for equipment	Firefighting system
Safety for staff	They have BPDB guideline, and also helmets and gloves, but nobody cares *There is no penalty for not following a manual ・Staff can take lectures at BPDB training center
Efficiency management	Monthly average efficiency calculated by operation sector *performance test carried out during commissioning period only *managed by performance acceptance committee
Fuel analysis	No analysis *using fixed value that was established in commissioning period because same gas field's gas has same content
Environmental regulation	No regulation
Organization for operation	9 staff /shift (engineer *3, skilled technician) 5 groups, 3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	None
Capacity limitation	None
Future plan	None
Peculiar information	None
Staff issues	Because salary is low, the human resources they developed flow out to other power stations *short of staff
Training system	OJT *every member of staff goes to training center at Tongi twice/year *the contents are mainly lectures
Uneasiness concerning natural gas supply	Unidentified

Source: JICA Survey Team

(6) Ghorasal thermal power station (main fuel : natural gas)

Basic information	:	COD unit 4: 1989, unit 5: 1995
Capacity (COD)	:	210MW, 210MW
Capacity (Now)	:	180MW, 190MW

Organization chart:



Source: Ghorasal thermal power station

Figure 18-10 Ghorasal Organization Chart

Table 18-6 Ghorasal Thermal Power Station

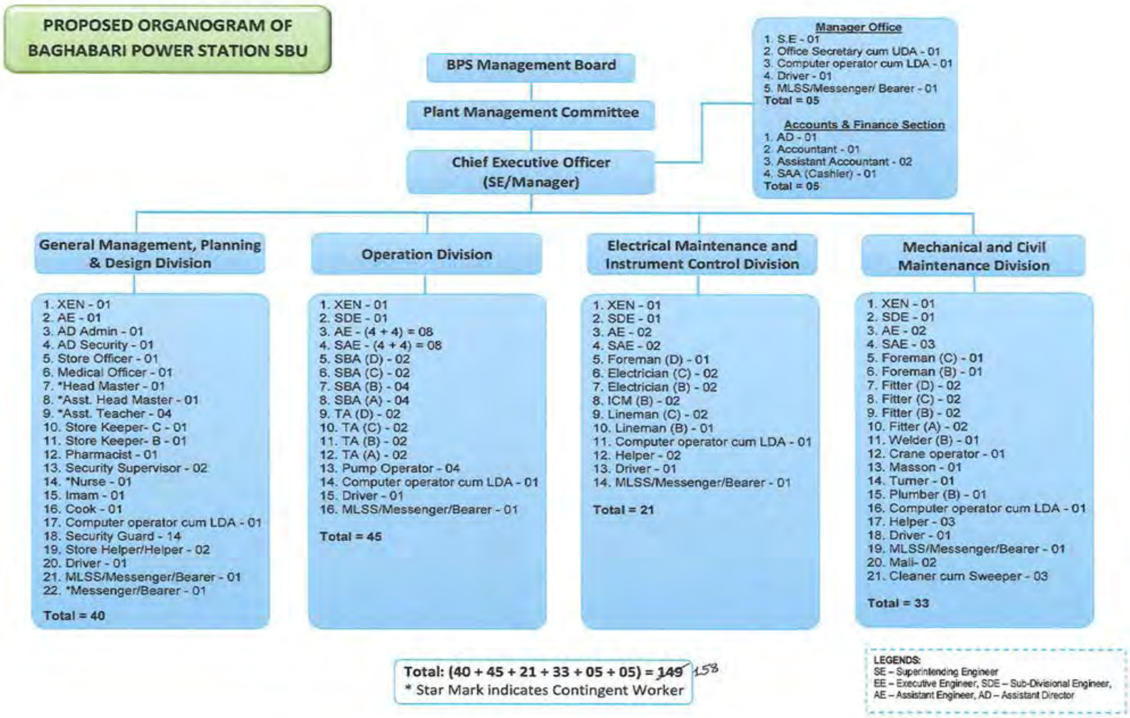
Maintenance plan	4 section managers make, -> plant manager approves, BPDB approves finally
Maintenance plan basic idea	Make every year
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Unidentified
Manufacture support for daily	None *No contract, no support *basically, there is no contract
Daily maintenance	Maintenance staff + workshop
Major inspection	Main: Maintenance staff, Some portion: manufacture
Safety for equipment	Firefighting system
Safety for staff	BPDB guideline
Efficiency management	Calculated by efficiency division every day *Monthly average report to head office *No performance test
Fuel analysis	No analysis
Environmental regulation	Unidentified
Organization for operation	Engineers: 5 groups/3 shifts Technicians: 4groups/3 shifts 5 officers, 25 staff /2 units Total of 20 officers and 100 staff for 4 control rooms; Units 1 & 2, units 3 & 4, units 5 & 6 and network
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *Overhaul need for 25 year old plant *DCS and exciter have to be replaced
Capacity limitation	Yes
Future plan	Unit 5 will have overhaul from Feb 2016 Units 3 & 6 have a repowering plan with duck burner in flue gas duck Unit 7 is under construction (target 365MW)
Peculiar information	None
Staff issues	No problem
Training system	OJT They have training center *the contents are mainly lectures *every member of staff attends a 60 hour lecture per year
Uneasiness concerning natural gas supply	No

Source: JICA Survey Team

(7) Baghabari thermal power station (main fuel: natural gas)

Basic information	:	COD unit 1: 1991, unit 2: 2001
Capacity (COD)	:	71MW (Flame 7B), 100MW (Flame 9E)
Capacity (Now)	:	71MW, 100MW

Organization chart:



Source: Baghabari thermal power station

Figure 18-11 Baghabari Organization Chart

Table 18-7 Baghabari Thermal Power Station

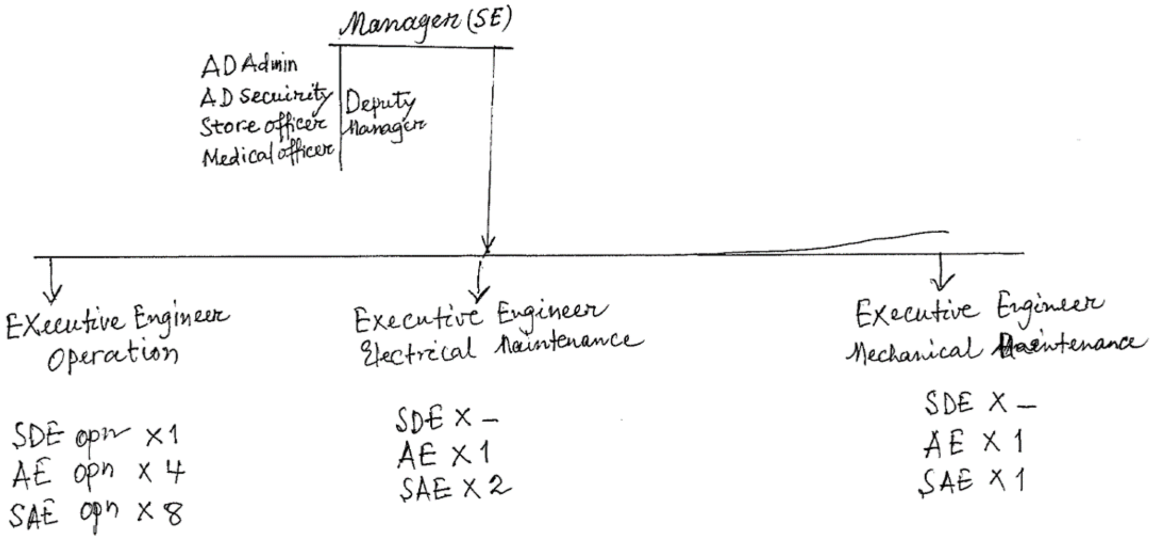
Maintenance plan	Engineer + Plant manager ＞ BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	*Approve -> purchase order -> shutdown permission; this flow takes a long time *BPDB does not allow LTSA contracts. Before periodic maintenance, they have to buy every needed spare part and consumable part. It also takes a long time
Manufacture support for daily	None *need contract with manufacture
Daily maintenance	Maintenance staff
Major inspection	CI: maintenance staff HGPI, MI: GE
Safety for equipment	Firefighting system
Safety for staff	They have BPDB guideline, and also helmets and gloves, but nobody cares
Efficiency management	Calculated by shift engineer every day *Monthly average report to head office *No performance test
Fuel analysis	No analysis Getting analysis data from gas company *the analysis data is similar to EPC analysis data during commissioning period
Environmental regulation	Every 2 years, they have DOE survey
Organization for operation	5 staff/shift (Shift engineer *1, service assistant *1, assistant (electric) engineer *1, turbine attendant *1, data sampling *1) 4 groups (total 20 staff)/3 shifts
Patrol for site	Unidentified
Plant condition report	Electric engineer, turbine engineer make each part of a daily log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	None
Capacity limitation	None
Future plan	Unit 2 has combined cycle power generation remodeling plan (100MW→150MW)
Peculiar information	None
Staff issues	No problems
Training system	OJT No curriculum for training BPDB training is theory lecture mainly
Uneasiness concerning natural gas supply	Unidentified

Source: JICA Survey Team

(8) Shahbazar thermal power station (main fuel: natural gas)

Basic information	:	COD 2000 (GT 2 units)
Capacity (COD)	:	35MW (Flame 6B)*2
Capacity (Now)	:	35MW*2

Organization chart:



Source: Shahijbazar thermal power station

Figure 18-12 Shahjibazar Organization Chart

Table 18-8 Shahjibazar Thermal Power Station

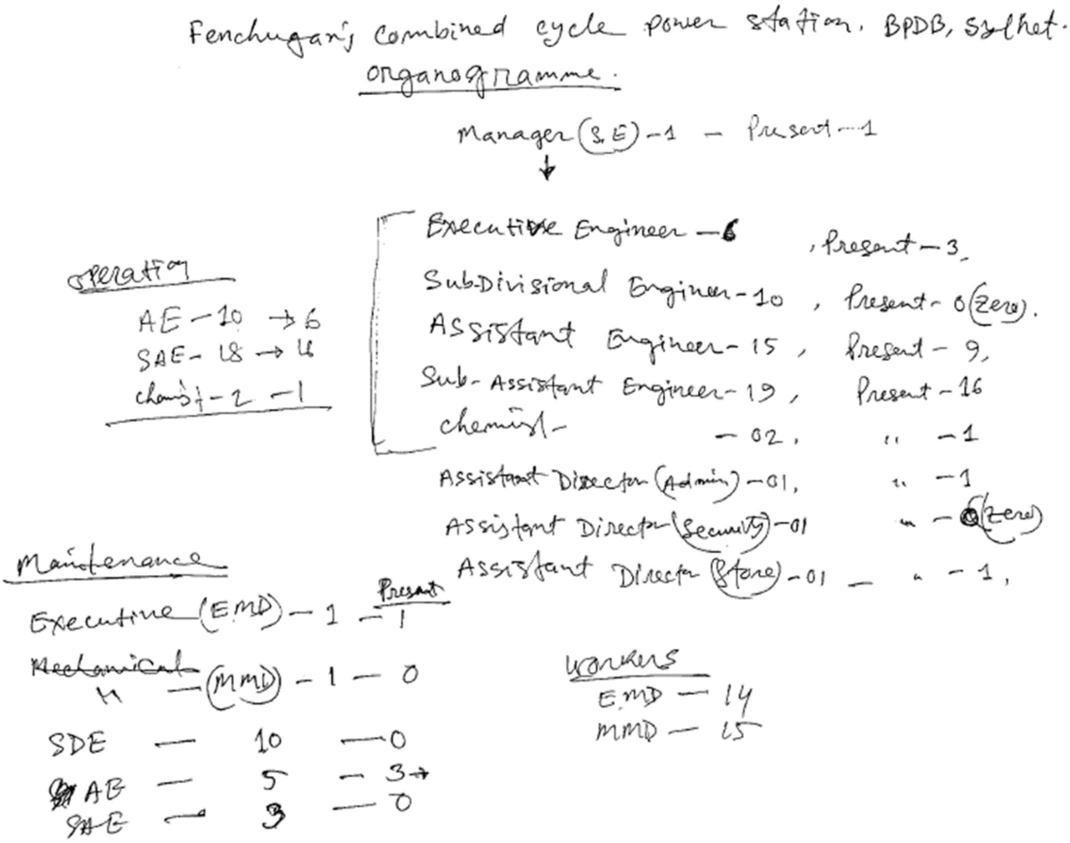
Maintenance plan	Maintenance staff, -> plant manager coordinate, finally BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Have to wait for shutdown permission from Power Div
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	CI, HGPI: Maintenance staff MI: manufacture support
Safety for equipment	Firefighting system
Safety for staff	At the time of introduction, training only *they have a concept
Efficiency management	Monthly average efficiency only *No performance test
Fuel analysis	No analysis
Environmental regulation	No regulation (no CEMS)
Organization for operation	5 staff/shift (chief *1, sub chief *1, operator *3) 4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *basic information
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Before major inspection they have to purchase all needed spare parts, so cannot proceed as scheduled
Capacity limitation	None
Future plan	70MW -> 105MW (add ST)
Peculiar information	Considering combined cycle power generation remodeling plan, because it can generate more with same amount of gas, and improve efficiency
Staff issues	None
Training system	OJT *need maintenance/operation skill improvement
Uneasiness concerning natural gas supply	Unidentified

Source: JICA Survey Team

(9) Fenchuganj thermal power station (main fuel: natural gas)

Basic information	:	COD unit 1: 1995, unit 2: 2011
Capacity (COD)	:	97MW, 104MW
Capacity (Now)	:	62MW, 66MW

Organization chart:



Source: Fenchuganj thermal power station

Figure 18-13 Fenchuganj Organization Chart

Table 18-9 Fenchuganj Thermal Power Station

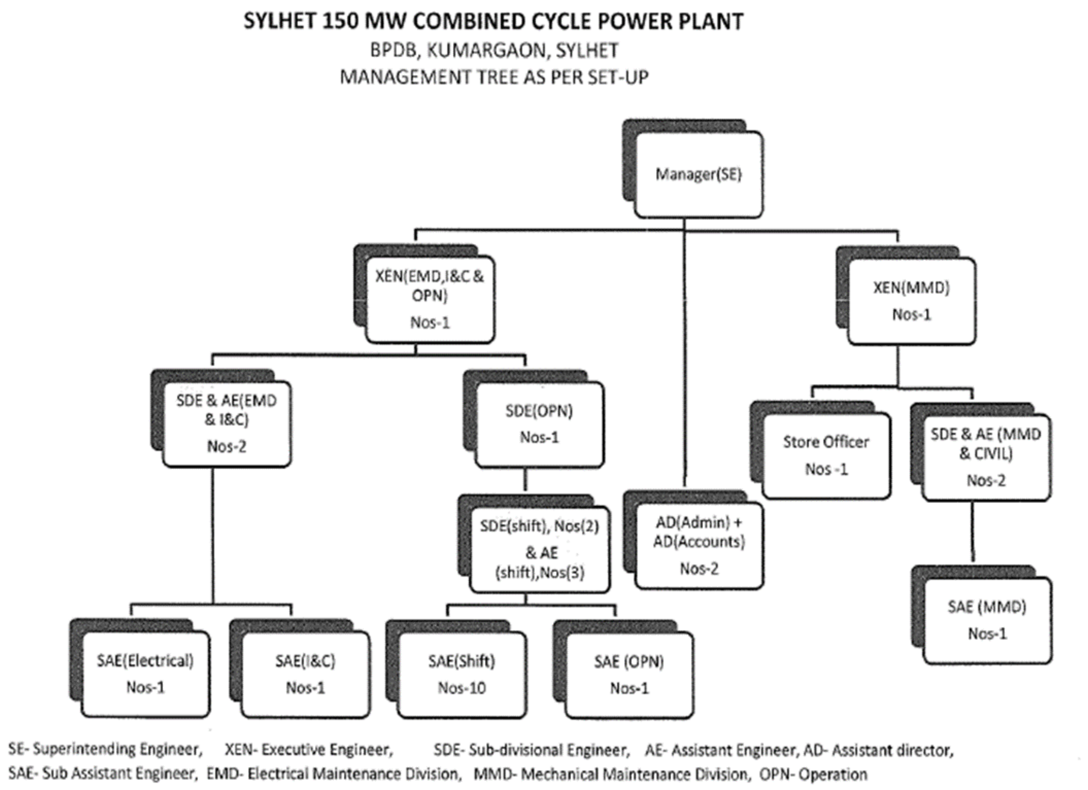
Maintenance plan	Chief engineer -> BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Waiting for shutdown permission from Power Div *BPDB approval -> parts purchase -> shutdown permission
Manufacture support for daily	None *when trouble happens, they correspond with neighboring power plant staff
Daily maintenance	Maintenance staff
Major inspection	CI, HGPI: maintenance staff MI: GE
Safety for equipment	Firefighting system
Safety for staff	Have a concept, but there is nothing actually implemented
Efficiency management	Monthly average efficiency only *No performance test
Fuel analysis	No analysis
Environmental regulation	No regulation
Organization for operation	5 staff/shift (chief *1, sub-chief *1, operator *3) 4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *hand writing is official
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *unit 1 is made by a Japan team There is no problem with the facilities, which have already passed 20 years. *unit 1 has 2 GTs, and they basically needed major inspection at 48,000 hours, but they have already passed 65,000 hours because inspection could not proceed as scheduled. Therefore, combustion temperature has to be decreased and, as a result, output also goes down. *unit 2, which is made by a China team, is only 5 years past COD, but it has a lot of trouble. *2 GTs did not change combustion; therefore, they have to decrease combustion temperature. They do not have LTSA, and they cannot change combustion periodically.
Capacity limitation	Already passed gas turbine maintenance timing. To prevent gas turbine trouble, they have to decrease combustion temperature; therefore, both units' output decreases.
Future plan	Next year, first major overhaul for unit 1 (already operated 20 years)
Peculiar information	4 gas turbines have decreased combustion temperature GT1: 22MW, GT2: 26MW, GT3&4: 22MW
Staff issues	Staff need to move every 2-3 years; therefore, difficult to keep skilled staff
Training system	OJT
Uneasiness concerning natural gas supply	No *because near the gas field

Source: JICA Survey Team

(10) Sylhet thermal power station (main fuel : natural gas)

Basic information	:	COD 2012
Capacity (COD)	:	150MW
Capacity (Now)	:	150MW

Organization chart:



Source: Sylhet thermal power station

Figure 18-14 Sylhet Organization Chart

Table 18-10 Sylhet Thermal Power Station

KPI	None
Maintenance plan	Staff -> BPDB approves
Maintenance plan basic idea	No plan *because they had a warranty period to 10 November 2014
Feasibility of maintenance plan	As scheduled during warranty period
Reason to disturb it	No
Manufacture support for daily	Yes *they have an LTSA (to 2019) and, during major inspection, Ansaldo will support them (includes 6 engineers) Expect GT, if they have contract to manufacture, they can get support
Daily maintenance	Staff + SEC (EPC) advisor
Major inspection	CI, HGPI: maintenance staff MI: not decided yet (because just finished warranty period)
Safety for equipment	Firefighting system
Safety for staff	They have BPDB guideline, but nobody cares *There is no penalty for not following a manual
Efficiency management	Monthly average efficiency only *no management
Fuel analysis	No analysis *using fixed value that was established in commissioning period
Environmental regulation	No regulation (no monitor) *requirement to EPC : under Nox 30ppm
Organization for operation	7 staff/shift (Shift in charge *1, shift supervisor *2, operator *4) 5 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *hand writing is official
Report for Head office	Monthly report made by operator (handwritten) Operation group makes operation log sheet
Equipment issues	Air quality is bad; need air filter replacement frequently. *3 years' experience. They know that the quality of Chinese products is bad, but Japanese products are expensive. It is difficult for them to buy Japanese products
Capacity limitation	None
Future plan	They have combined cycle power generation remodeling plan (150→225MW) *Now at final stage of this plan.
Peculiar information	Base load plant *during rainy season, they need to keep about 70MW; easy to control system frequency
Staff issues	None
Training system	OJT *BPDB has a training center, and every member of staff attends a 60 hour lecture per year. *the contents are mainly lectures, with no real machines.
Uneasiness concerning natural gas supply	None

Source: JICA Survey Team

18.3.2 Summary of actual O&M situation

To summarize the information on the power stations which the JICA survey team visited, mentioned above:

Table 18-11 Summary of BPDB Thermal Power Stations

Maintenance plan	According to manual and experience ➔ BPDB approval
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	
－Budget approval	Waiting for BPDB budget approval
－purchase	After approval of budget, start bidding, sign contract, then get equipment and parts
－shutdown permission	Waiting for shutdown permission from Power Div
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff and manufacture (for major equipment)
Safety for staff	Only have BPDB guideline *there is no periodic education on safety
Efficiency management	Nobody cares *only calculate average for one month *no periodic performance test
Fuel analysis	No analysis
Environmental regulation	No regulation *there is no regulation now, but DOE plans to devise this in the near future
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*Does not reach rated output *There are many problems, but information sharing, such as the cause correspondence, is limited
Staff issues	* Shortage of human resources in BPDB, and their being used in a variety of positions worsens this problem
Training system	*OJT *Only theoretical lectures in training center *Need maintenance/operation skill improvement

Source: JICA Survey Team

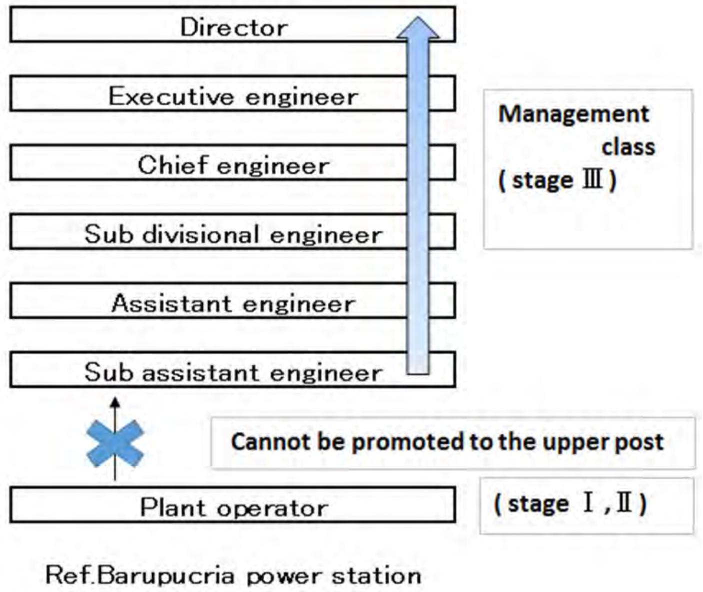
The JICA study team has divided the things it gathered in the list mentioned above into “staff”, “facilities, repair plan”, “budget” and “information” and organized the information.

18.3.3 Staff

(1) Curriculum and organization in a power station in Bangladesh

Curriculum in Bangladesh as follows:
Stage Ⅰ: from kindergarten to standard Ⅹ
(SSC: Standard Secondary Certificate: graduate high school level in Japan)
Stage Ⅱ: ⅩⅠ～ⅩⅡ (HSC: Higher Secondary Certificate; graduate professional school level)
Stage Ⅲ: Admission for undergraduate

Organization of thermal power station as follows:



Source: JICA Survey Team

Figure 18-15 Education and Organization

The upper figure is an example from Barapukuria, but all power stations are thought to be similar. Depending on education before the entering a company, some people cannot attain the engineer post.

(2) Lack of education, shortage of staff

BPDB has 6 training centers, but these are basically only for lecture training. The contents of the training centers' lectures are theory and the experience of seniors. And there is no training with actual equipment. The place that people can experience real duties is the power station only. Only a few power stations have training centers and are educating staff; the others cannot educate their staff with training facilities.
In addition, staff at the power station is conclusively lacking for the personnel required. It was supposedly the case that one held an additional post of three posts depending on the power station. In addition, some staff whom they trained transfer to other BPDB power stations.

(3) Safety for staff

They have the BPDB guideline, but nobody cares. One of reasons is that there is no penalty for not following a manual, and then there is the cultural side. In addition, consciousness of safety is very low, probably because the power station shutdown period will not be very long.

18.3.4 Facilities, repair plan

(1) Periodical maintenance and feasibility of parts replacement

Because maintenance cannot proceed following the plan, many power stations worry about their facility. Gas turbine equipment is a particular problem, because hot gas path parts need periodic replacement, but this cannot be done; thus, they have to decrease the firing temperature to protect the equipment and this causes power output decrease. One of reasons is that they do not have an LTSA agreement with the manufacturer and there is a delay in budget approval.

(2) Shutdown permission

Because of the delay in getting shutdown permission from Power Div (sometimes, it takes 2-3 years), it also causes delays in periodic maintenance.

(3) Does not reach rated output

Some power stations have to operate with malfunctions.

(4) Efficiency

Do not care about power plant efficiency. Consciousness of maintaining efficiency and efficiency improvement is not felt. Therefore, they do not care about fuel gas analysis. But everyone wants to introduce the newest high efficiency power plant.

(5) Manufacturer support

Without a contract, manufacturers do not support them or submit related information.
If a malfunction happens, every power station performs trouble correspondence with neighboring power station staff.

18.3.5 Budget

(1) It takes a long time for budget approval, so power plant maintenance cannot proceed.
(2) BPDB does not allow LTSA with manufacturers.

18.3.6 Information

(1) Trouble addressing depends on own experience.
(2) Without a contract, manufacturers do not submit related information.
(3) Do not have other power stations' information except via direct contact.

18.3.7 Summary

The summary of the above survey results are shown in the table below.

Table 18-12 Summary

Staff	*Lack of education and only theoretical lecture curriculum *Low safety awareness *Discrimination towards the post due to education before entering a company
Facilities, repair plan	*Does not reach rated output *Cannot proceed with periodic maintenance as scheduled *Delay in shutdown permission *No manufacturer support *Do not care about power plant efficiency
Budget	*Delay in budget approval *No permission for LTSA
Information	*Trouble addressing depends on own experience *There is no information submitted *There is no positive information sharing among power stations

Source: JICA Survey Team

18.4 Problems

The details of the problems found in the survey results are explained in the following subsections.

18.4.1 Staff

The existing training center only has a lecture curriculum, and there is no training using concrete facilities. The staff has to do On the Job Training (OJT). Therefore, staff only get knowledge through the OJT. Thus, there is no place where they can learn what they must not do, and also no chance to learn what they cannot do on the site. In other words, there is no place to experience what happens when they go too far. And some power stations have a training center, but there are shortages of information for education and organization. In conclusion, there is no effective curriculum or facility. So, the construction of a facility that possesses concrete facilities and an education curriculum is needed. This facility should not only be for BPDB power station staff, but also loaned out for a fee to other companies. This would improve the Bangladesh power sector's O&M skills.
The details of the training facility are explained in 18.6 Training Center.

18.4.2 Facilities, repair plan

Almost all power stations mentioned the delay in maintenance work. Through the site visits, the JICA survey team found that during the process of making the maintenance plan to implementing it, there were 2 key points: one of them is BPDB budget approval, and the other one is shutdown permission from Power Div.

(1) Approval of maintenance plan and budget

BPDB has to check all of the plants' maintenance plans and budget. But every power plant submits its plan and budget one by one. It is thought that it is hard to make an objective, rough estimate of the necessary expense for BPDB as a whole beforehand. As a result, after ascertaining the whole plan and budget, they approve each power plant's plan, and this causes delays in approval. In conclusion, a maintenance plan for several years for all power stations is not gathered in objective form and this is an issue.

(2) Shutdown permission

It seems that Power Div does not have all power plants' maintenance plans; therefore, there are few judgment grounds to shut down a power station in a particular time. It is necessary to coordinate with individual power stations and to judge accordingly and, as a result, judgment for the shutdown permission is late.
The above 2 items cause time delays.

(3) Does not reach rated output

There are several kinds of reasons, like lack of power supply, inability to shut down and repair, lack of information for repair work, inability to get manufacturer support and the long time taken to purchase needed parts and, because of these reasons, many power units cannot reach rated output.

(4) LTSA

Regarding gas turbine plants, many power stations are not allowed to make LTSA contracts with manufacturers. The purposes of LTSAs are as follows: on-time parts supply, emergency correspondence, and measures for technical issues. However, because these power stations do not have LTSAs, they depend on past experience to deal with malfunctions. Combustion also needs replacing every 1-2 years, but because combustion needs budget approval and shutdown permission they have to wait, they cannot replace things on time, and then they have to operate at a decreased output.

(5) Efficiency

They do not care about power plant efficiency. In the near future, Bangladesh needs to import LNG from overseas. This means that fuel prices are getting high, and generation costs are getting high. The Bangladesh government plans to introduce high efficiency thermal power units, improve average thermal efficiency, and reduce fuel costs. Japan also does the same, so it is a good idea, but there are some problems. For example, they do not analyze every day and every hour efficiency, and do not carry out performance tests just after maintenance work is done. These items are needed to ascertain the change in situation after the maintenance operation period. In Japan, because almost all fuel has to be imported, fuel cost reduction is a very important issue in every sector; thus, each sector has its own targets and takes measures. Bangladesh also needs targets and to take measures.
Bangladesh faces the following problems.

Severe condition of power supply:
-> Power plant cannot shut down but has to operate
  -> Power plant stops suddenly
    -> Power supply decreases
      -> Other power plants have to operate

Due to this, it is in a "negative spiral".

18.4.3 Budget

Budget and plan approval takes a long time as mentioned above, and this issue is caused by information not being gathered in an "objective" manner. Therefore, BPDB approves each power station's maintenance plan and budget only after fixing all of the plant maintenance plans.
The issue of LTSAs also exists. Because an LTSA includes a technical issue treatment fee, it is more expensive than only purchasing needed parts, but it includes a "certain supply of periodic replacement

parts" and "needed parts will be supplied when emergency trouble happens". Considering the actual situation, LTSA is a useful and efficient countermeasure for stable operation.

18.4.4 Information

Actual conditions depend on past experience and measures taken for malfunctions. They cannot get manufacturer support and there is no positive information sharing among power stations. It also means that power station staff's technical levels stop at some point, because they cannot get any more information. If they can share trouble-related information, they can learn suitable countermeasures and prevent the trouble from happening again. To achieve this, they need an information sharing strategy.

18.4.5 Problem Analysis

Almost all power stations mentioned the delay in maintenance work, which is mainly caused by a delay in BPDB approval of maintenance plan/budget, and a delay in shutdown permission from Power Div. BPDB has to check all of the plants' maintenance plans and budget. But every power plant submits its plan and budget one by one. It is thought that it is hard to make an objective, rough estimate of the necessary expense for BPDB as a whole beforehand. It is also found that Power Div. does not have all power plants' maintenance plans; therefore, there are few judgment grounds to shut down a power station in a particular time. It is necessary to coordinate with individual power stations and to judge accordingly and, as a result, judgment for the shutdown permission is delayed. The survey results include some more problems such as the run-to-failure policy, the absence of manufacturer's support, and the procurement delay of spare parts.

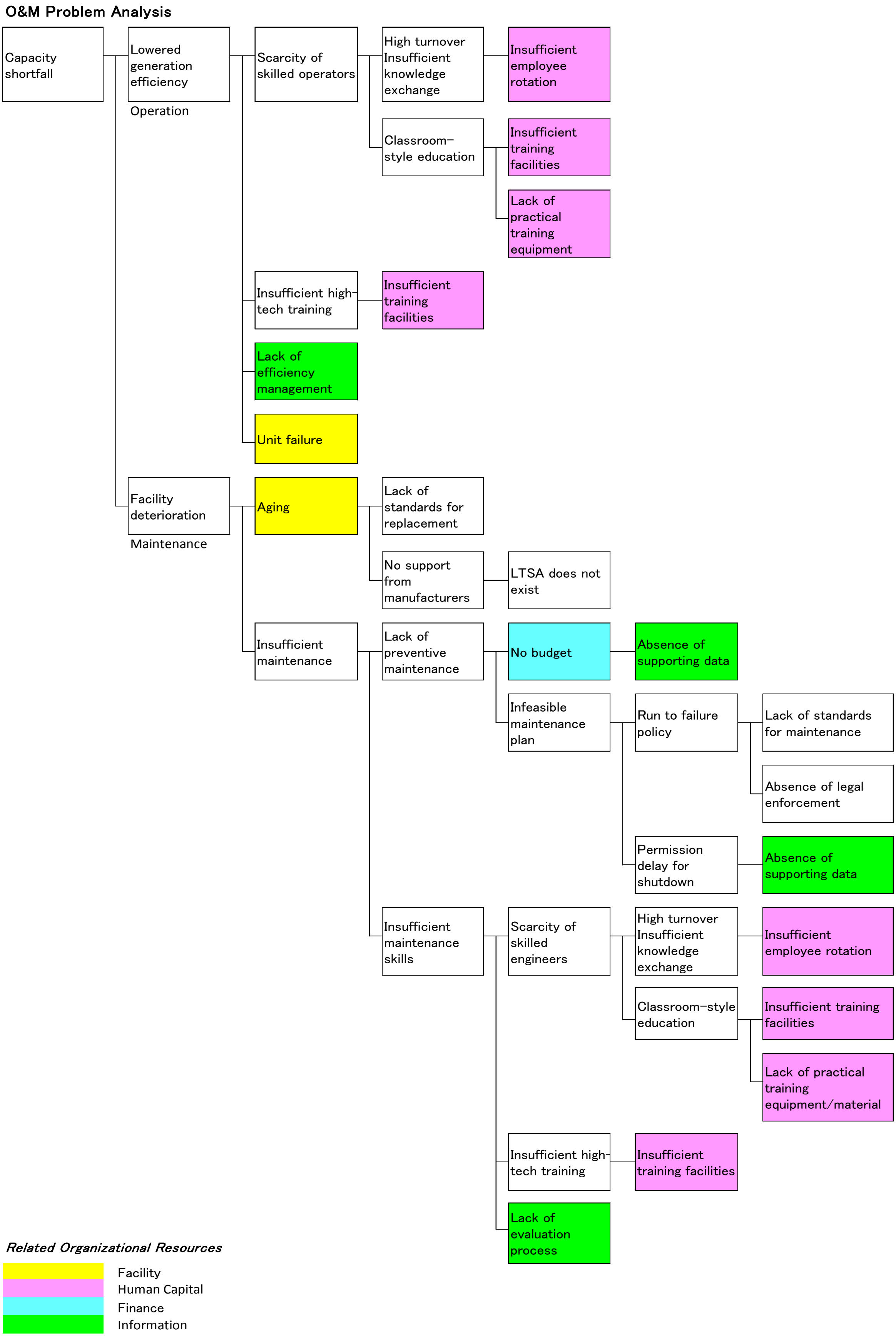
The problems are categorized into Human Capital, Facility, Finance, and, Information which are commonly referred to as organizational resources in management of an enterprise. As shown in the table below, the problems exist across the organizational resources.

Table 18-13 Summary

Human Capital	- Classroom-style education, no opportunities to lean dos and don'ts - Low awareness of safety
Facility	- Capacity shortfall - Infeasible maintenance plans - Permission delay for shutdown - Low awareness of efficiency
Finance	- Budget approval delay - No LTSA policy
Information	- No support from manufacturers - Lack of knowledge sharing among power plants

Source: JICA Survey Team

The figure below shows the problems and the causes in an analytical way based on the problem tree analysis technique.



Source: JICA Survey Team

Figure 18-16 Problem Tree Analysis

Table 18-14 Problems in Organizational Resources

Core Missions and Areas	Human Capital	Facility	Finance	Information
Generation Capacity	—	Unit failure. Aging.	—	—
Daily Operation	Insufficient employee rotation. Lack of practical training equipment. Insufficient training facilities.	—	—	Lack of efficiency management.
Maintenance & Repairs	Insufficient employee rotation. Lack of practical training equipment and material. Insufficient training facilities.	—	No budget.	—
Maintenance Planning and Budget Creation	—	—	No budget.	Absence of supporting data for maintenance plan and shutdown permission. Lack of evaluation process.

Source: JICA Survey Team

Some of the problems remain untouched in the tree, which are:

- Lack of standards for replacement
- LTSA does not exist
- Lack of standards for maintenance
- Absence of legal enforcement

These are firmly connected with the legal framework which should be enacted by the government. The problems exist out of the target organizations or the scope of operations and maintenance of power facilities. The details of the legal framework are explained in the previous section. However, regular maintenance can be applied before the legal basis is established.

In the next subsection, solutions to the problems are shown along with implementation proposals.

18.5 Solutions

18.5.1 Outline of solution proposals

As a facility enhancement solution for the capacity problem, this Study proposes rehabilitation and conversion to combined cycle. It also proposes the following plans to facilitate regular maintenance which requires information management and plant crew trainings.

Table 18-15 Solution Proposals

Core Missions and Areas	Human Capital	Facility	Finance	Information
Generation Capacity	—	Steam turbine rehabilitation & conversion to combined cycle. Scheduled maintenance.	—	—
Daily Operation	Training center equipped with simulators and hi-tech training materials. Work rotation.	—	—	Collection of unit data and fuel data, and efficiency monitoring.
Maintenance & Repairs	Training center equipped with real machines and hi-tech training materials. Work rotation.	—	Mid-to long-term maintenance budget.	—
Maintenance Planning and Budget Creation	—	—	Procurement based on maintenance plan. Financial efficiency monitoring and cost optimization	Database for budgeting, shutdown planning, investment decision making and evaluation.

Source: JICA Survey Team

The team proposes the following feasible plans to implement the solutions above, which are considered to be effective in facility enhancement, human capital development, and, strategic use of plant information for maintenance planning and budget creation.

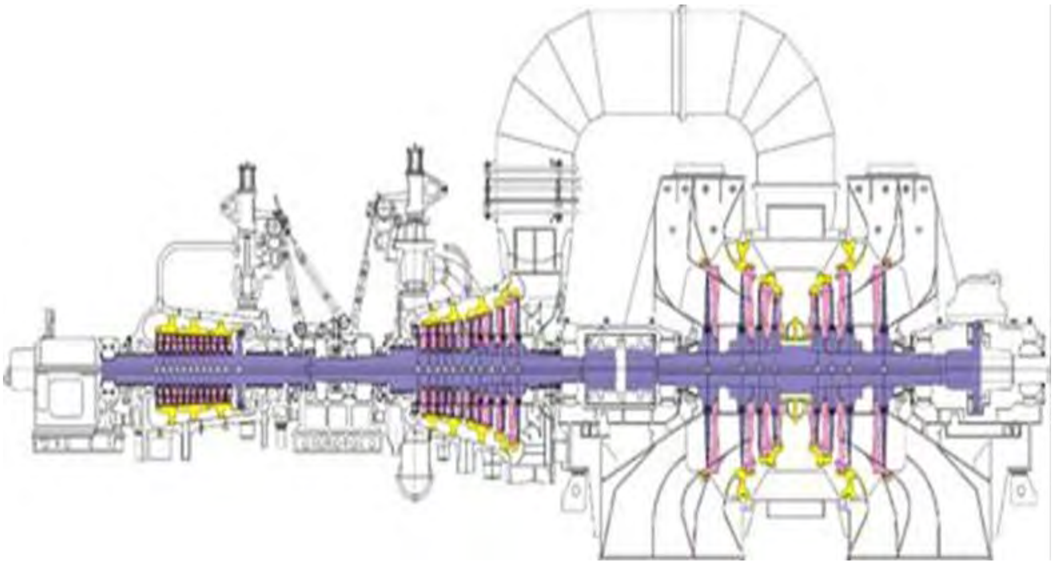
(1) Facility enhancement

Here, the JICA survey team suggests measures for the issues of “Does not reach rated output” and “efficiency improvement”. For recovering output or efficiency, the rehabilitation of facilities or combined cycle power generation remodeling are effective. Firstly, we introduce Japanese technology.

(a) Steam turbine rehabilitation

There are many steam turbine products made by the turbine manufacture, LMZ, in the former Soviet

Union, in Bangladesh. These LMZ steam turbines are already aged, and the original design efficiency is lower than that currently. In the LMZ series, Japanese manufacturers have rehabilitation experience of LMZ210 that was designed in the 1960s. The content of rehabilitation is mainly using the newest design blade. They have rehabilitation experience in Bulgaria, in 2010 and 2011, and finished the work successfully. Each steam turbine improved its output about 10-15MW. Therefore, rehabilitation is suitable for LMZ210MW and is a good selection.



Source: JICA Survey Team

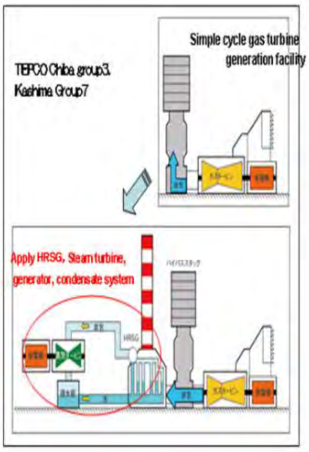
Figure 18-17 Steam Turbine Rehabilitation

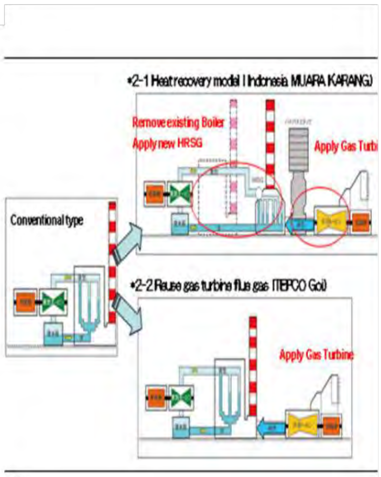
Detailed study is mentioned in 18.6 Rehabilitation.

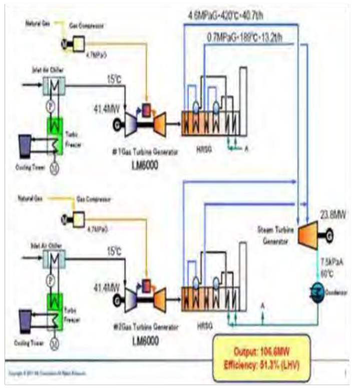
(b) Combined cycle power generation remodeling plan

For high efficiency and output reinforcement of the existing power stations, remodeling to combined cycle is one of the ideas. For combined cycle remodeling, there are two types of combined cycle applicable (CASE 1 and CASE 2) and the scrap & build model (CASE 3). CASE 1 is “Adoption of the bottoming system model” (HRSG, Steam turbine, generator and condensate system), and CASE 2 is “Adoption of Gas turbine model”. A bottoming system model has been adopted at TEPCO’s “Chiba thermal power station group No.3” and “Kashima thermal power station group No.7”. As for “Adoption of gas turbine model”, there are two types of model. One of them is the Heat recovery model (*2-1) which entails removing the existing boiler and installing a gas turbine and HRSG. The other one is the exhaust reuse model (*2-2) which entails installing a gas turbine, and the existing boiler reuses the exhaust gas of the gas turbine. The former (*2-1) has been adopted at “MUARA KARANG Power plant” in Indonesia, and the latter (*2-2) has been adopted at TEPCO’s “Goi thermal power station unit No.6”.

CASE 1	CASE 2	CASE 3
adoption of bottoming system model	adoption of gas turbine model	Scrap and build model







Source: JICA Survey Team

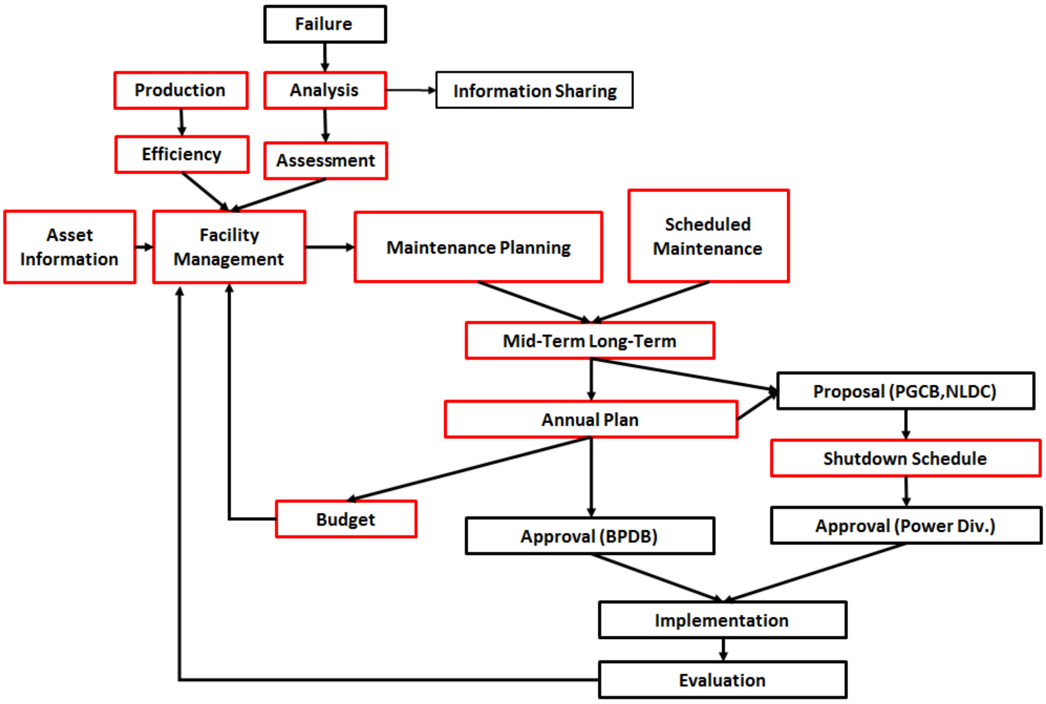
Figure 18-18 Combined Cycle Power Generation Remodeling Plan

Detailed study is mentioned in 18.7 Combined cycle power generation remodeling plan.

(2) Strategic use of plant information

For power station administration, information becomes important over all of the maintenance plan, budgets and techniques for facilities. Through the site survey, lack of information sharing and poor management causes many problems in various places. The generation company must understand the importance of information management and use this knowledge throughout its operations. To achieve this, they must utilize the visualization of data, timely data collection and data sharing, and it is necessary to promote the PDCA cycle of the business. To promote information utilization, they can manage things like a periodic inspection schedule and the budget for shutdown timing for each power plant, and can prevent blackouts and power supply over/under. This will also allow effective management for the power plants.

The following figure shows a sample from Japan. The red boxes show an example of effectively utilizing information.



Source: JICA Survey Team

Figure 18-19 O&M Best Practice Supported by Information Sharing System

In addition, Japanese utilities adjust the gap between supply and demand by coordinating it with the power grid control system section when making the maintenance plan. The following figure shows the flow of maintenance plan - supply-demand gap ascertainment before the adjustment.

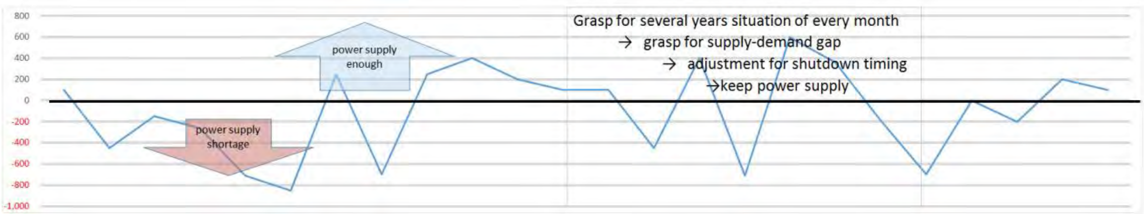
Maintenance plan for several years

maintenance plan	Year1												Year2											
Plant	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Plant A ; 450MW	○	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○
Plant B ; 660MW	○	○	○	-SD-	-SD-	-SD-	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○
Plant C ; 350MW	○	○	○	○	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○
Plant D ; 200MW	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○
Plant E ; 100MW	○	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○
Plant F ; 600MW	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○	○	○	○	-SD-	-SD-	-SD-	○	○
Plant G ; 550MW	○	○	○	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	-SD-	○	○	○	○
Plant H ; 550MW	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○	○	○
Plant I ; 400MW	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○	○	○	○	-SD-	-SD-	○	○	○	○	○

Compare with demand forecast, ascertain supply-demand gap

power supply ability	Year1												Year2											
Plant	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Plant A ; 450MW	450	450	450	450	0	0	450	450	450	450	450	450	450	450	450	0	450	450	450	450	450	450	450	450
Plant B ; 660MW	660	660	660	0	0	0	660	660	660	660	660	660	660	660	660	0	660	660	660	660	660	660	660	660
Plant C ; 350MW	350	350	350	350	350	350	350	0	0	350	350	350	350	350	350	350	350	350	350	0	350	350	350	350
Plant D ; 200MW	200	200	200	0	0	200	200	200	200	200	200	200	200	200	200	0	200	200	200	200	200	200	200	200
Plant E ; 100MW	100	100	100	100	0	0	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	100
Plant F ; 600MW	600	600	600	600	600	600	600	0	600	600	600	600	600	600	600	600	600	600	600	0	0	0	600	600
Plant G ; 550MW	550	550	550	550	550	550	0	0	550	550	550	550	550	550	550	550	550	550	0	0	550	550	550	550
Plant H ; 550MW	550	0	0	550	550	550	550	550	550	550	550	550	550	0	550	550	550	550	550	550	550	550	550	550
Plant I ; 400MW	440	440	440	440	440	0	440	440	440	440	440	440	440	440	440	440	440	0	0	440	440	440	440	440
total of supply	3,900	3,350	3,350	3,040	2,490	2,250	3,350	2,400	3,550	3,900	3,900	3,900	3,900	3,350	3,900	2,590	3,800	3,460	2,910	2,400	3,300	3,300	3,900	3,900
demand forecast	3,800	3,800	3,500	3,300	3,200	3,100	3,100	3,100	3,300	3,500	3,700	3,800	3,800	3,800	3,500	3,300	3,200	3,100	3,100	3,100	3,300	3,500	3,700	3,800
Supply-demand(MW)	***100***	***-450***	***-150***	***-260***	***-710***	***-850***	***250***	***-700***	***250***	***400***	***200***	***100***	***100***	***-450***	***400***	***-710***	***600***	***360***	***-190***	***-700***	***0***	***-200***	***200***	***100***

Making graph



Source: JICA Survey Team

Figure 18-20 Illustration

Before the adjustment of the maintenance plan, making a graph like that shown above and reviewing the maintenance plan is needed to proceed with periodic maintenance. Of course, it also needs to be shared with PGC. To forecast several years into the future, the budget plan needs to be connected to the maintenance plan.

The significance of information management is explained in 18.8 Information Strategy.

(3) Human capital development

The human capital development proposal includes a new training facility with a practical training system (Training Center). The Training Center is purported to provide trainees with:

- ➢ High-tech education for new power facilities.
- ➢ Practical training courses and opportunities to experience real operations and maintenance practices.
- ➢ Education for certifications in compliance with laws and regulations.

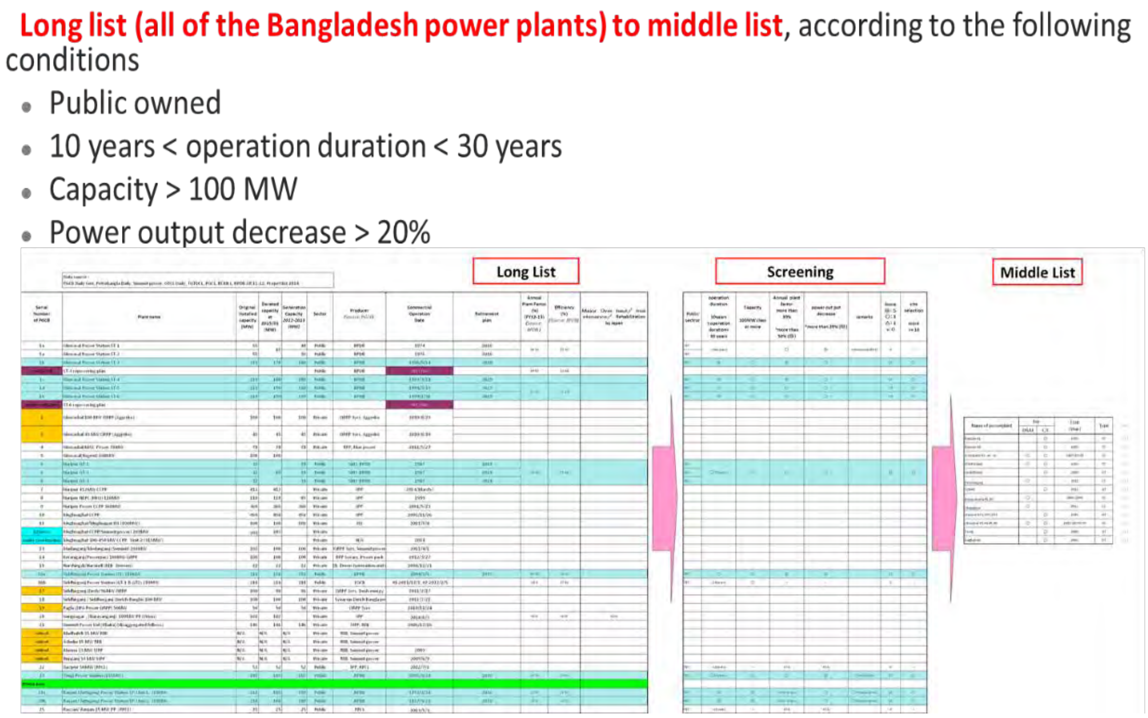
In order to meet the training demand, the study mentions about inviting trainees to Japan during the construction of the training facility.

The details of the proposal for human capital development are explained in 18.9 Training center.

18.6 Rehabilitation

18.6.1 Rehabilitation considerations

According to 18.2.1 (1) O&M target site selection, target sites were selected. The following is an illustration of the selection.



Source: JICA Survey Team

Figure 18-21 Long-Mid List Selection Illustration

Middle List (21 plants of 12 sites) to short list, according to the following conditions

- Land space
- Grid capacity
- Gas supply

Middle List

Name of powerplant	For O&M	For C/C	COD (Year)	Type	Fuel	Installed (MW)	Derated (MW)	Plant factor (%)	Efficiency (NET) (%)	Working group	Donor	visited	visit plan
Rauzan #1		○	1993	ST	Gas	210	200	21.55	31.26	×		2014/11/29	-
Rauzan #2		○	1997	ST	Gas	210	180	15.80	32.53	×			
Ashuganji #3, #4, #5	○	○	1987/87/88	ST	Gas	450	390	97.64	36.16			2014/11/30	-
Siddhirganj	○	○	2004	ST	Gas	210	150	56.98	32.63			2014/12/3	-
Barapukuria #1 ,#2	○		2009/2009	ST	Coal	250(125*2)	200	75.37	31.47				2015/3/8-3/9
Chandpur	○		2012	CC	Gas	163	163	49.68	39.38				2015/3/23
Tongi		○	2005	GT	Gas	105	105	38.38	27.07	○			2015/3/24
Ghorasal #3,#4,#5,#6	○	○	1987/89/95/99	ST	Gas	420(210*2)	360	69.53	33.68	×	○		2015/3/25
Shahjibazar		○	2000	GT	Gas	70(35*2)	66	76.36	25.63		○		2015/3/29
Fenchuganj	○		2011	CC	Gas	104	104	49.08	31.95				2015/3/30
Sylhet		○	2012	GT	Gas	150	142	51.96	29.86		○		2015/3/31
Baghabari		○	2001	GT	Gas	100	100	87.52	28.36		○		2015/4/1
Haripur GT1,GT2,GT3		○	1987	GT	Gas	32*3	60	38.09	21.26				2015/4/2

O : World Bank "A Power Sector Investment Strategy Framework for Bangladesh, July 2014"

JICA Survey Team will investigate ADB and other donor in next site survey

Short List

Select 3-4 sites for Conversion / Rehabilitation

Source: JICA Survey Team

Figure 18-22 Mid-Short List Selection Illustration

Because they are adopting the LMZ 210MW type steam turbine, Ghorasal #4 & #5 and Siddhirganj were selected as steam turbine rehabilitation candidate sites, and budget and calculation of the cost-effectiveness were estimated as follows.

18.6.2 Cost-effectiveness

Estimated cost for steam turbine replacement is about 30 million US dollars, and its output will increase about 10MW. Estimated operation years will be 30 years, but other equipment will not be replaced; therefore, we are using boiler operation years. Generally, the operation period of a boiler is 30 years; thus, the estimated operation period is 30 years - boiler operation years.

	Site name	Target unit	COD	capacity condition installed	de-rated	remarks	New	output increase	Estimated Cost	Unit price	Efficiency after	now	Manufacture support	Remaining plant life after rehabilitation (plant life time 30years)	Year cost
				A	B	C	D	D-C	Mill dollar	mill dollar / MW					Mill dollar
ST rehabilitation	Ghorasal	Unit4	1989	210	180	180	190	10MW	30	3.0	improved	37.8 (*3) / 28.8 (*2)	Toshiba	5	0.60
	Ghorasal	Unit5	1994	210	190	190	200			3.0				9	0.33
	Siddhirganj	Unit1	2004	210	110	110(gas limitation)	120			3.0		33.8 (*1)		19	0.16

Source: JICA Survey Team

Figure 18-23 Cost-effectiveness of Turbine Rehabilitation

Estimated cost to increase power output is 3 million US dollars/MW. Considering Boiler operation years, investment cost per year is as follows.

Ghorasal	unit 4	0.6 million US dollars/year
Ghorasal	unit 5	0.33 million US dollars/year
Siddhirganj		0.16 million US dollars/year

However, when the JICA survey team visited the power station, the staff mentioned that Siddhirganj's Power unit generator has a problem and it has a 150MW limitation. Unless the generator is repaired, there is no point in pursuing steam turbine rehabilitation. Therefore, it is excluded as a target.

18.6.3 Power station comments

According to the above idea, the JICA survey team got some comments from Ghorasal power station.
*Currently, unit 4 is under overhaul, and unit 5 will start overhaul from next February.
Therefore, they are not thinking of rehabilitation with huge expense.
*They need the idea that the output greatly increases, like unit 3 and unit 6
An answer on turbine rehabilitation where Japanese technology could be utilized was not provided.

18.7 Combined Cycle Power Generation Remodeling Plan

18.7.1 Combined cycle power generation remodeling examination

According to 18.2.1 (1) O&M target site selection, target sites were selected the same as for turbine rehabilitation. Based on the target power station selection, the JICA survey team carried out further target narrowing. The characteristics of each plan, CASE 1, CASE 2 and CASE 3, and narrowing method are as follows:

(1) CASE 1 Adoption of the bottoming system model

Adoption of the bottoming system model is adopting HRSG, Steam turbine, generator and condensate system in the existing gas turbine plant. Operation years of the existing gas turbine is the important point. The JICA survey team found that BPDB already has plans to upgrade gas turbines currently in operation to combined cycle power generation. If the gas turbine has already been operating for 10 years or more, maintenance and modification is needed for the gas turbine itself before combined cycle remodeling. Because of the basic philosophy of site selection, the JICA survey team selected an operation period of more than 10 years; therefore, an old gas turbine's combined remodeling plan needs gas turbine rehabilitation, and so, the adoption of a bottoming system has technical and cost difficulties.

(2) CASE 2 Adoption of gas turbine model

Adoption of the gas turbine in the existing boiler-turbine plant. Before the site visits, the JICA survey team regarded Ghorasal power station unit 3 – unit 6 and Ashuganj power station units 3, 4 and 5 as target candidates for combined remodeling. However, Ghorasal power station already has a plan for combined cycle remodeling for unit 3 and unit 6, and unit 4 and unit 5 do not have enough space to adopt gas turbines. In addition, Ashuganj power station has a scrap and build plan until 2023: they will scrap units 3, 4 and 5, then build combined cycle power generation plants in sequence. For Siddhirganj power station, although there is enough space to build, because steam turbine generation has a problem the steam turbine generation needs to be repaired first. Therefore, the JICA survey team decided to remove it as an examination candidate.

(3) CASE 3 Scrap & build (S&B) model and build & scrap (B&S) model

This case means to scrap the existing power plant first, then build a new combined cycle power generation plant. First of all, the scrap and build (S&B) plan is not suitable for Bangladesh, because scrapping the existing power generation plant first causes severe conditions for the Bangladesh power grid system.
This plan needs more than 2 years from shutdown and scrap to start of power generation. Therefore,

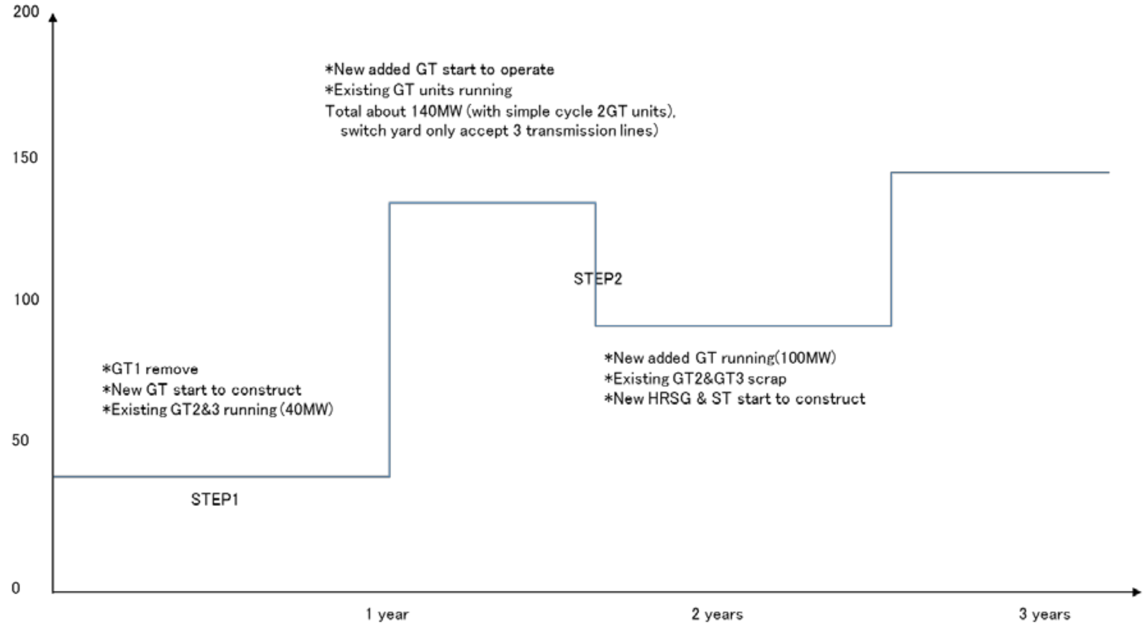
the JICA survey team proposes the build and scrap (B&S) model - that is, construct a new gas turbine and start operation first, then scrap the existing power plant and construct a new HRSG and steam turbine next. It is a very severe situation to build a new gas turbine next to an operating Power plant, and it is also risky to construct new equipment because the underground situation is not clear. However, thinking about the current situation in Bangladesh, it is an unavoidable method.

Combined cycle power generation remodeling case	Target site	Target unit	Propriety	reason
Adoption of the bottoming system model	Shahibazar	35MWGT	×	Gas turbine is too old to remodel
	Baghabari	100MWGT	×	Gas turbine is too old to remodel
	Sylhet	150MWGT	×	They have combined cycle power generation remodeling plan
Adoption of Gas turbine model	Ghorasal	unit4,5	×	No space
	Ashuganj	unit 3,4,5	×	will be retired till 2023 and they have CCGT construction plan
	Siddhirganj	unit1	×	Generator problem
Scrap & build (S&B) / build & scrap (B&S) model	Fenchuganj	unit 1,2	○	-
	Haripur	1,2,3GT	○	-

Source: JICA Survey Team

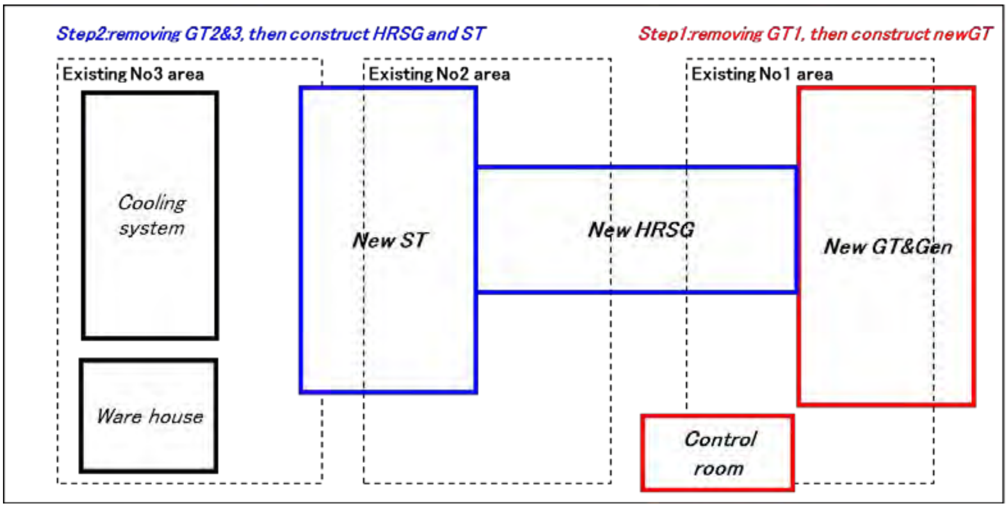
Figure 18-24 Application Judgment by Each case

Below is an illustration of the Haripur B&S construction schedule and the layout for Haripur and Fenchuganj.



Source: JICA Survey Team

Figure 18-25 B&S Schedule with Power Output

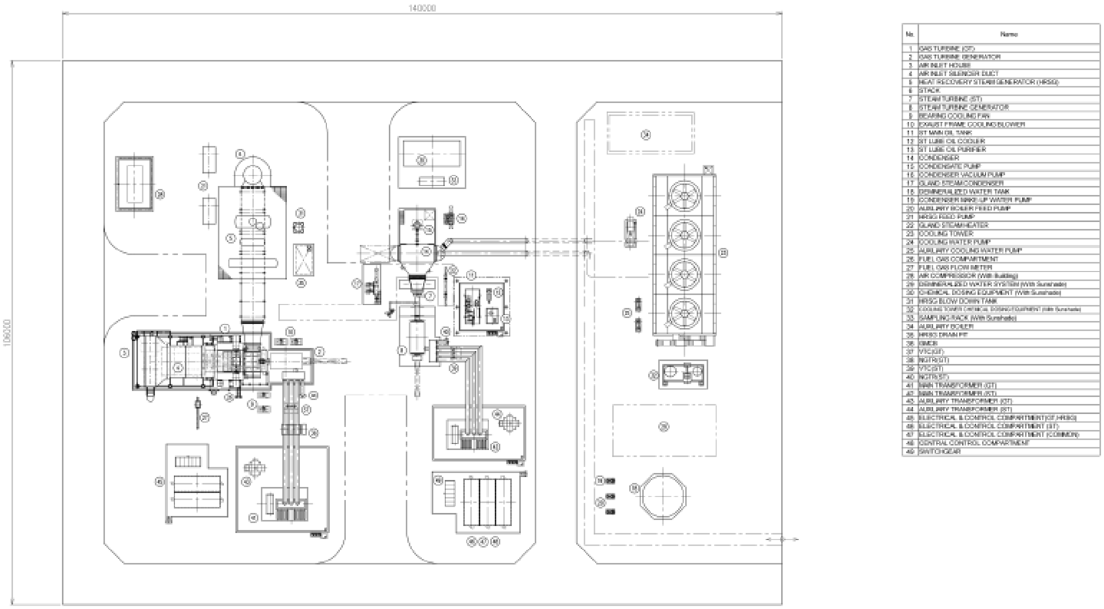


Source: JICA Survey Team

Figure 18-26 B&S Image on Old Haripur Area

Source: JICA Survey Team

Figure 18-27 Haripur Layout



Source: JICA Survey Team

Figure 18-28 150MW Combined Cycle Layout Image

18.7.2 Frequency instability problem in Bangladesh and small class gas turbine combined cycle generation plant

One of the problems that the electricity sector in Bangladesh has is that the band of the frequency is big (more than 50Hz +/-1Hz). To stabilize this frequency instability problem, it is very effective, due to the following reasons, to install the latest combined cycle plant.

Reasons:

(1) It is a very short time from long term shutdown to startup complete.
(2) High efficiency during low load operation.

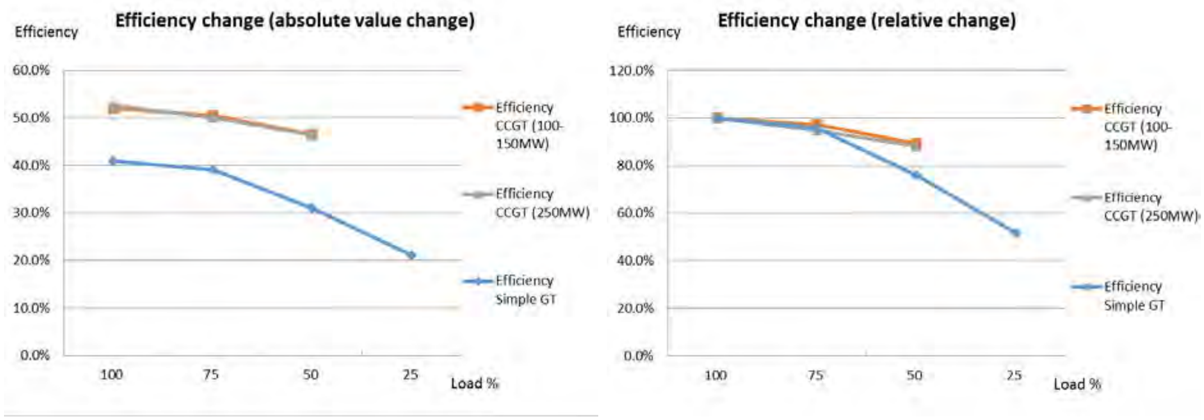
(1) First of all, concerning the startup period, it only takes 2 hours just after cold start up to full load operation, as per the following figure. This means that if you know demand peak just 2-3 hours before, you only order start up for this small combined cycle plant and the plant startup finishes just on time.

Plant capacity	Hot start	Cold start	efficiency
400MW Class CCGT	1hour	6hours	50%
250MW Class CCGT	< 1hour	4hours	50%
100-150MW Class CCGT	0.5hour	2-3hours	50%
Simple GT	0.5hour		40%(new) 30%(old)

Source: JICA Survey Team

Figure 18-29 Short Start Time Characteristics and Efficiency

(2) The following figure shows efficiency change with load % between 100-150MW, 250MW and simple cycle units. The newest combined cycle plants can maintain high efficiency compared with a simple cycle gas turbine plant and a 100-250MW unit can maintain high efficiency during load change.



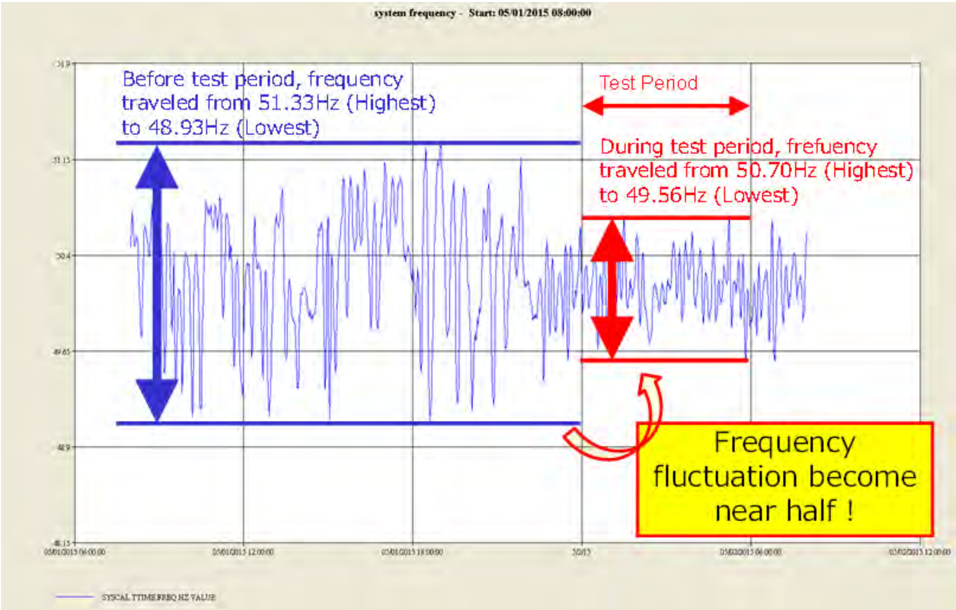
Source: JICA Survey Team

Figure 18-30 Efficiency Comparison

From this, it is very significant to install a 100MW class combined cycle power generation plant to solve frequency instability.

18.7.3 Cost-effectiveness

One of the problems that the electricity sector in Bangladesh currently has is that the frequency band is very big (more than 50Hz +/-1Hz). One of the methods to resolve this is to make a 100-250MW combined cycle unit and adjust the system frequency. We can see by the results of the test at Khulna power station, carried out on May 2nd 2016 at a 150MW capacity unit, that it is useful for adjusting the frequency fluctuation.



Source: JICA Survey Team

Figure 18-31 Frequency Fluctuation Record during Test Operation in Khulna Power Station

Although, simple cycle gas turbine can adjustment its power output, but not efficiently (please see Figure 18-30 Efficiency Comparison) .Because its efficiency is to suddenly decrease with a load drop. Therefore combined cycle is advantageous.
On the other hand, combined cycle needs a slight start-up period (a few hours) from cold start mode condition. Therefore, it is necessary to have accurate demand forecasting for several hours ahead and for the start order to be given promptly when the load control center judges it is necessary. Cold start mode is caused by around a 1 week shutdown period. As unit capacity gets larger, the steam turbine also gets larger, and if the steam turbine is large the start-up time will be long. Therefore, 150-200MW class combined cycle would be suitable for Bangladesh.
Power unit capacity and expense will be examined in the feasibility study.

18.8 Information Strategy

18.8.1 Presumptions

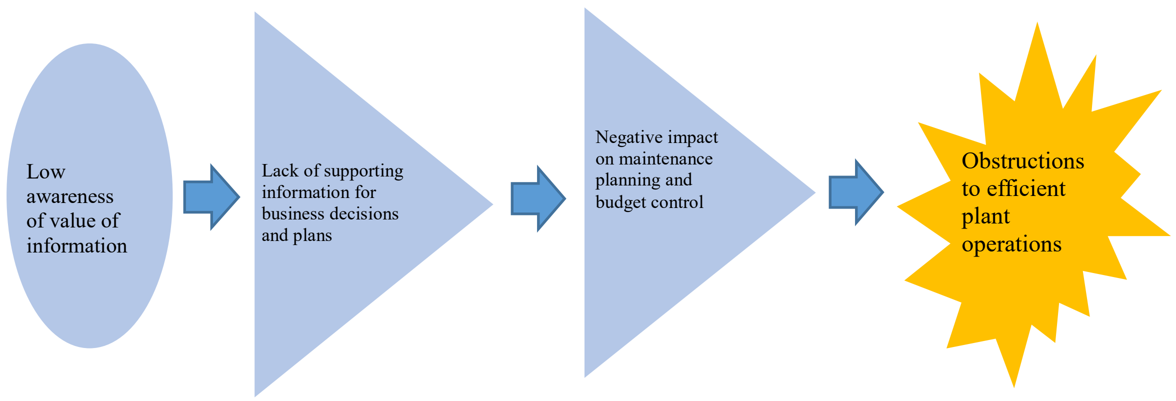
As mentioned in the previous sections, some of the problems in operation and maintenance can be solved by installing new facilities and rehabilitating ongoing facilities. This section explains that the main problems the country faces can be broken down into smaller problems, some of which are caused by lack of information. Based on the survey results, the JICA team made a hypothesis that the following descriptions of the current situation may be connected with the risk factors which cause the problems.

Table 18-16 Conventional Information Management Practices and Risk Factors

Category	Current Situation	Risk Factors	Affected Performance Factors
Acquisition of Plant Data	No data logger Manual meter reading	Human errors Time inaccuracy	Accuracy
Recording of Plant Data	Paper based	Human errors Overheads	Accuracy
Delivery of Plant Data	Verbal conversation	Miscommunication	Accuracy
Other Information Handling	Paper documentation	Document loss Data obsolescence Access/reference inconvenience	Accuracy Efficiency Responsiveness
Reporting	One month delay in monthly report writing	Slow decision making Negative Impact on maintenance planning and scheduled shutdown	Efficiency Readiness Responsiveness

Source: JICA Survey Team

According to the survey results, the descriptions of information handling show how information management is typically performed at the power plants. However, the overall impression of the results implies that there is a big problem in the mindset of the plant workers, who are satisfied with the conventional way of information handling. Lack of motivation for improvement in their work performance can be the biggest problem when the risk factors may cause negative outcomes in terms of accuracy, efficiency, responsiveness and readiness. The figure below shows how the efficiency in plant operations is affected by the low awareness of information handling.



Source: JICA Survey Team

Figure 18-32 Current Situation and Obstructive Factors

18.8.2 Information management strategy

In response to impending demand growth, the power sector of Bangladesh is trying its best to keep the facilities operating. The plant operators know that their facilities are deteriorating faster than those which are properly maintained. A problem lies in the absence of sufficient information to answer a simple question: How much faster?

The survey results are mainly based on information gathered through interviews and meetings with the sector representatives. The findings indicate that there are some challenges in information management. In particular, lack of supporting data for practicing preventive maintenance, planning and creating a feasible budget are the key problems which need to be addressed in priority.

Power generation companies nowadays are familiar with a range of activities, each of which is driven by the economic value of the significance of managing information. As measurable achievements are always expected, it is clear that continuous performance monitoring is key to successful plant operations. An integrated strategy for information management through the entire lifecycle of a power plant is required to facilitate effective data acquisition and sharing. This section explains how to implement information management in a modern power sector, and shows an overview of the conceptual model of information management for a power plant in Bangladesh.

18.8.3 Goal and objectives

(1) Goal of information management in power generation sector of Bangladesh

Our goal is to achieve the best practice for a modern power sector in the field of Operation and Maintenance by facilitating a business process cycle to run towards improvement based on measurable achievement.

(a) Set a framework for effective information management for business efficiency
(b) Enforce information management strategy throughout the organization to strengthen organizational capacity
(c) Enforce improvement cycle by monitoring and measuring results

(2) Rationale

In general, commercial entities engaging in business process improvement set a performance framework in which efficiency and productivity are continuously monitored and analyzed. The survey results indicate that effective use of operation data can be the key to successful plant management in terms of reliability and economic efficiency. It appears that, at least in some power plants, paper based document handling is replaced by computer file operations and email systems. However, all the processes are managed in isolation and the information is not shared with other business units and power plants across the organization. For example, in one of the power plants, computers are used to write monthly reports for the management team. It takes about a month to complete a report because the information sources are dispersed through various processes and their timings are different. Another example is a disruption between the planning phase and field activities. Most of the power plants answer positively to a question about the significance of scheduled maintenance while many of them keep failing to actually implement it.

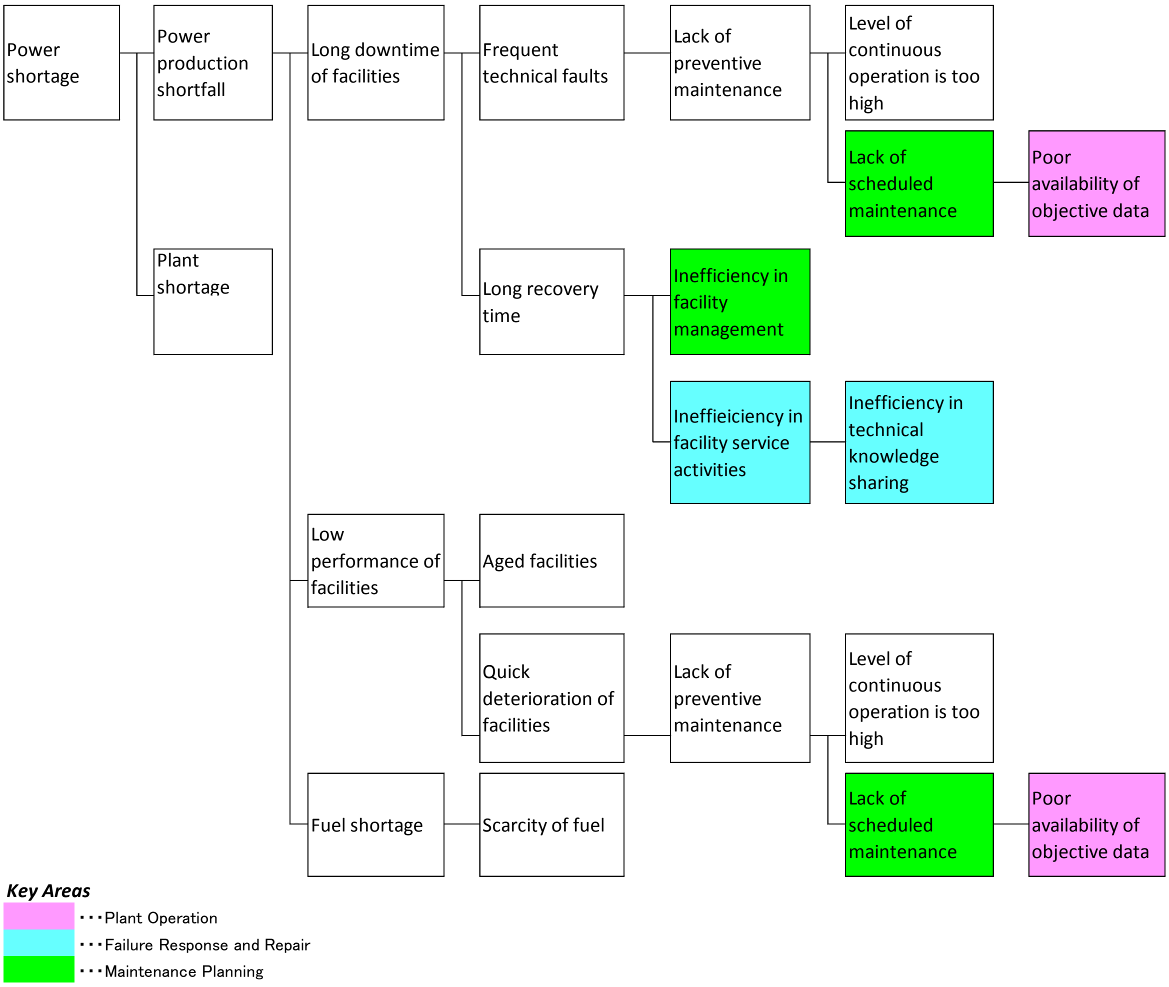
Typically, organizations have a hierarchical structure with multiple divisions, each of which is responsible for a specific activity such as plant operation, maintenance, procurement, administration or planning. Analytical use of accumulated information from daily and monthly reports enables the planning division to estimate future costs for maintenance of and repairs to the facilities which can be more accurately budgeted, while condition based maintenance enables scheduled shutdown for maintenance. Scheduled maintenance also contributes to procurement efficiency. The results of improvements should be observed as changes in various performance indicators.

As mentioned above, replacing paper documents with computer files only makes limited improvements in business efficiency. It is necessary to build a platform for information management integrated across the organization, from field activities to corporate management, from procurement to production, so that making efficient and effective use of information can be achieved.

Competitive business practices often demonstrate how they enforce the improvement cycle, a series of continual steps of Plan, Do, Check, Act. In order to achieve the goal, the business objectives must be aligned with the organizational strategy for information management. In implementation of the cycle, the Plan phase defines key performance indicators and sets baselines as measurable achievements. In the Do phase, performances are measured throughout the organization. The Check phase is for evaluation of the results. If there is any difference between the expected results and the actual results from the activities, corrective actions are taken in the Act phase. Information management strategy depicts the 'what', 'when', 'where', 'who', 'how' and most importantly 'why' of information handling through the cycle. Some of the 'whys' are answered in the problem analysis as shown below.

(3) Challenges

Based on the survey results, a problem tree analysis was performed in order to find the key problems which have caused the current situation. The main problems the country faces today are broken down into manageable factors. The key problems fall into three areas from the viewpoint of business processes: Maintenance Planning, Plant Operation, and Failure Response and Repair.



Source: JICA Survey Team

Figure 18-33 Problem Tree Analysis and Key Problems

The biggest problem the country faces today is power shortage, which is presumably caused by:

(a) The number of power plants is too small, or the total capacity of the plants is too little.
(b) The production level of each power plant is not sufficient.

The former is a factor for which we can expect solutions out of the scope of information management. The latter is caused by:

(a) The facilities are not fully operating.
(b) Performance of the facilities is low.
(c) Fuel shortage hinders power plants from achieving maximum performance capacity.

The first one is caused by long downtime. The second one is perhaps caused by aged facilities. However, some of the factors can be improved by the application of proper maintenance. The problem of fuel shortage is not within the scope of information management. However, if the fuel sources change in the future, efficiency in procurement and inventory control can be improved by implementing information management.
As for maintenance, which appears three times in the breakdown, we focus on the significance of preventive maintenance, which requires effective handling of data and documents, knowledge and planning skills. Failure response plays a large role in the downtime of a power plant. By organizing historical data which contains a lot of lessons to learn, the crew can take appropriate actions quickly.

The findings from the tree analysis are meaningful leads to envisage higher efficiency in the activity areas. For example, most of the power plants have difficulty applying preventive maintenance because facility data is not effectively collected. Although preventive maintenance needs a large amount of data for the physical state assessment of facilities, most of the power plants do not have an elaborate information platform to handle a wide variety of types of data which keeps growing.

Another example of a finding is process disruption. In failure response, looking up failure history is a common practice. However, the case records are stored in a software application in an isolated manner. Maintenance and repair activities involve various administrative tasks such as staffing, scheduling, purchasing and hiring contractors. At some power plants, it takes a long time for approval when a procurement request is filed. In this case, the obstacle between maintenance and procurement is the lack of plan and budget.

The three activity areas are actually the core processes of the power generating business and do not operate independently. Therefore, it is pointless to single out a problem from the activity areas and try to fix it. Poor information management and process disruption are the obstructive factors in many cases observed in the organization.

The table shows the obstructive factors found from the survey results. Efficiency is measured by the performance indicators commonly used by many companies. The organization perceives the performance of the processes through its key performance indicators which are, from an enterprise perspective, aligned with the organization's resources. This means that improvements in the activities' performances are measureable and quantitatively assessable.

Table 18-17 Obstructive Factors Found in the Survey

	Enterprise Resources		
	Human Asset	Facility	Finance
Obstructive Factors Found from Survey	Inefficient use of historical data Poor communication between business units	Heavy dependence on manual handling, paper based handling of data Weak interaction between engineering and administrative fields, or business units in the organization Poor management of process cycle	Weak awareness of cost due to lack of up-to-date supporting data Traditional governance on expenditure due to lack of forecast
Performance Factors Possibly Affected	Failure Responsiveness Employees skills	Performance Indicators in Power Generation (Reliability, Availability) Facility Lifecycle	Financial Indicators (ROE, ROI)

Source: JICA Survey Team

Although, from the managerial point of view, the primary objective of indicators is to have a clear view of the operational performance and set standards for the organization, it is not realistic to cover all the performance factors across the power plants. It also requires the management team to set a framework to define meaningful indicators and keep tracking them. While most of the power generation companies focus on reliability, availability, safety and efficiency, other areas such as environmental impact should be considered in compliance with government regulatory changes. In the implementation effort on information management and sharing, designing a flexible system is crucial to embrace such changes in the business environment.

(4) Conclusion

Survey results indicate that there are some problems in the three core activities of the power

generation business: plant operation, failure response, and maintenance planning. The problems are mainly caused by the absence of sufficient information and process disruption. Regardless of the level of management, activities need objective data to support improvement efforts.
The management team and the business units of the organization can achieve their improvement goals by carefully choosing meaningful performance indicators from a wide variety of types of information. Therefore, an integrated strategy for information management through the organization is necessary. This can be implemented by setting a framework for data acquisition and sharing, and interaction between business processes. Once the processes are established and the information for sharing is defined, it is very easy for the activities to make a plan, take an action, measure the efficiency and apply the results in decision making. This improvement cycle should be enforced across the organization so that the processes of the activities can work together by sharing information, which will bring higher efficiency in the overall activity of the organization. And then, the achievement will be perceived as the effective use of enterprise resources such as human assets, facilities and money.

18.8.4 Integration of information management strategy

(1) Key processes

The key problems (factors) identified and categorized in the tree analysis affect the performance of the organization as a whole. The table below shows how the problems are connected with the organizational performance from the point of view of enterprise resources. The activities in the colored cells of the table correspond to the colored boxes in the problem tree.

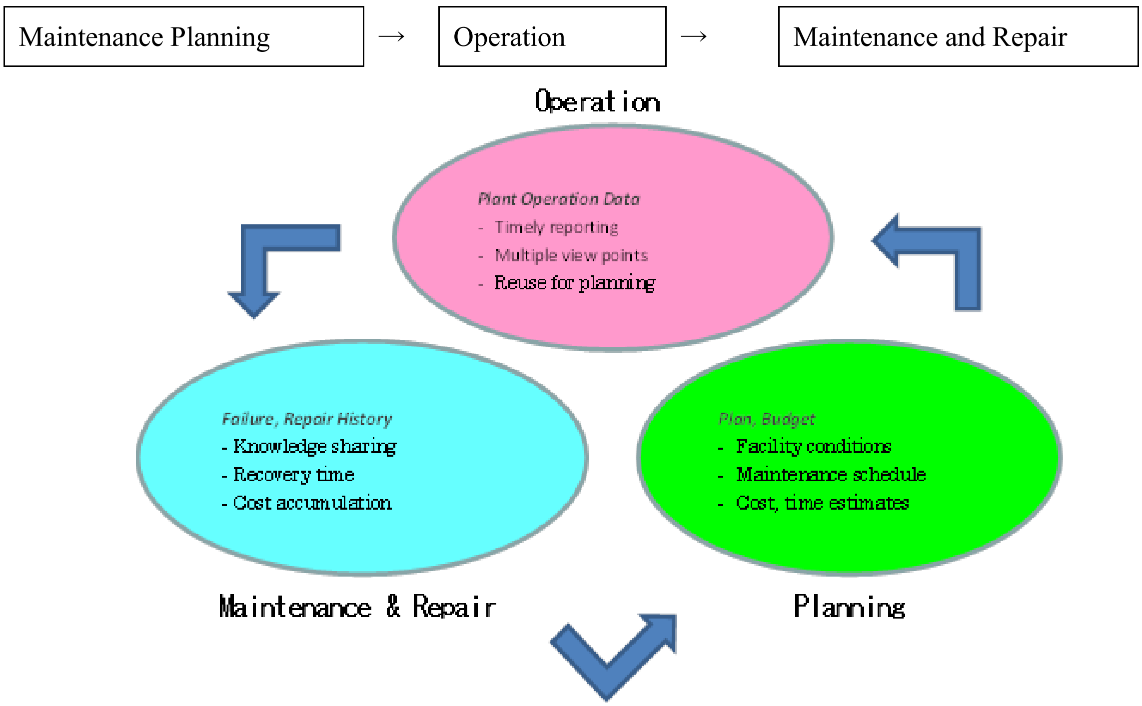
Table 18-18 Key Problems in the Three Key Activity Areas

Activity/Resource	Human Asset	Facility	Finance
Plant Operation	—	Data loggers and information networks do not exist at some power plants.	—
Maintenance Planning	There is some need for technological enhancement.	Generally, facilities often keep performing until a forced outage occurs. Spare parts' inventory control is respectively implemented at power plants.	Budgeting and procurement planning processes are complicated. Maintenance plans often fail.
Failure Response and Repair	Although failure records are available, knowledge and know-how is not available to share.	Activities are not linked with facility conditions. Activities are not linked with procurement.	Total cost of owning the failed equipment is not managed. Past repair costs are not traced.

Source: JICA Survey Team

(2) Process cycle and data

The three activity areas are the key processes (or core processes) of the power generation business, which typically has a business process cycle as below.



Source: JICA Survey Team

Figure 18-34 Business Process Cycle in the Power Generating Business

The cycle has a fixed time period and occurs at different levels of management. Its focuses are broken down into detailed parameters and shared across the power plants and other business units. The frequency of monitoring and controlling varies depending on the level of management. Monthly reporting to the head office creates a control point at plant level while daily walkthrough reports are firstly delivered to the relevant manager who has span of control in the engineering field. The most important point is that those business process cycles across the hierarchy and structure of the organization are synchronized. Our objective is to set a framework for information management integrated through the organization, so that the management team and all of the business units can achieve their performance goals, which are measured by key performance indicators regardless of the level of management or the profession.
In order for the cycle to keep moving towards improvements, selection of appropriate data (parameters) is the key. The following are the data areas corresponding to the business process and the challenges the processes have followed by improvement ideas for the data areas.

(a) Plant Operation Data

Inefficient reporting processes often hinder quick managerial analysis and decision making, which is caused by the fact that information management relies heavily on manual handling. Timely reporting and analytical re-use of plant operation data lead to the efficient management of a modern power sector.
Switching from paper based reporting to information systems, aiming for:

- Timely, accurate, analytical, visualized presentation of plant performance
- Re-use of data for planning and budgeting

(b) Failure, Repair History

Although a software application is used for failure management at some power plants, it is not

integrated with other systems. The management process is isolated and also handled manually. It is not easy to allocate optimal resources to the failure response team. History data, accumulation of know-how and lessons learned should be organized and shared by the field crew and transferred to other business units such as the procurement division for other purposes. For example, collectively controlling spare inventory across power plants, parts sharing and having an internal purchase program can contribute to a reduction of procurement overheads. Also, assessment of failure impacts improves the readiness for possible failures.
Knowledge sharing, aiming for:

- Accumulation of knowledge to help crew solve impending problems
- Reduction of response time, recovery time
- Improvement in activity efficiency based on lessons learned from history
- Learning opportunities for field engineers
- Case studies for other plants which own similar equipment.

Integration between failure trends, activities, procurement and budget, aiming for:

- Smooth procurement of spare parts and optimum replacement
- Spare inventory optimization
- Control of Total Ownership Cost

(c) Plan, Budget

A number of research studies and analysis results suggest that corrective maintenance costs more than preventive maintenance. Although it usually takes time to recognize the effects of preventive maintenance, sufficient data will be acquired to support rationalization of planned shutdown instead of forced shutdown in response to facility failures. It is also expected that implementing scheduled maintenance and procurement contributes to financial efficiency by optimizing inventory level and budget.
Creation of feasible maintenance plan, aiming for:

- Improved readiness for possible malfunction by predicting based on facility condition
- Accurate time and cost estimates
- Budget control, optimal procurement plan and spare inventory
- Grasp of facility lifecycle cost, investment decisions
- Facility life extension by performing proper maintenance

Implementing scheduled shutdown, aiming for:

- Mitigation of impact on the grid
- Reduction of opportunity cost and start-up/shut-down cost

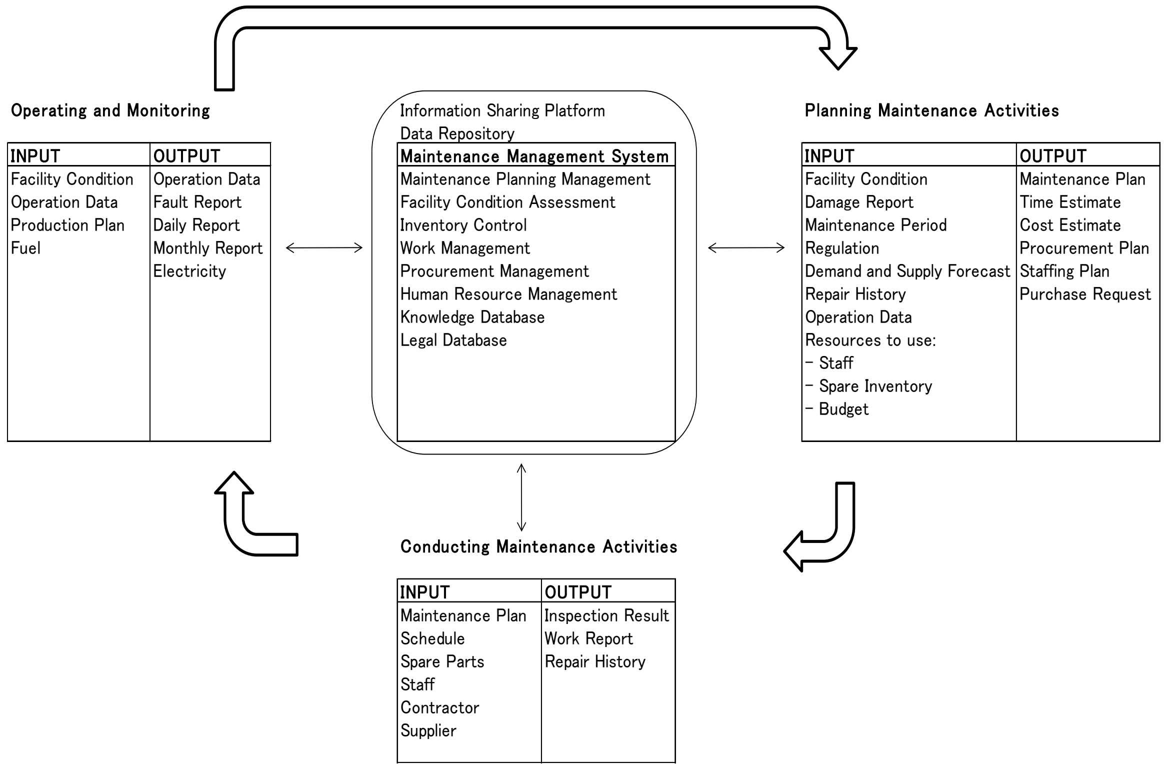
18.8.5 Implementation of information management system

(1) Information sharing platform

The three core activity areas and data areas in the cycle have various works which are performed by either people or computers. For example, data collection can be done by receiving paper documents or computer files. Maintenance plans are created primarily based on the physical state of the facility. Requirements from laws and regulations and manufacturers' recommended maintenance periods are taken into account as well. Maintenance managers also have to care about blackout schedules, staffing and procurement. Thus, data collection involves a lot of manual work and document handling. An information sharing platform allows all business units to access the necessary data to complete their work. Procurement managers can update purchase plans upon request from maintenance managers. The benefits of the use of an information sharing platform are:

(a) Centralized information management mitigates problems arising from data proliferation.
(b) Business processes are easily controlled and interactions are facilitated.
(c) It can be flexible and scalable.

The figure shows an example of the implementation of the maintenance process cycle on the information sharing platform. Each phase has Input and Output, of which information comes in various ways such as paper documentation, verbal conversation, and email and computer files. Therefore, it is very important for the management team to set a framework for an organization-wide information management strategy. Once the data handling rules are decided, the data repository stores the various types of information in a uniform, structured manner.



Source: JICA Survey Team

Figure 18-35 Information Sharing Framework for Maintenance Activities

Concerns in collecting data from day-to-day activities vary depending on the level of management. The information management framework defines a set of indicators aligned with the performance goals of the activities. By carefully choosing parameters and their delivery methods, effective data collection can be achieved.
The table shows an example of a set of performance factors and information sources required to measure or calculate the organizational performance on each level of management. Data acquisition and delivery methods influence how efficiently the information is collected. Manual meter reading and manual data entry into an application system can be replaced by automated data acquisition in order to reduce delays and errors in reporting processes.

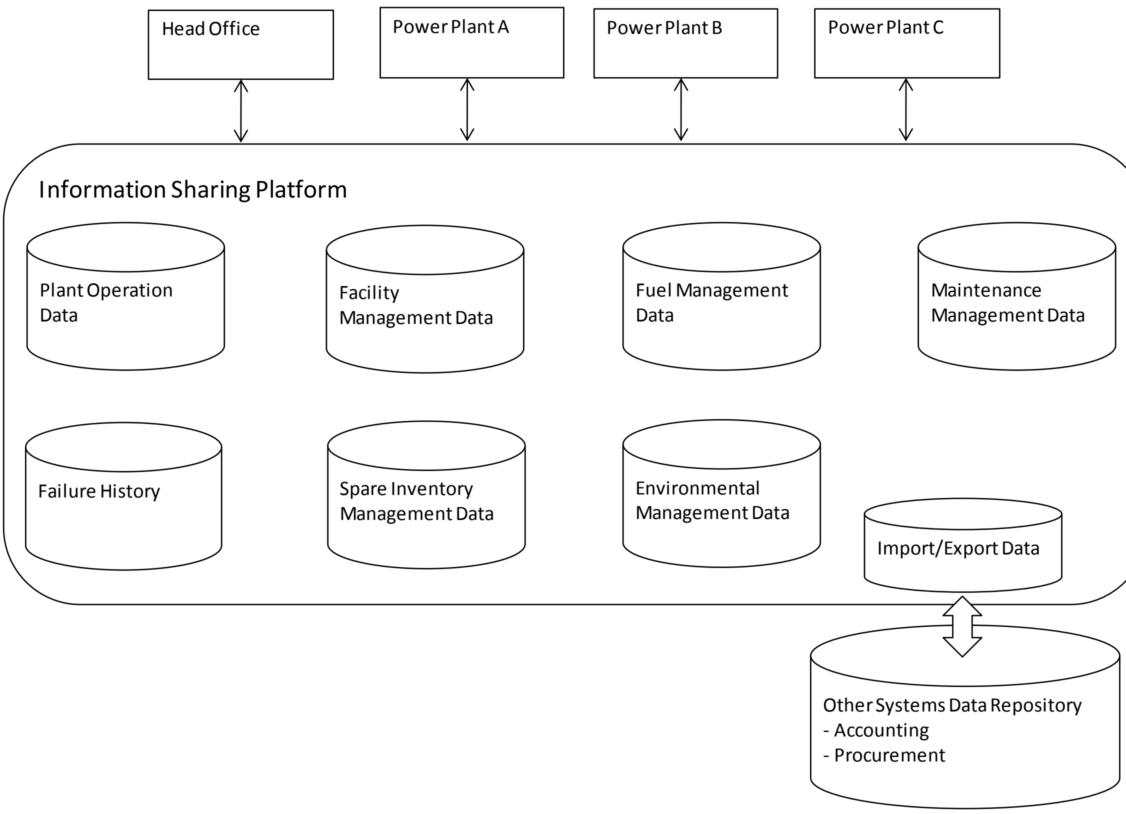
Table 18-19 Examples of Performance Indicators and Data Sources

		Performance Factor	Example of Information Source – Data Delivery Method	Data Acquisition Method
ENTERPRISE LEVEL	Financial Performance	Financial Performance Indicators	Accounting Data – Computer Files from Accounting System	Manual Data Entry
	Facility Condition	Reliability Availability Efficiency	Plant Operation Data – Computer Files from Data Loggers Damage Report – Paper Document Walkthrough Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing
	Human Asset	Number of Incidents Number of Qualified Employees Turnover	Human Recourse Data – Computer Files from HR Periodical Report – Paper Document from Power Plants	Manual Data Entry Manual Report Writing
PLANT LEVEL	Productivity	Production Consumption Thermal Efficiency	Plant Operation Data – Computer Files from Data Loggers Periodical Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing
	Maintenance Efficiency	Budget Balance Downtime	Activity / Procurement Plan – Paper Document Purchase History – Computer Files from Accounting System	Manual Data Entry
	Fault Management	Fault Responsiveness Downtime	Activity Report – Paper Document	Manual Data Entry
	Environmental Impact	Emission Effluent Discharge Disposal	Emission Data – Computer Files from Data Loggers Periodical Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing

Source: JICA Survey Team

The information sharing platform connects Head Office and other business units seamlessly. Information flows are orchestrated and reporting processes are simplified. Although there are some legacy systems being used in some business units, most application software products have functions to export and import data in standard formats which allow the systems to interact with the integrated information management system on the platform. This function can be extended to external organizations such as grid operators.

The figure below shows an example of a platform for information sharing. The platform provides the system users with data sharing functions through a range of user interfaces of application systems. The main functions are database access and file handling.



Source: JICA Survey Team

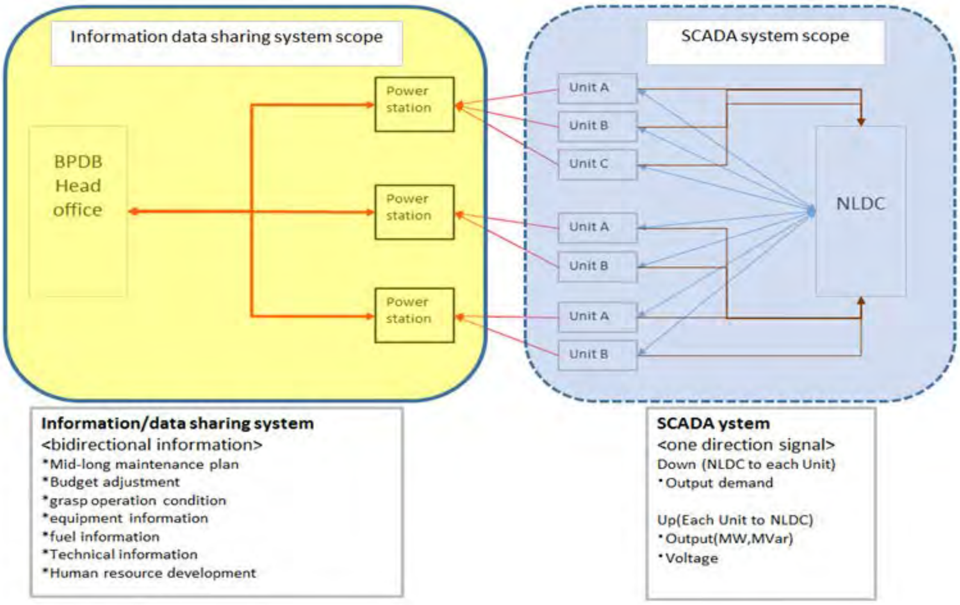
Figure 18-36 Conceptual Model of the Information Sharing Platform

(2) Integrated plant operations management system

According to the survey results, some power plants have application systems for the management of operational information which includes failure history. It is necessary to take into account such valuable information assets in the legacy systems when implementing a new system. Management of legacy data must be part of the organization-wide integration strategy for information management. ERP and EAM are examples of integrated application systems to provide data sharing functions in a uniform manner to various types of users who use the system for different purposes. One of the advantages of ERP or EAM is that data and business processes are structured based on the sector's standards. Configuration of the system includes templates for business processes and target data as well as report formats and data table formats which can be customized to meet the company's requirements. As mentioned before, the flexible and scalable platform allows the application system to embrace changes in organizational structure or policies. Interfaces with external organizations are usually available.

The figure below shows the scopes of the information management system and the SCADA system, which connects the dispatch center and the power plants.

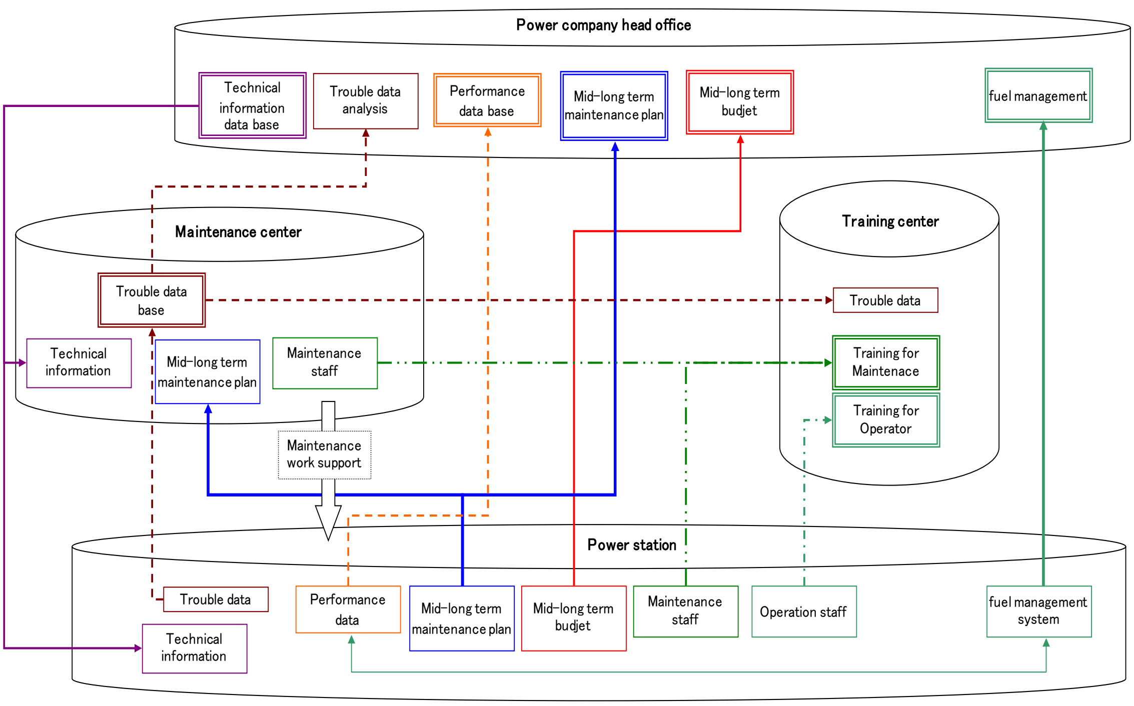
The SCADA system is an independent network system which does not share its purposes with the information management system.



Source: JICA Survey Team

Figure 18-37 Scope of Information Sharing System and SCADA System

The figure shows a conceptual model of a Thermal Power Plant Operation Management System envisioning future implementation of information sharing among current business units and new agencies, Maintenance Center and Training Center. Maintenance Center is a data repository for technical information, maintenance information, failure response support and data collection. It also provides field support services during facility inspection. Training Center provides training services to plant operators and maintenance engineers. While maintenance activities and training activities are performed separately, the improvement cycle of facility operation and maintenance as a whole can be practiced effectively by controlling the data flows on the platform. The scope of the system covers maintenance knowledge, maintenance plans, activity results and failure information, which appear in the diagram below as data flows between business units.



Source: JICA Survey Team

Figure 18-38 System Functions and Data Flows for a Power Plant in Bangladesh

(3) Application modules

The system consists of the three main components for business functions listed below. The users of the system can work concurrently through the information sharing platform by either accessing one of the modules or accessing the interface and files from other application systems which are integrated with the system.

(a) Production Management
(b) Maintenance Management
(c) Failure History Management

New modules can be added to the system for future extension. For example, if the government is going for new environmental regulations, an Environmental Management System can be introduced. Fuel Management may be added in the future if a new facility which uses coal as fuel is installed. The following explains the functions of each one of the main modules.

(a) Production Management

This module is equipped with presentation tools for visualization of plant performance. Data is mainly collected from the power generation facility. For some of the parameters used for calculation of plant performance indicators, data acquisition relies on manual entry. Key performance indicators vary depending on the level of management.

- Data acquisition frequency and report period settings
- Graphs and tables for analysis
- Data aggregation and comparison for multiple levels of management

(b) Maintenance Management

A project management tool to create plans and manage activities. By focusing on resources such as staff, materials and money, maintenance managers can monitor the efficiency of maintenance work and budget balance.

- Schedules and work progress management
- Procurement plans and budget control
- Maintenance and repair history management

(c) Failure History Management

Case database linked with facility maintenance information. Information on the failed equipment and associated information is handled in a collective manner. Preventive maintenance requires historical data for the equipment, by reference of which a decision on further investment for the equipment can be made.

- Assistance to field crew to search similar cases
- Management of cost information along with technical information
- Organized data which is reusable for training purposes.

An additional module may be considered for the future installation of new facilities as the country's energy policy shifts from natural gas to coal.

(d) Fuel Management (For Future Plans)

The users of this module can keep track of the status of the fuel from procurement to delivery. The information contains the amount of fuel unloaded and its cost. Monthly report indicates the purchase trends, which can be useful information for procurement planning.

- Management of fuel transport, reception, inventory, delivery
- Management of fuel property and quality
- Management of fuel prices and associated cost

(e) Ash Disposal Management (Matarbari and other coal fired facilities)

In order to ensure environmentally sound disposal and recycling, it is crucial to keep track of the status of the coal ash the facility generates. This module covers transport and disposal costs, from budgeting to payment to contractors. Contractors are paid based on the amount of ash processed. The system holds the qualification information of the contractor and the contract information including unit prices for disposal.

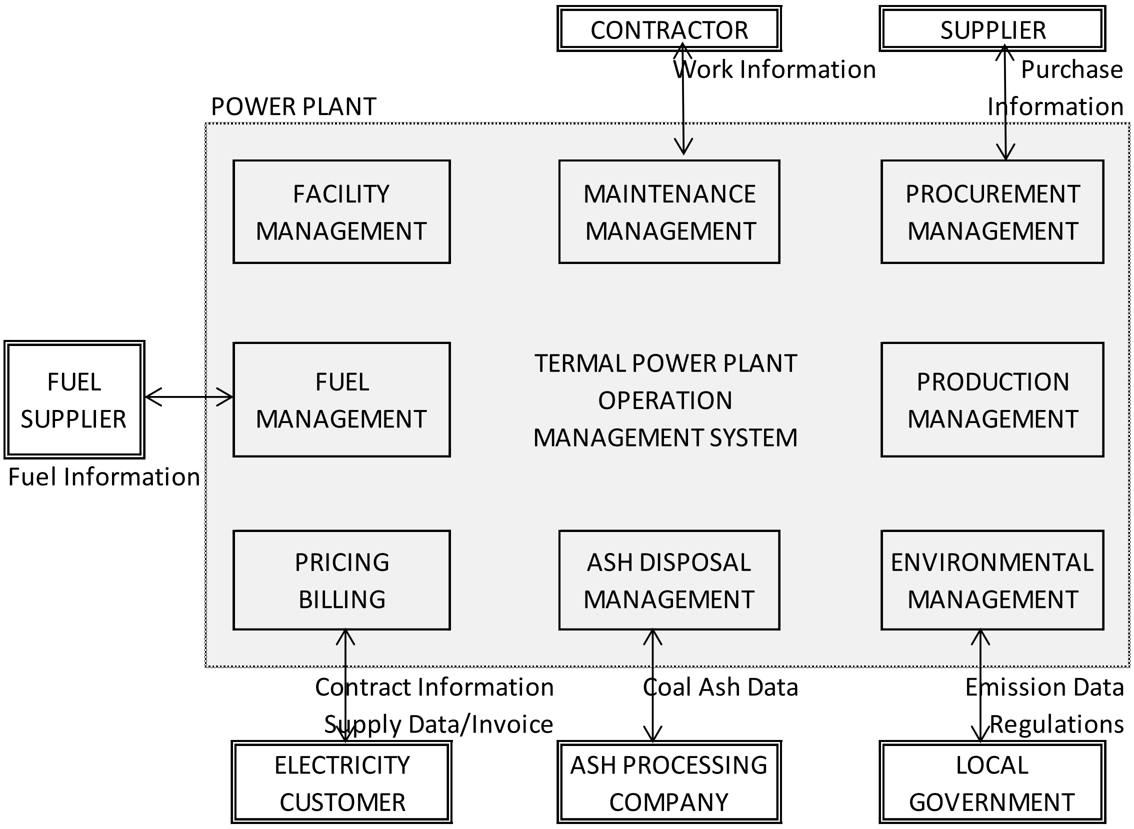
- Management of ash produced
- Management of budget, cost and payment
- Management of contract information and price

(f) Environmental Management (Matarbari and other coal fired facilities)

Emissions, effluents and waste data collected by monitoring devices. As the country's energy policy changes, the emissions associated with coal burning should be a concern in the short term. In the future, this module can be enhanced in compliance with the standards of an Environmental Management System (EMS).

- Management, analysis and assessment of monitoring data.
- Regulatory documentation and reporting.

(4) Example for further enhancement
As shown above, the system will be enhanced in the future to suit the business growth and meet the requirements from the market in Bangladesh. As a further example of best practice for information management aimed at higher reliability and efficiency, an overview of the power plant information management system at one of the leading companies in Japan is shown in the figure below.



Source: JICA Survey Team

Figure 18-39 Modern Information Management System in Japan

Over the past two decades, the company has injected efforts in information management as part of its achievements for maintaining reliability and efficiency. The challenge is to deal with the various types of facilities which are dispersed across more than 10 locations near the demand places in populated regions. On top of the inefficiency of paper based documentation, isolated systems on PCs limit the efficiency of data handling. One of the solutions to the challenge was to integrate the core business systems on an enterprise-wide network platform.

In Japan, power facilities are maintained with highly sophisticated information technology. The scope of information management includes environmental impact, safety, regulatory compliance, accountability to shareholders and social responsibility. The power sector is under severe watch by the government, and often in the center of public attention; therefore, the impact of information on its business is huge. Predictive maintenance technologies are also the key to successful operations of the high-performance large-capacity facilities. In consideration of future growth and market changes in Bangladesh, this implementation can be a good example of best practices in information management.

18.8.6 Implementation proposal

(1) Preparation for successful implementation

Strong leadership from top management is required for drawing up a plan for implementation of the integrated information management strategy. Relationships between business processes represent roles and objectives of the business units in the improvement cycle, which defines what information to share. While plant operators focus on maintaining production level, field engineers decide which piece of equipment needs to stop. Production planning and maintenance planning should be working concurrently by sharing schedules and facility condition data. The procurement manager needs to know when purchase requests will be filed from the maintenance manager because delays in supplier selection and financial arrangement lead to an overall delay in maintenance works, which may result in a longer downtime.

It might be a time consuming task to draw all the blueprints for information and process flows across the organization. Therefore, phased implementation is recommended. In a phased implementation approach, implementation is done by gradually replacing conventional business processes and data handling with new systems based on the new information strategy. The management team is expected to prioritize the business objectives and carefully select performance indicators which are to be shared on the data sharing platform. As the platform is flexible and scalable, it is a feasible way to introduce new application systems step by step.

In the preparation for the implementation, there are many points which need to be considered. The priority processes must be examined to determine which tasks can be automated and which data can be accommodated in the data repository. Strategic ICT planning includes the following points, each of which must be addressed.

(a) ICT Infrastructure

- Data Acquisition from Power Generation Facility
- Plant LAN (Local Area Network)
- Data Repository (Data Center)
- Enterprise Network

(b) Management

- Business Process
- KPI (Key Performance Indicators)
- External Organizations (Suppliers, Contractors, etc.)
- Employee Training

(c) ICT System Operation

- Legacy Systems and Data Integration
- ICT Policies and Guidelines
- ICT Education

In order to address the points listed above, further survey is expected to be carried out as shown below.

Table 18-20 Items Expected to be Addressed in Further Survey

Category	Item	Details
ICT Infrastructure	Data acquisition from power generating facility	Connectivity between facility and data acquisition devices
		Data parameters, collection periods
	Plant LAN	Local Area Network availability in power plants
	Data repository (Data Center)	Data center location, storage capacity and scalability
	Enterprise network	Network availability, connectivity among business units and multiple locations, and its security, reliability and capacity.
Management	Business process	The three core business processes, tasks and their business requirements.
	KPI	Framework setting for KPIs and other indicators.
	External organizations	Interaction with stakeholders, data sharing scope and rules. Interaction with legal framework.
	Employee training	PC users and employees' computer literacy
ICT System Operation	Legacy systems and data integration	Legacy systems and legacy data.
	ICT policies and guidelines	ICT policy setting. Guidelines for operating and maintaining the information management system.
	ICT education	ICT staffing and the required skills.

Source: JICA Survey Team

(2) Implementation options

There might be some modifications needed to the current business processes. The organization must respond to the requirements from the market, which rapidly keeps changing. The procurement policy may change to accept new suppliers or new energy sources, or to reflect new contract types of purchase or outsourcing of repair work. While the information management system can be flexible and scalable to embrace changes, conventional business processes may well remain unchanged due to the rigid structure of the organization based on roles and functions. In order for the process cycle to keep moving towards improvement, there are several options in which some part of the processes may be redesigned.

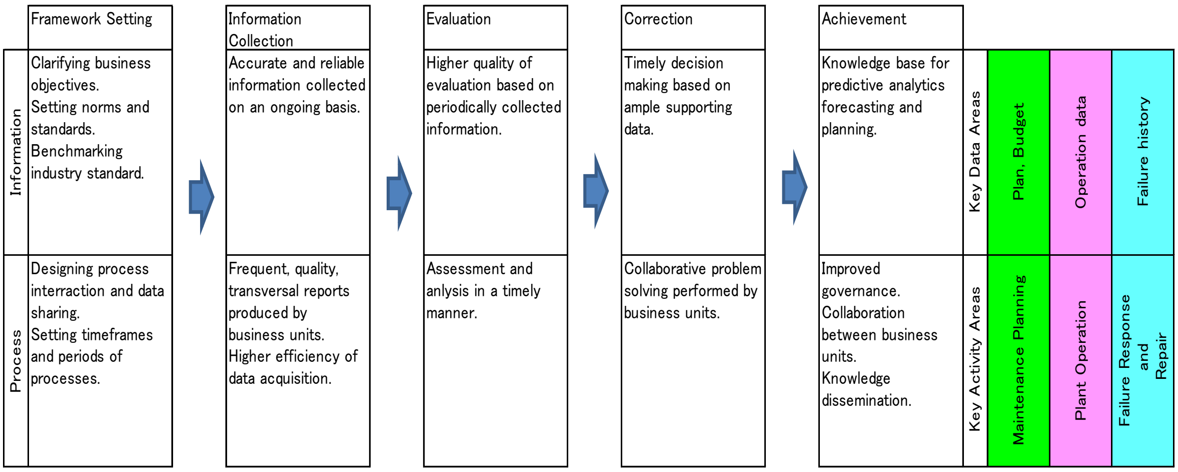
Table 18-21 Implementation Options and Process Modification Options

	Business Process Change		
System Implementation Options	No Process Change	Partial Modification	Process Reengineering
Configuration of Application System	Not realistic. Feasibility study is required to know if system best suits process. Legacy system is a burden.	Take advantage of business templates. Feasibility study is required to know which process to modify to suit the system. Data redundancy and duplication of work remain.	Take advantage of business templates. Quick implementation. Most economical but radical. Suitable for startups. Move from legacy system to new system.
Customization of Application System	Use business templates and out-of-box functions. Integrate with legacy system. Initial cost is relatively high.	Use business templates and out-of-box functions. Integrate with legacy system. Cost is relatively high.	Use business templates and out-of-box functions. Integrate with legacy system. Less expensive. Data redundancy and duplication of work remain.
Development of Tailored Application System	The processes do not need to change if they are performed through best practices. System may be inflexible and vulnerable to environmental change. Initial cost is high.	Carefully designed system can be flexible. Cost is high.	Develop system which best suits the organization. Align system to business strategy. Integration with legacy system is guaranteed. Long term ICT strategy is required.

Source: JICA Survey Team

18.8.7 Expected results

By promoting certain practices such as process interaction and information sharing, positive results will be obtained in the key activity areas. The figure below shows the sequence of intended events by implementing the information management strategy in the power generating business.



Source: JICA Survey Team

Figure 18-40 Improvement Cycle and Otcomes

As a result, the following improvements in the three core activity areas will be expected.

(a) Maintenance Planning

- Ensuring regulatory compliance.
- Accurate time and cost estimate for maintenance enables precise budget control, and optimization of procurement and spare inventory.
- Ascertainment of facility lifecycle cost and optimum investment decisions brings financial efficiency.
- Facility life extension by applying proper maintenance reduces total ownership cost.
- Implementing planned shutdown mitigates impact on the grid, and reduces opportunity cost and start-up/shut-down cost.

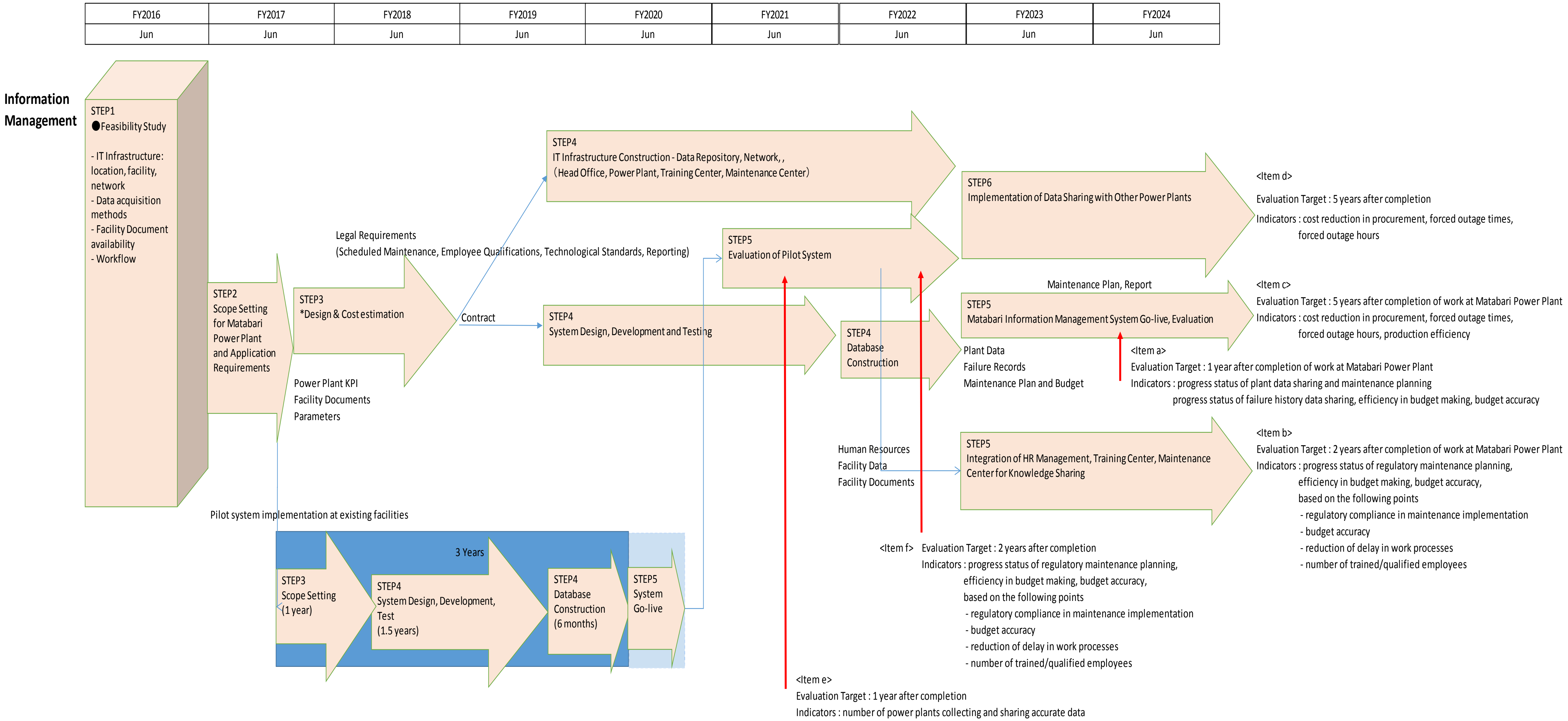
(b) Plant Operation

- Timely collected, accurate and reliable data improves the quality of evaluation and decision making, which contributes to facility assessment and maintenance planning.
- A wide variety of types of data, which is structured and assorted in a uniform manner, facilitates process interaction for problem solving and improvement.

(c) Failure Response and Repair

- Knowledge base helps field crew solve impending problems and reduce recovery times in the case of failure.
- Improvement in activity efficiency based on lessons learned from history will be achieved.
- Roll-out of maintenance techniques.
- Process interaction and data sharing with procurement leads to a reduction of total ownership cost and inventory cost.

In consideration of application of new regulations and technological standards, the information management system can bring largest benefits when it is implemented at a new facility such as Matarbari Power Station. In order to maintain the cutting edge facility to ensure the high performance and efficient operation, sophisticated management methods should be introduced, which should embrace the dynamic changes of the business environment such as legal and market requirements. The figure below shows the implementation timeframes targeting Matarbari site along with evaluation timings and indicators for expected effects.



Source: JICA Survey Team

Figure 18-41 Implementation of Information Management System at Matarbari Power Plant

The evaluation timings and indicators are listed below.

Category : Information Management

＜Item a＞

Target Year	One year after completion of work at Matarbari
Indicators	Achievement of plant data sharing, accumulation, scheduled maintenance
Criteria	Number of parameters for KPI, maintenance plans, activities accomplished
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

<Item b>

Target Year	Two years after completion of work at Matarbari
Indicators	Achievement of scheduled maintenance, budget process efficiency, accuracy
Criteria	Compliance: 100% (Number of qualified employees), unbudgeted expenditure: 0, process delay: 0
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

<Item c>

Target Year	Five years after completion of work at Matarbari
Indicators	Procurement cost, forced outage, downtime, generation efficiency
Criteria	(Benchmarking) Cost reduction: 2.5%, forced outage: 0, reduction of downtime: 7.5%
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

<Item d>

Target Year	(Pilot implementation) Five years after completion of work
Indicators	Procurement cost, forced outage, downtime, generation efficiency
Criteria	(Benchmarking) Cost reduction: 2.5%, forced outage: 0, reduction of downtime: 7.5%
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

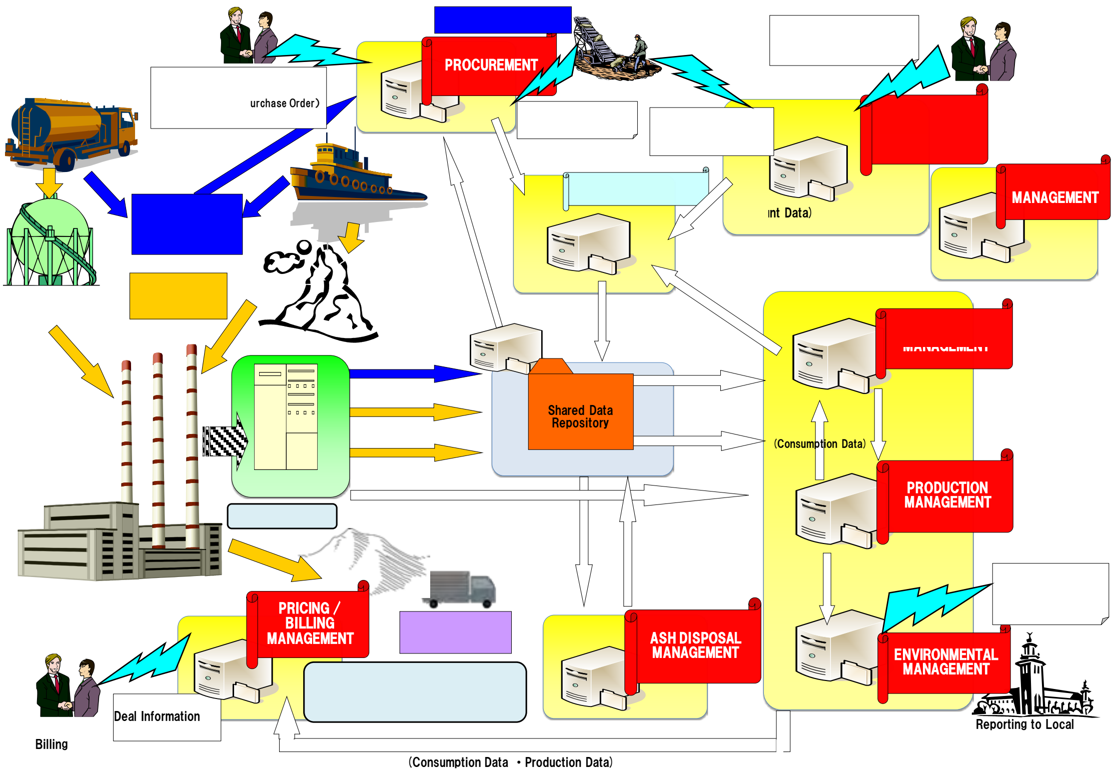
<Item e>

Target Year	(Pilot implementation) One year after completion of work
Indicators	Achievement of plant data sharing, accumulation, scheduled maintenance
Criteria	Number of parameters for KPI, maintenance plans, activities accomplished
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

<Item f>

Target Year	(Pilot implementation) Two years after completion of work
Indicators	Achievement of scheduled maintenance, budget process efficiency, accuracy
Criteria	Compliance: 100% (Number of qualified employees), unbudgeted expenditure: 0, process delay: 0
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

The figure below depicts an overview of the power plant information management system which is envisioned for future implementation.

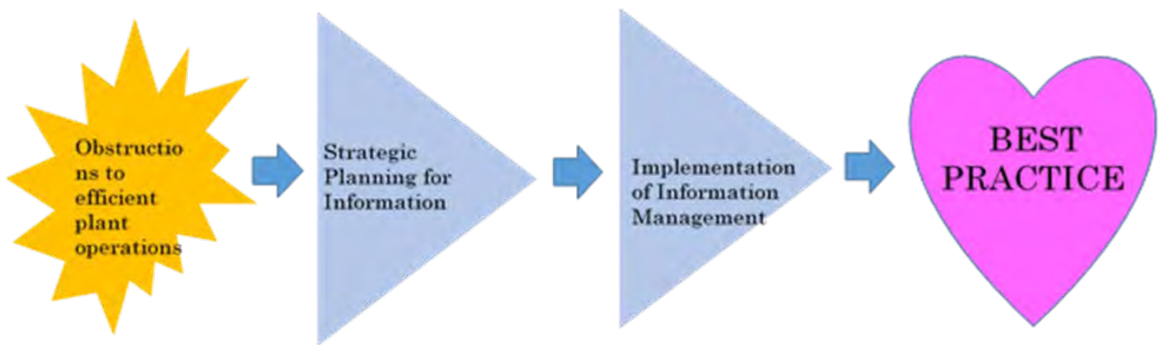


Source: JICA Survey Team

Figure 18-42 Future of the Power Plant Information Management System

The study results emphasize implementation of the strategic use of information across the core business activities of the power generating business. The implementation process consists of a series of steps: Plan, Do, Check, Act. This PDCA cycle is a powerful tool to use in business performance improvement activities. The cycle can be enforced throughout the organization by information sharing and collaboration among business units. The top management is expected to create an information management strategy to define and control information flows and process interactions.

Once the processes are established and the information for sharing is defined, it is very easy to make a plan, take an action, measure the efficiency and apply the results in decision making. One of our objectives is to enforce this improvement cycle throughout the organization by implementing information sharing and collaboration among the business units.



Source: JICA Survey Team

Figure 18-43 Information Management towards a Best Practice of O&M

18.9 Training Center

18.9.1 Necessity of training center

To improve Bangladesh's O&M skills, the most necessary thing is construction of the training organization. As mentioned in 11.3.2 Summary of actual O&M situation, Bangladesh does not have an efficient training center. Therefore, it needs to have an effective training center and curriculum and also to develop instructors.
In reference to training facilities and training courses in Japan, the JICA survey team explains what is necessary for Bangladesh, as follows.

18.9.2 Training course

In Japan, to develop staff, several courses are prepared for them according to their skill level, and their knowledge level is confirmed.

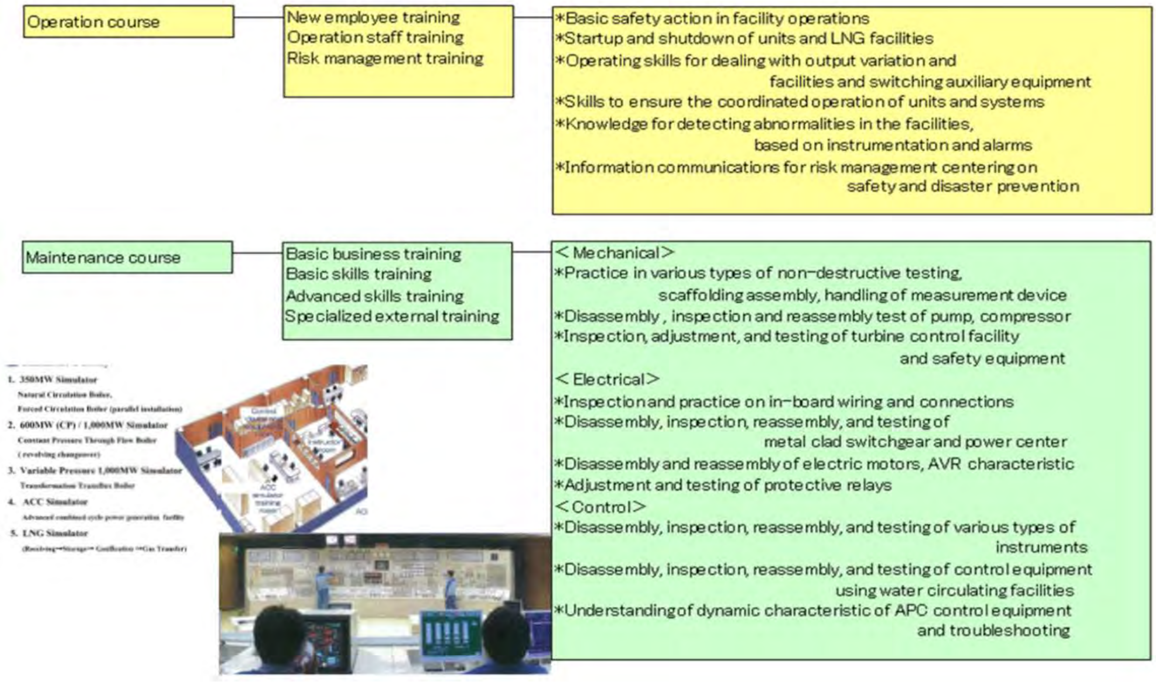
"Sample of operator training course"

(a) Training course for new employee
(b) Operator training course
(c) Risk management training course (Guide class, practitioner class, manager class)
(d) Chemical treatment, water treatment, drainage treatment training course

"Sample of maintenance course"

(e) Basic training course
(f) Applied training course (boiler, turbine, electrical, control)
(g) Special training course by manufacturer

The above courses are separated into several, more detailed courses.
And operator and maintenance staff need to be checked and authorized according to their years of experience.



Source: JICA Survey Team

Figure 18-44 Sample of Training Curriculum

18.9.3 Instructors

Instructors need a high level of skill and knowledge, and they also get a high level of education and training. Because every instructor is also an operator or maintenance staff, they also have personnel rotation between the training center and power station, getting site knowledge and feeding this back into the training content. The most important thing is to keep instructors' skill and knowledge levels high, by gathering people of ability from every power station, performing periodic personnel rotation between the training center and power station and ensuring that instructors do not forget the feeling of working at a site.

18.9.4 Training facility (simulator)

A training simulator is very useful for a training facility.
The simulator has to satisfy the following functions.

Functions for instructor

(1) Simulator execute, stop and snapshot function
(2) Initial condition setting function
(3) Variable speed control function
(4) Back track, reappearance function
(5) Malfunction
(6) Change operation condition function

Functions for trainee

Graphic screen has to show the same level screen as an operator console, and be able to operate the same as an operator console. It must also be able to show a control logic, trend graph and alarm screen.

Functions for simulator

The simulator has to simulate the following systems.

(1) Plant automatic start up and shut down control system
(2) Usual operation control system
(3) Burner control system
(4) Boiler sequence control system
(5) Turbine sequence control system
(6) Other sequence control system
(7) Plant operation simulation system after parameter tuning

Except for main facilities like boiler, turbine and generator, other facilities like a coal handling system, steam turbine, water analysis system, fire extinguishing system and so on vary with manufacturer, so the need for their inclusion in the simulator should be judged in consultation with the owner.
Of course, control logic and parameters need to be equal to a real unit control system, so that the plant simulator becomes a more realistic simulation.

18.9.5 Training facility (maintenance)

During training, maintenance staff learn how to re-assemble, adjust, fix and assemble several facilities. Therefore, when selecting a training facility, one which is the same as the facility in Bangladesh is suitable and effective.
The following facilities are those basically needed.

(1) A motor and pump
(2) Turbine feed water pump
(3) Control valve and actuator
(4) Pressure transmitter and flow transmitter
(5) A control system that has a control valve, pump and water tank in one loop
(6) A centrifugal fan or axial flow fan
(7) Non Destructive Inspection (PT, MT, UT) training facilities
(8) Rotary apparatus balance adjustment training facilities using a vibration analysis device

This is an example, and it is desirable to have the necessary facilities in the training center.

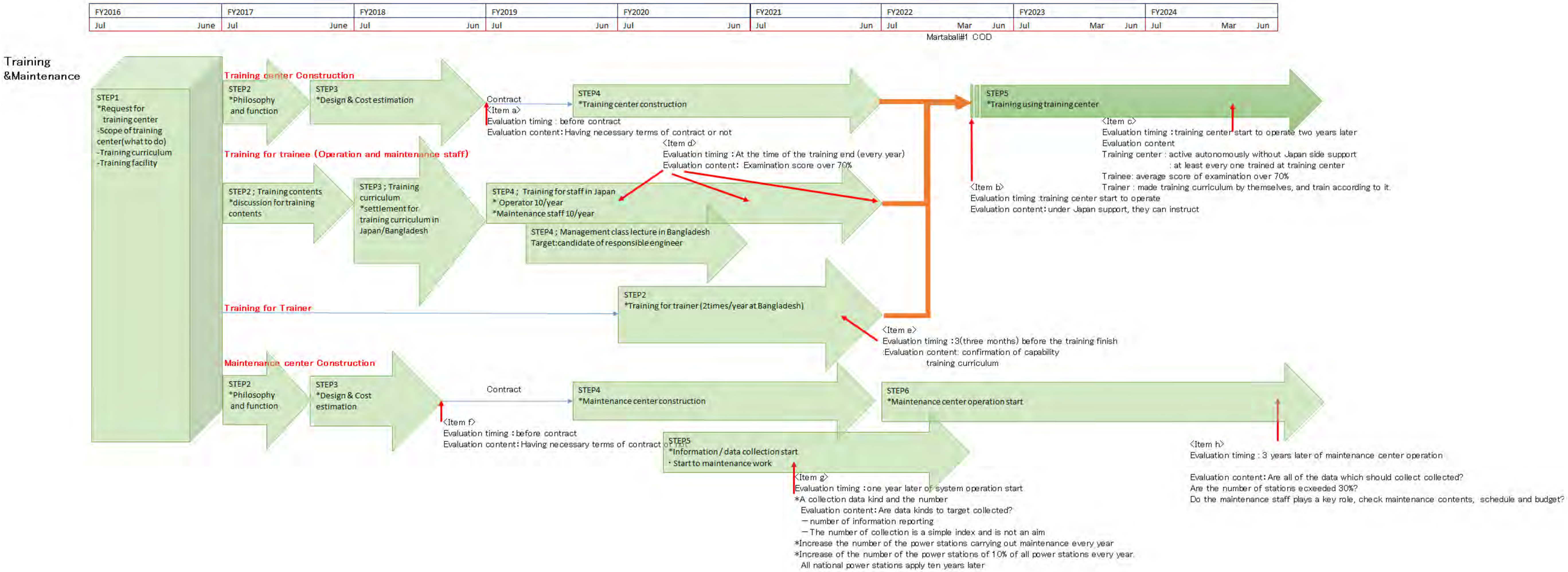
18.9.6 Important points for training center

It is important that the training center satisfies the following

(1) Curriculum from new employee to veteran
(2) Lecturer development, personnel interchange
(3) Most suitable training facility

18.9.7 Schedule for training center construction

Below is the schedule plan for O&M personnel development training center establishment when the target is the commercial operation date for Matarbari.



Source: JICA Survey Team

Figure 18-45 Training Center Construction Schedule Image

The evaluation timings and indicators are listed below.

Category: training center construction
<Item a>

Target Year	Before signing contract for training center construction
Indicators	Requirements not having any omissions
Criteria	Omission rate 0%
Follow-up Activity	Review of specifications and advice
Evaluator	The organization which carried out FS

<Item b>

Target Year	At the time when training center operation starts
Indicators	Instructors can carry out lectures by themselves
Criteria	Examination scores higher than 80%
Follow-up Activity	Re-instruction for instructors
Evaluator	The organization which carried out instructor education

<Item c-1>

Target Year	2 (two) years after training center operation starts
Indicators for training center	Technical staff of all power stations taking lectures once per year
Criteria	Attendance rates higher than 80%
Follow-up Activity	Mandatory attendance
Evaluator	The organization which carried out instructor education

<Item c-2>

Target Year	2 (two) years after training center operation starts
Indicators for instructor	Creation of training curriculum content Training schedule development
Criteria	Curriculum progress rate
Follow-up Activity	Re-instruction for Instructors
Evaluator	The organization which carried out instructor education

<Item c-3>

Target Year	2 (two) years after training center operation starts
Indicators for instructor	Examination results after attendance
Criteria	Examination scores higher than 70%
Follow-up Activity	Re-training for trainees
Evaluator	Training center instructors in Bangladesh

Category: training for trainees
<Item d>

Target Year	After the training ends (every year)
Indicators for instructor	Examination results after attendance
Criteria	Examination scores higher than 70%
Follow-up Activity	Re-training for trainees in training center in Bangladesh
Follow-up timing	After training center construction
Evaluator	The organization which carried out trainee education

Category: training for instructors
<Item e>

Target Year	Within 3 months after the training ends
Indicators for instructor	Lecture skill confirmation
Criteria	80% results in same examination as trainee
Follow-up Activity	Self-study until training center begins to be used → check according to Item b
Evaluator	The organization which carried out instructor education

Category: maintenance center construction
<Item f>

Target Year	Before signing contract for maintenance center construction
Indicators	Requirements not having any omissions
Criteria	Omission rate 0%
Follow-up Activity	Review of specifications and advice
Evaluator	The organization which carried out FS

<Item g>

Target Year	1 (one) year after starting information sharing system
Indicators	Kinds of data collected and the number of reports to head office
Criteria	No omission in data collected Number of data reports shall be deemed reference
Follow-up Activity	System repair/improvement
Evaluator	The organization which carried out FS

<Item h>

Target Year	3 (three) years after starting information sharing system
Indicators	Number increase situation of power stations
Criteria	Target of increasing number of power stations by 10% per year Amount of deviation from budget
Follow-up Activity	Improvement request to the head office
Evaluator	The organization which carried out FS