Chapter 9 Power System Analysis

In this chapter, the study of a long-term transmission network expansion plan is carried out based on the power demand forecast and the optimum power development plan by 2030 in Bangladesh, taking into account potential interconnection with neighboring countries. The required system analysis is carried out by utilizing the system analysis software PSS/E.

9.1 Basic concept for the optimum transmission network development plan

9.1.1 Conditions for implementation of the optimum transmission network development plan planning criteria

The BPDB developed the Bangladesh Power System Master Plan in 1995, and updated it in 2006 to the year 2025 under support of Asian Development Bank (ADB). The PSMP Study Team will review the 2006 Power System Master Plan and implement the optimum transmission network development plan according to the Study for power demand forecasts and the power supply development plan.

Moreover, the adequacy of the power supply capability of the present transmission system in light of future power demand increases will be studied. Therefore, it is necessary to establish an optimal transmission network development plan including the provision of a power system interconnected with neighboring countries from the viewpoint of securing long-term stability in power supply capability.

As for the implementation of the transmission network plan, the horizon year 2030 plan and the near future year 2015 plan will be implemented first, followed by the year 2020 and 2025, taking into account the following factors:

(1) Power demand forecast
(2) Linkage with the amount of power and energy available at the time, i.e., power supply development plan,
(3) Effective utilization and expansion of the existing transmission network, and transmission network development plan,
(4) Satisfaction of facilities expansion criteria,
(5) Provision of the power system interconnected with the neighboring countries,
(6) Facilities to be developed on a least cost basis, and
(7) Environmental situation

9.1.2 Planning criteria

This Study formulates a power system expansion plan, which satisfies the reliability criteria based on the PSMP 2006.

A power system expansion plan, which satisfies the reliability criteria under normal conditions and outage contingencies of facilities, should be formulated for the formation of power system facilities, taking into account the frequency and effect of the facilities failure.

The reliability criteria used in this Study is defined as the target level for system reliability in single outage contingencies of facilities, according to the “BANGLADESH GRID CODE DRAFT” dated 18/10/2000.

Practical reliability criteria under normal conditions and the outage contingencies of facilities are shown in Table 9-1.

Table 9-1 Reliability criteria in normal conditions and outage contingencies of facilities

Normal conditions of facilities	- Facilities loading <100% - Steady-state voltage range: ±5%
Single outage contingencies of facilities (N-1)	- Facilities loading < 100% - Steady-state voltage range: ±10% - Transiently stable to 3-phase to ground fault with normal clearing

Source: BANGDALESH GRID CODE DRAFT (October 18, 2000)

In order to formulate the power system expansion plan, it is necessary to evaluate properly whether it satisfies the reliability criteria as shown in Table 9-2.

Table 9-2 Evaluation method of reliability criteria

Item	Evaluation Method
Normal capacity and overload capacity of facilities	It is necessary that the power flow does not exceed the normal capacity and overload capacity of the facilities in order to prevent damage such as potential harm to the transmission line and substation.
System reliability	In the AC power system, it is necessary to secure system reliability because if such trustworthiness cannot be maintained the generator will be out-of-phase resulting in adverse effects to the power system. Specifically, the steadiness of the power system is necessary in terms of the transient stability. If the system reliability is not secured, appropriate countermeasures such as the multi-route transmission line and the installation of an intermediate switching station should be taken.
Voltage stability	In the power system, the effect of the controls such as effective reactive power compensation facilities and transformer taps for the voltage control becomes insufficient starting with the power system disturbance due to rapid increasing load and outage contingencies of the transmission line etc. during the heavy load period. Finally, it is necessary to secure voltage stability because the system voltage decreases to an abnormal level and is likely to arrive at a wide-ranging power supply outage, when it becomes impossible to maintain the voltage stability. When the voltage stability cannot be secured, appropriate countermeasures such as the installation of the reactive power compensation facilities should be taken.

Source: PSMP Study Team

9.1.3 Improvement in quality of electricity

In establishing the transmission network development plan, supplying high quality electricity is the main purpose of The PSMP Study Team. To this end, the following elements are to be secured:

(1) Electric power shall be supplied continually at an optimum level that ensures as much as possible less power outages and periods under normal operating conditions as well as having safeguards in place in the event of an accident. (Power Supply Reliability).

(2) For the prevention of load increases, accidents and an imbalance of reactive power of long-distance transmission lines (Voltage Maintenance), system voltages shall be maintained within an appropriate level by installing voltage regulators such as an AVR, on-load tap changing equipment, etc. and phase modifiers such as static capacitors, shunt reactors etc.

9.1.4 Efficient, stable and economic plans & designs

In order to transmit electric power efficiently and stably, the transmission lines and substation facilities will be planned and designed in consideration of both the “Electrical Performance” such as the transmission capacity, voltage maintenance and failure prevention, and the “Mechanical Performance”. Effect of the reduction of transmission losses shall also be extensively considered.

Technical measures for reduction of transmission losses to raise economic efficiency are:

(1) Application of a thicker conductor size and additional circuits

(2) Application of an upper system voltage

(3) Adjustment of reactive power by installing static capacitors and shunt reactors.

In designing transmission lines and substation facilities in the optimum transmission system, the aforementioned countermeasures coupled with economic efficiency are to be considered.

9.1.5 Environmental and social consideration

The impact of transmission lines and substations to the environment and society is usually moderate compared with hydroelectric and thermal power projects. Routes of new transmission lines and locations of new substations will be examined in cooperation with environmental management and social consideration experts in reference to the terms stipulated in the environmental law and legislation of Bangladesh. In addition, the following elements will be examined in selecting the line routes and locations of substations through the map study and site investigation:

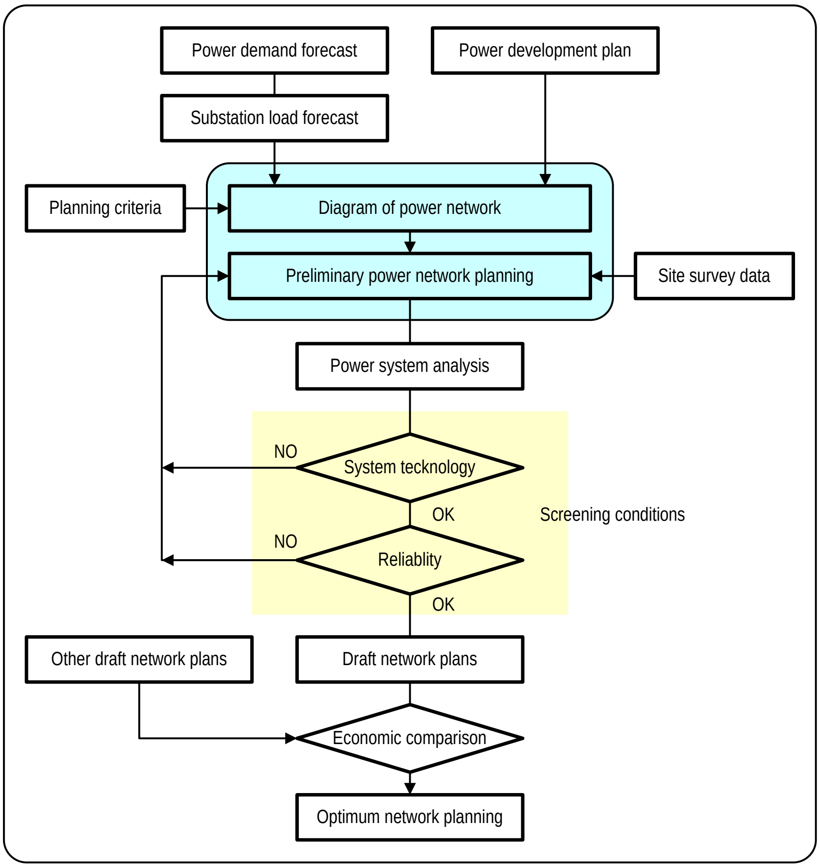
(1) To minimize interference with the existing infrastructures
(2) To minimize the clearing of trees
(3) To avoid historic spots and cultural heritages
(4) To avoid National Bio-diversity and Conservation Areas and scenic areas
(5) To avoid foreseeable natural disaster zones and geologically peculiar areas
(6) To avoid military zones, airport zones and public facilities
(7) To minimize the resettlement of people and the disturbance to habitats

9.2 Establishment procedures of the optimum transmission development plan

9.2.1 Selection of the optimum transmission development plan

The establishment procedure of the optimum transmission development plan is assumed based on the following steps, as shown in Fig. 9-1:

(1) Review of the existing plan
(2) Status confirmation of existing equipment and information gathering
(3) Data confirmation of power system and generator
(4) Confirmation of a power demand forecast and an optimum power supply development plan
(5) Preliminary establishment of a transmission network development plan
(6) Power System analysis (power flow/system voltage, fault current, system stability calculation)
(7) Establishment of an optimum transmission network development plan



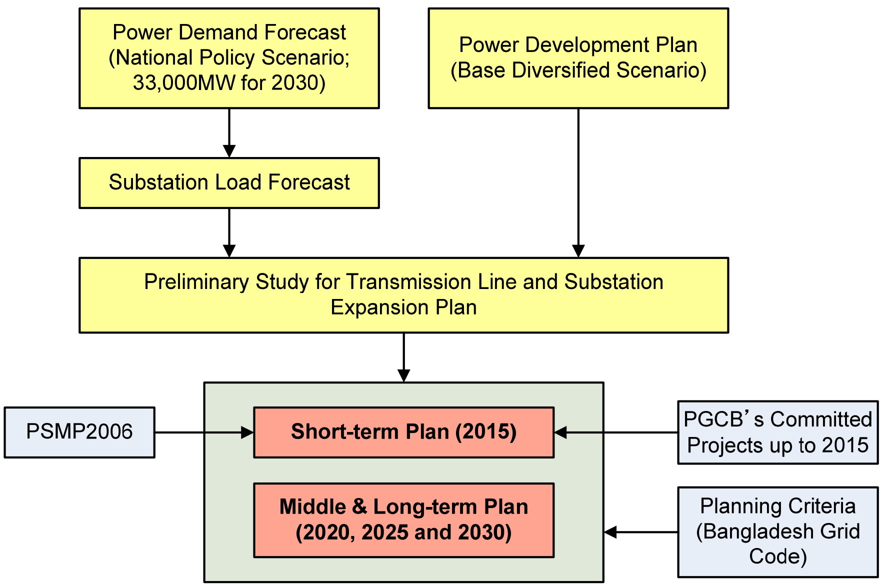
Source: PSMP Study Team

Fig. 9-1 Establishment procedure of an optimum transmission development plan flow

(1) First, according to the assumed power development plan and power demand forecast, a power supply diagram will be made. This is a power system diagram that includes the power source and demand location (existing and planning substation location) with the transmission line, based on the power system diagram of the existing power system. In addition, the preliminary design of the transmission and substation equipment in the short-term, middle-term and long-term phases will be carried out based on the basic conditions and considerations for plan implementation and electrical data will be set up.
(2) Based on the above data, power system analysis will be carried out as described later.
(3) In case the results do not meet the screening conditions of the facilities expansion criteria such as the technical requirements and the power supply reliability, "planning" and "analysis" will be repeated until the results fulfill the conditions with modifying parameters such as voltage, transmission construction, conductors (the number of conductor or circuits) and transformers (capacity or the number of transformers).
(4) Similar analysis will be also repeatedly carried out for the route option between the power station and the substation, and the system plan will be established to fulfill the criteria and condition.
(5) The overall costs of the power facilities including the power supply costs will be compared with various transmission network development plans. The relation between the effect of the forecast and the investment will be established, and the highest efficient optimum transmission network development plan will be selected from various plans.

9.2.2 Power system analysis

Based on the power demand forecast in Chapter 7 and the power development plan in Chapter 8, an optimum power system plan that satisfies the system planning criteria has been formulated taking into account the PSMP2006 and the PGCB's committed projects up to 2015, as shown in Fig. 9-2. Power flow, voltage regulation, fault current and stability in the power system are technical basic elements that a power system will be properly and appropriately operated.



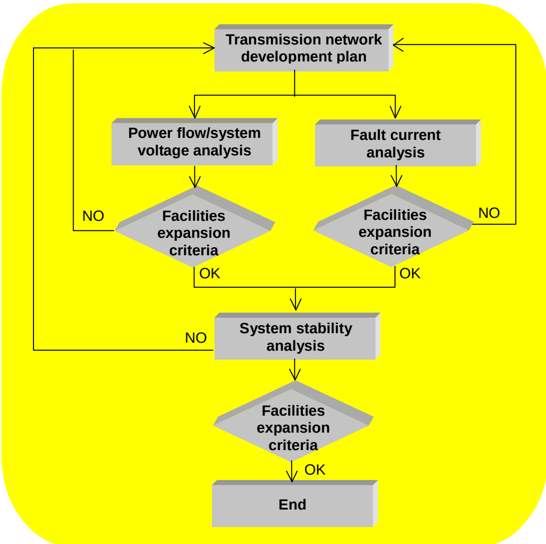
Source: PSMP Study Team

Fig. 9-2 Items to be taken into account power system analysis

Power system analysis is an integral part of verifying the transmission network development plan. The flow of the power system analysis is shown in Fig. 9-3. An evaluation will be carried out taking into account the following points:

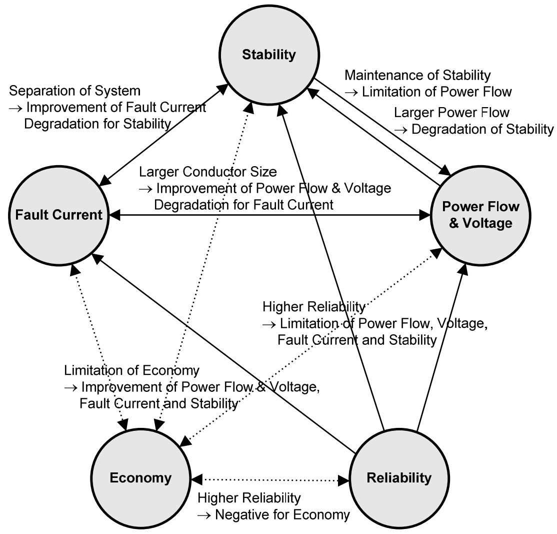
- Power flow/System voltage analysis: Check whether or not an overload and/or an abnormal voltage condition will occur
- Fault (short circuit) current analysis: Check for an extremely large fault current occurrence
- System stability analysis: Check if generators can maintain stable operations

The PSMP Study Team will use the software such as a PSS/E for the power system analysis.
The aforementioned technical basic elements interact among them, as seen in Fig. 9-4. For example, the larger conductor size might resolve an overload condition of a transmission line but increase the fault current. Therefore, a “revision of the system planning” and a “system analysis for the technical basic elements” were repeatedly examined until the planned system satisfies the system planning criteria for all the technical basic elements.



Source: PSMP Study Team

Fig. 9-3 Power system analysis flow



Source: PSMP Study Team

Fig. 9-4 Relations among elements for power system analysis

9.2.3 Items to be taken into account system planning

(1) Scope of the study for facilities expansion

Since the 132kV system analysis is impractical and the volume of all system analysis is huge, the scope of the study for facilities expansion is proposed to PGCB. The agreed scope of study is shown in Table 9-3.

Table 9-3 Scope of study for facilities expansion (○: necessary study)

		Short-term plan	Middle and long-term plan		
		2015	2020	2025	2030
Transmission line	400kV	O	O	O	O
	230kV	O	O	O	O
	132kV	O	–	–	–
Substation	400/230kV	O	O	O	O
	230/132kV	O	O	O	O
	132/33kV	O	–	–	–

Source: PSMP Study Team

(2) Substation load forecast

Based on the methodology for power demand forecast (Chapter 7), each substation load for system analysis by 2030 is shown in AP Table 9-1.

(3) Basic concept of substation expansion

Based on the discussion with PGCB, the maximum power flow through the 230kV and 132kV substation is shown in Table 9-4. If the power flow exceeds this value, the substation expansion will be basically studied.

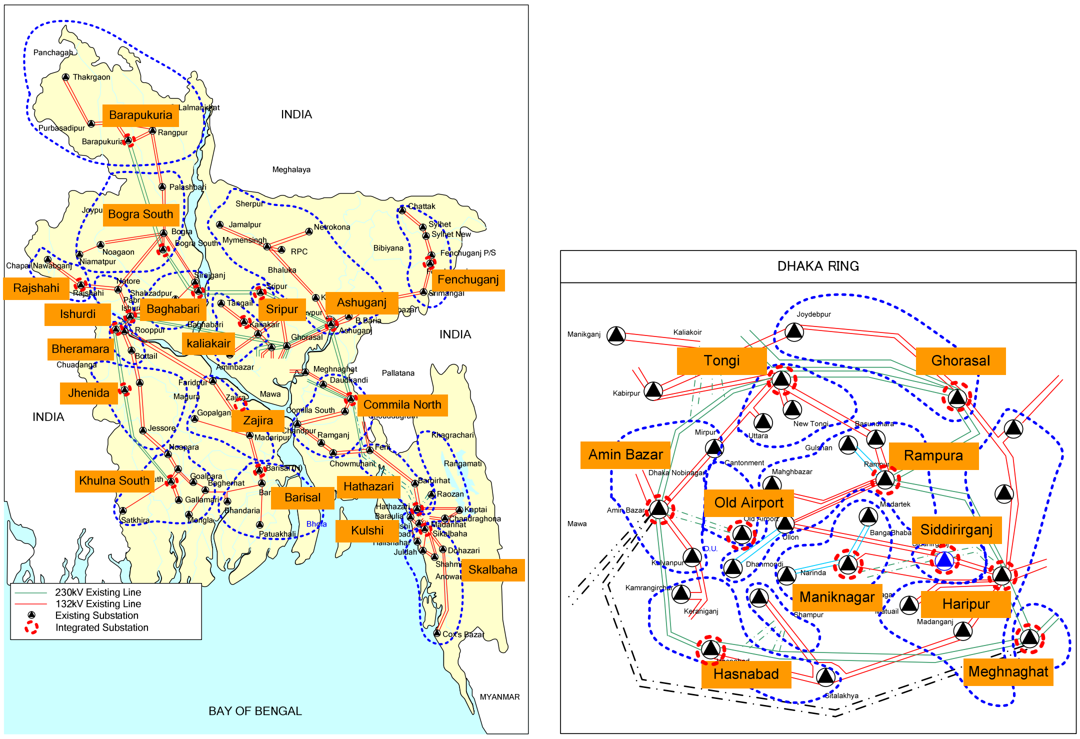
Table 9-4 Scope of study for facilities expansion

		Maximum passing power flow
230kV substation	Urban area	500MW
	Rural area	300MW
132kV substation		100MW

Source: PGCB

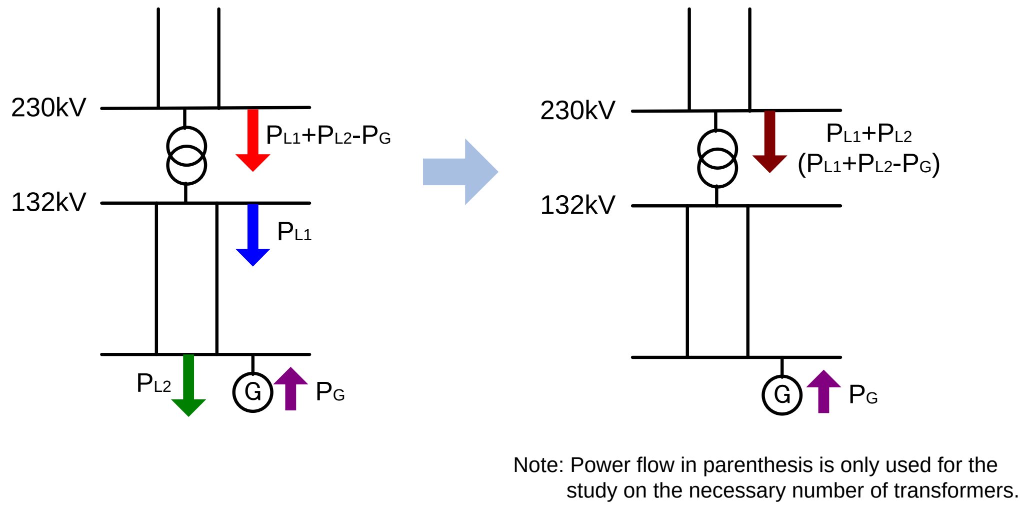
(4) System simulation method of study for middle and long-term plan

For the simulation method of study for the middle and long-term plan, the 132kV substation load is summarized in the 230kV substation bus as shown in Fig. 9-5 and Fig. 9-6.



Source: PSMP Study Team

Fig. 9-5 Summarization of 132kV substation load



Source: PSMP Study Team

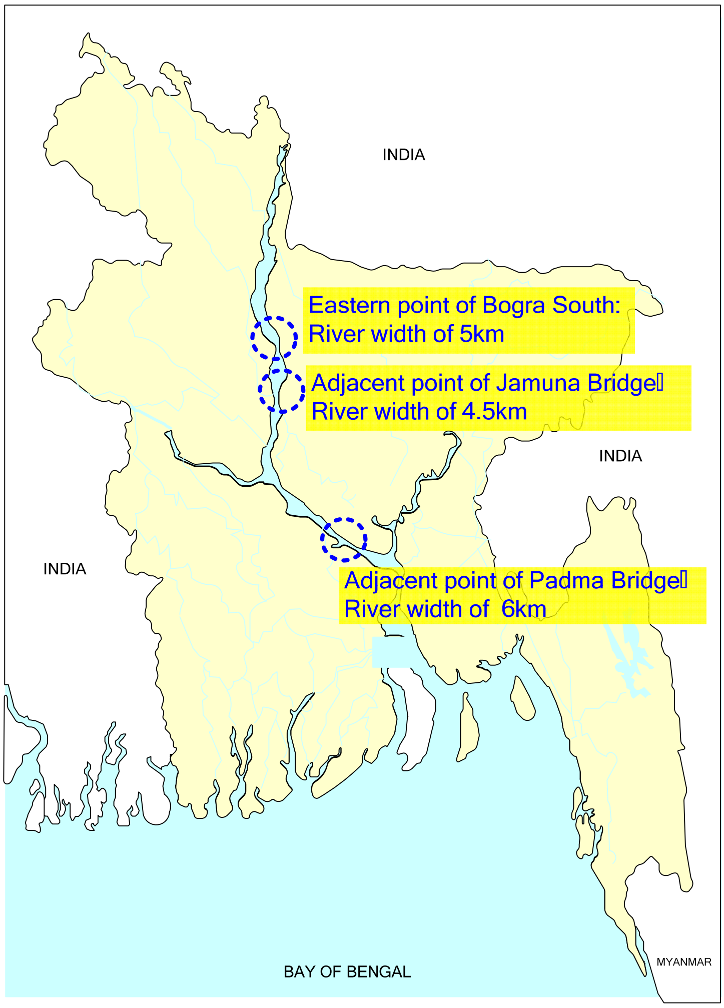
Fig. 9-6 Summarization method of 132kV substation load

(5) Items to be taken into account expansion of transmission line across the river

Based on the discussion with BPDB and PGCB, the following items have been taken into account in the expansion of the transmission line across the Jamuna and Padma River.

(a) Candidate site point

Three site points across the Jamuna and Padma River where the width of a river is relatively narrow have been made a candidate, as shown in Fig. 9-7.



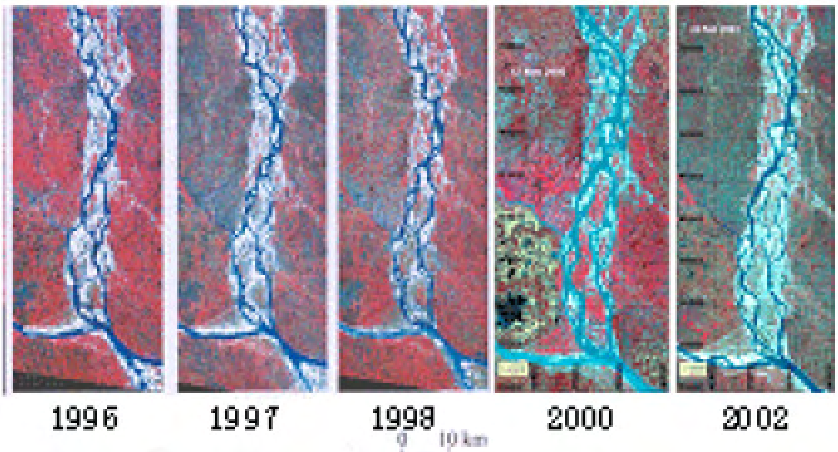
Source: BPDB, PGCB, PSMP Study Team

Fig. 9-7 Candidate site point across the Jamuna and Padma River

(b) Availability of submarine cable adoption

The adoption of the submarine cable is considered to be difficult for the following reasons. Therefore, the proven overhead transmission line across the river in Bangladesh should be essentially adopted.

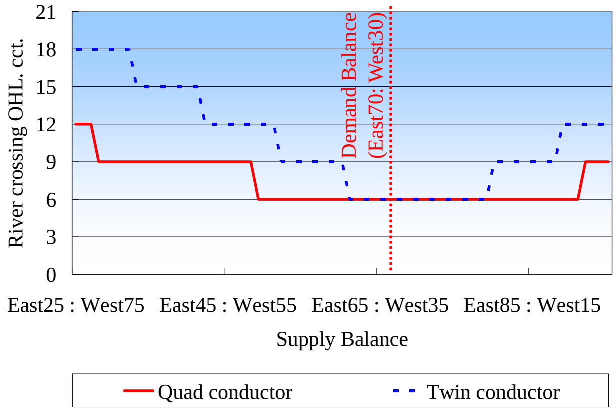
- The river concerned is known as one of the leading rage rivers in the world. The light and fine-grained sand carried from the Himalayas repeats the deposition and the movement. Further the flow channel geometry of the braided river always changes as shown in Fig. 9-8. Moreover, the position of the river might move at as much as 5km due to a flood. Therefore it is inappropriate for the construction of the submarine cable.
- If the submarine cable is adopted, it should be laid on the riverbed so that the unexpected power is not applied by the flow of the river. In addition, it is necessary to lay the underground deeply so as to not allow the cable to erode by exposure. As a result, the construction cost becomes expensive.
- Moreover, repairing cable trouble if the depth of the burial cable becomes deep by deposition becomes extremely difficult.



Source: Y. Tamakoshi, "Fundamental study on of the bank erosion along the braided river and its control", Master's thesis mid-term presentation for Master Civil Engineering Division, Graduate School of Engineering, Gifu University (September, 2005)

Fig. 9-8 Year-on-year configuration of flow channel geometry of Jamuna River

(c) Larger capacity of transmission line



Source: PSMP Study Team

Fig. 9-9 Study results of the number of circuits across the Jamuna River

The construction of the transmission line across the Jamuna River requires a tremendous of expense. Therefore, it is possible to cut costs by reducing the number of circuits across the river. The preliminary study for the number of circuits across the Jamuna River has been carried out when the supply balance between the east and west and the transmission line type (number of conductors) has been changed, as shown in Fig. 9-9. The following measures against the reduction of the number of circuits across the river are effective.

- Formulation of the power development plan corresponding to the power demand balance between east and west
- Larger capacity of the transmission line

Therefore, in order to deal with the interconnection power flow from the west to the east that increases over the mid to long-term, the adoption of a 400kV larger capacity transmission line (quad conductor) will be basically adopted.

The quad conductor has the following features compared to the single conductor which has an equivalent cross-section.

- The critical corona inception voltage shows a nearly 15-20% rise, which results in decreased corona loss and noise.
- The inductance of the transmission line decreases by nearly 20-30%, while the capacitance of that increases by nearly 20-30%. As a result, the surge impedance decreases, and the surge impedance loading increases by nearly 20%.

- The high current capacity can be ensured and the transmission capacity increases due to the less skin effect.

(d) Possibility of installation of cables along the Padma multipurpose bridge

The currently-projected Padma multipurpose bridge with a length of 6.15km has been designed to have the 400kV double circuit 3000mm^2 XLPE cable with a duct system installed. [1], [2]

The following items should be considered for the installation of cables along the bridge.

- There are two kinds of methods such as the installation to the ladder or the trough and the installation to the duct. For the installation to the ladder or the trough, it is easy to construct an intermediate joint comparatively because it is possible to construct utilizing the installation method similar to the standard installation to the tunnel.
- On the other hand, the span length of the cables is limited from the point of the pulling tension of the long distance for the duct system as well as a standard underground cable. It is necessary to prepare the intermediate joint space including the construction space.
- It is necessary to consider the expansion and contraction of the bridge (the heat expansion and contraction, and the deflection of the bridge to the vertical direction according to the pass of the super-heavy load such as and the railroad trains), the vibrations depending on the car and the train, etc., and the downward slip of the cable (especially for the duct system, transition section from the bridge to the underground) because it differs from the construction of a standard underground cable.
- The measures against expansion and contraction are the pantograph type expansion and contraction absorbers and the installation of the long offset. Moreover, measures against the deflection of the bridge are the installation of angular bend absorbers and the prevention of a downward slip of the cable.
- In addition, it is necessary to evaluate the influence of the impact on the intermediate joint work from the vibration of the bridge and the vibration to the cable after installation.

The installation of 400kV class cable along the bridge has a cost advantage compared to the overhead transmission line across the river because the construction cost of installing a 400kV class cable along the bridge is almost the same as that of a standard underground cable except for the aforementioned special equipment such as the expansion and contraction absorbers. However, there is no country that has adopted the installation of a 400kV class cable along the bridge, and it is considered to be difficult for the following reasons. Therefore, the proven overhead transmission line across the river in Bangladesh should be essentially adopted in this Study. Incidentally, two anchor towers on either side of the line will be installed on the bank with the terminal arrangement.[2]

Table 9-5 Comparison of the river crossing method

Options	Advantages	Disadvantages
Overhead transmission line	• Experience with 230kV • Easy and quick to repair	• Higher construction cost
Cable on the bridge	• Lower construction cost	• No experience in Bangladesh • Measures for behavior bridge • Constrained work in the case of construction and maintenance due to other utilities such as roads and railways • Significant decrease in supply reliability to restore the cable fault etc. for a long time

Source: PSMP Study Team

[1] ADB: "Proposed Technical Assistance Loan People's Republic of Bangladesh: Padma Multipurpose Bridge Design Project", November 2007

[2] Bangladesh Bridge Authority: “Environmental Assessment, Report: Padma Multipurpose Bridge Project“, July 2010

Incidentally, the number of circuits necessary for the river crossing at the point concerned is four circuits as described later in the 2030 plan for the 400kV overhead transmission line (quad-conductor), and it becomes necessary by approximately four circuits for the 400kV double circuit 3000mm^2 XLPE cable.

9.3 Existing transmission network and its expansion plan

9.3.1 Existing transmission network

The existing Bangladesh transmission facilities incorporate two main voltage levels, 230kV and 132kV. The circuit length of the 230kV transmission line is 2,644.5km, and that of the 132kV transmission line is 5,818km (as of the end of June 2010).

A 230kV bulk power system consists of an all double-circuit transmission line and the loop network is additionally formed with a 132kV system around the Dhaka region. Currently, there is a 230kV transmission line that interconnects the eastern and western part of the country. A 230kV line planned between Meghnaghat and Aminbazar in the Dhaka region will be upgraded to 400kV in the future. The number of the 230kV/132kV substation is 15 (6,850MVA), and that of the 132kV/33kV substation is 93 (9,899MVA), as shown in Table 9-6 and Table 9-7 (as of the end of June 2010). The representative 230kV transmission and substation facilities are shown in Fig. 9-10 and Fig. 9-11 . The power system diagram (132kV and above) in Bangladesh is shown in Fig. 9-12.

Table 9-6 Existing 230kV/132kV substation facilities (as of the end of June 2010)

	PGCB		BPDB		DPDC	
	No. of S/S	Total (MVA)	No. of S/S	Total (MVA)	No. of S/S	Total (MVA)
Chittagong	1	450				
Comilla	1	225	1	300		
Dhaka	5	3,375	1	250		
Khulna	1	450				
Bogra	4+1 (Switching)	1,800				
Total	**13**	**6,300**	**2**	**550**		
Grand Total (MVA)	**6,850**					

Source: PGCB Special Annual Bulletin (2010.7)

Table 9-7 Existing 132kV/33kV substation facilities (as of the end of June 2010)

	PGCB		BPDB		DPDC	
	No. of S/S	Total (MVA)	No. of S/S	Total (MVA)	No. of S/S	Total (MVA)
Chittagong	11	1,317	2	103	1	30
Comilla	9	837	2	157		
Dhaka	21	2,973	1	100	12	1645
Khulna	17	1,367			Bheramara GKP	20
Bogra	17	1,350				
Total	**75**	**7,844**	**5**	**360**	**13**	**1,695**
Grand Total (MVA)	**9,899**					

Source: PGCB Special Annual Bulletin (2010.7)

Source: Photo by PSMP Study Team
(November 2009)

Fig. 9-10 230kV Barapukuria -Bogra South transmission line

Source: Photo by PSMP Study Team
(November 2009)

Fig. 9-11 230kV/132kV Bogra South substation

Source: PGCB System Planning Division

Fig. 9-12 Power system diagram (132kV and above; as of June 2010)

9.3.2 Existing transmission network expansion plan

(1) PGCB's expansion plan

PGCB expects implementation of the 400kV and 230kV transmission line expansion plan by 2015, as shown in Fig. 9-8.

Table 9-8 PGCB's transmission line expansion plan

Section	Voltage	Length	No. of circuits	Region	Completion year
1, Meghnaghat – Aminbazar	400kV	50km	2	Dhaka	2010-11 (on-going)
2. Bibiyana – Kaliakoir	400kV	168km	2	Central	2011-12
3. Bheramara – Baharampur (India)	400kV	30km	2	Western	2012-13
4. Aminbazar – Maowa – Mongla	400kV	192km	2	Central Western	2014-15
5. Anowara – Meghnaghat	400kV	260km	2	Southern Dhaka	2014-15
6. Aminbazar – Old Airport	230kV	10km (6km U/G)	2	Dhaka	2010-11 (on-going)
7. Siddhirganj – Maniknagar	230kV	11km	2	Dhaka	2011-12 (on-going)
8. Fenchuganj – Bibiyana	230kV	32km	2	Central	2011-12
9. Bibiyana – Comilla North	230kV	160km	2	Central	2011-12
10. Barisal – Bhola – Burhanuddin	230kV	60km	2	Western	2012-13
11. Ishurdi – Rajshahi	230kV	70km	2	Northern	2012-13
12. Raozan – Sikalbaha – Anowara Hathazari – Khulshi	230kV	60km	2	Southern	2012-13
13. Comilla North – Tripura (India)	230kV	13km	2	Central	2012-13
14, Mongla – Khulna South	230kV	40km	2	Western	2014-15

Source: PGCB System Planning Division (December 2010)

(2) Expansion plan in PSMP 2006

PSMP 2006 recommended construction of the transmission lines by 2025 in PSMP 2006, as shown in Table 9-9.

Table 9-9 Transmission network expansion plan in PSMP 2006

Section	Voltage	Length	No. of circuits	Region
1. Meghnaghat – Aminbazar	400kV [1]	48km	2	Dhaka
2. Maowa – Aminbazar	230kV	40km	3	Dhaka
3. Haripur – Meghnaghat	230kV	11.6km	2	Dhaka
4. Aminbazar – Old Airport	230kV	10km	3	Dhaka
5. Sikalbaha – Madunaghat/New Sikalbaha	230kV	20km	4	Southern
6. Madanganji – Sitalakhya	230kV	4.5km	4	Dhaka
7. Bhandaria – Barisal	230kV	40km	2	Western
8. Mawa – Hasnabad	230kV	30km	5	Dhaka
9. Hathazari – Madunaghat	230kV	9km	3	Southern
10. Tongi – Uttara	230kV	9km	1	Dhaka
11. Milpur – Aminbazar	230kV	10km	3	Dhaka
12. Hathazari – Baraulia	230kV	12km	2	Southern
13. Madunaghat – Sitalakhya	230kV	12km	2	Southern

1 230kV operation at initial stage

Section	Voltage	Length	No. of circuits	Region
14. Hasnabad – Kulshi	230kV	12.7km	2	Dhaka
15. Uttara – Milpur	230kV	13km	2	Dhaka
16. Kulshi – Baraulia	230kV	12.9km	2	Southern
17. Madunaghat – Madunaghat/New Sikalbaha	230kV	12.9km	2	Southern
18. Maniknagar – Siddhirganj	230kV	11km	2	Dhaka
19. Tongi – Kasimpur	230kV	15km	2	Dhaka
20. Kasimpur – Kabirpur	230kV	15km	2	Dhaka

Source: PGCB System Planning Division (June 2010)

9.4 Transmission network development plan

9.4.1 Analysis condition

(1) Generation patterns

The list of generators for system analysis is shown in AP Table 9-2. The power flow and voltage analysis will be carried out to confirm to the power flow criteria explained in 9.1.1 is satisfied. In this study, the overloading will be checked for the two generation patterns, as shown in Table 9-10, in consideration of the output of the spinning service.

Table 9-10 Studied generation patterns

Generators	West-side	East-side
Pattern East	Reduced to match demand-supply balance	Full output
Pattern West	Full output	Reduced to match demand-supply balance

Source: PSMP Study Team

(2) Short-circuit and ground-fault current

A short-circuit and a ground-fault current maximum value at each point in the system increases as the system scale expands. They are especially easily greatly increased in the bulk power system that is directly susceptible to the newly installed generator. Therefore, the short-circuit and the ground-fault current will aim to remain below the value indicated in Table 9-11.

Table 9-11 Maximum value of short-circuit and ground-fault current in system

Votage Class	Short-circuit and ground fault current
400kV	63kA
230kV	63kA
132kV	63kA

Source: PGCB

When the short-circuit and the ground-fault current exceeds the value as shown in Table 9-11, appropriate reduction measures for the short-circuit and the ground-fault current as shown below will be adopted after comprehensively taking into account system stability, voltage stability and economic efficiency.

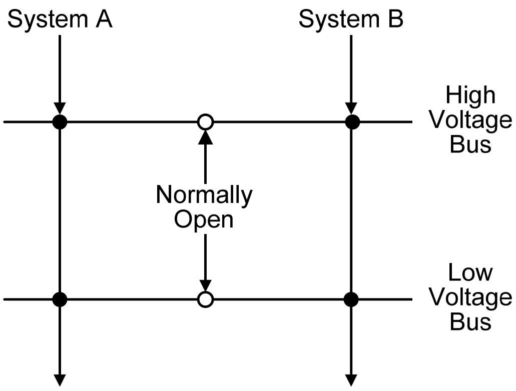
- System decomposition and generation dispersion
- Bus splitting of a power station and a substation under normal operations
- Bus separation of a power station and a substation in case of a fault
- Adoption of a high impedance transformer
- Adoption of a series reactor
- Adoption of an asynchronous method such as a DC transmission and a DC interconnection

There are two methods of the bus splitting of a power station and a substation to reduce the fault current as follows.

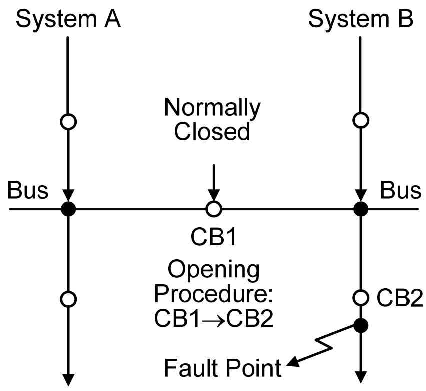
(a) Method of bus splitting under normal operations
The bus will be split with the normally-opened operations by installing the automatic bus tie circuit breaker.

(b) Method of bus splitting in the case of a fault
The bus will be interconnected under normal operations and the circuit breaker at the fault point after opening the bus in the case of a fault.

The method (a) is disadvantageous in that the advantage of the system interconnection is significantly damaged in spite of the most effective method. Meanwhile, the method (b) has disadvantages such as the unbalanced bank load and the fault clearing delay.



(a) Method of bus splitting under normal operations



(b) Method of bus splitting in case of fault

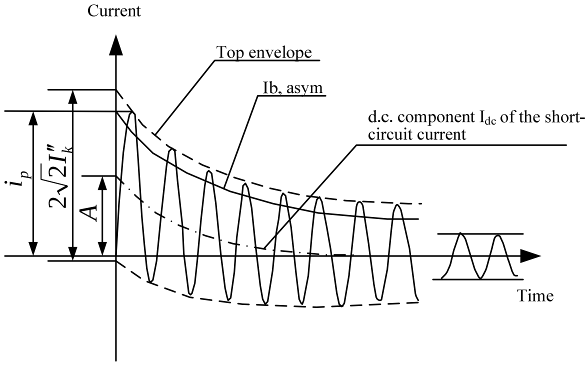
Source: PSMP Study Team

Fig. 9-13 Bus splitting method

This study has been carried out based on method (a). In addition, the replacement of the high impedance transformer and the installation of the series reactor will be effective as the measures for facilities.

As for the bus design of the power station and substation, its planning is necessary so as not to cause an interruption in system operations and maintenance by adopting an automatic bus tie circuit breaker method if necessary even when the bus is spitted by the aforementioned measures etc.

In the study of the short-circuit and the ground-fault current, the RMS asymmetrical short-circuit breaking current ($I_{b\ asym}$), defined in the IEC 60909 standard (Short-circuit calculation in three-phase ac systems), as shown in Fig. 9-14 will be calculated at a minimum time delay.



I''_k	Initial symmetrical short-circuit current
i_p	Peak short-circuit current
A	Initial value of the d.c. component i_{dc}
$i_{d.c.}$	d.c. component of short-circuit current

Source: IEC60909 etc.

Fig. 9-14 Fault current defined by IEC60909

(3) Transient stability

Transient stability will be carefully analyzed from the viewpoint of the overall power system in studying transmission planning according to power supply development. Various measures for stability improvement from the generator to the transmission line and substation facilities will also be studied, if necessary. After that, the necessary transmission capacity will be secured by effective measures.

Therefore, the transient stability analysis will be carried out according to the following conditions. The supply reliability will be secured without the limitations of significant generator output at the fault of a transmission line, as described in Table 9-1.

(a) Type of contingency

Three phase to the ground normally opened of a single-circuit transmission line at the same point for the system with a parallel double-circuit operation and the above transmission line

(b) Protection device and circuit breaker operations

The case of tripping the transmission lines by main protection and without reclosing will be studied. The fault clearing time by main protection is shown in Table 9-12.

Table 9-12 Maximum value of short-circuit and ground-fault current in system

Voltage class	Fault clearing time
400kV	160ms
230kV	160ms
132kV	160ms

Source: BANGDALESH GRID CODE DRAFT (October 18, 2000)

(4) Light load condition

As for the light load condition study, whether the proper voltage shown in 9.1.2 under the following condition was able to be maintained has been studied.

- Load of each substation: Setting for 45% of the load (heavy load condition) in case of the power flow and voltage study
- Generator: Stopping an inefficient generator until it corresponds to demand

The generator for the study is listed in AP Table 9-2.

(5) Existing facilities

Since there is some inadequate generator data, an analysis is carried out with the following standard data. (Table 9-13 - Table 9-15)

Table 9-13 Machine

Machine	Power factor	R Source (pu)	X Source (pu)	RG-Pos (pu)	XG-Pos (pu)	RG-Neg (pu)	XG-Neg (pu)	RG-Zero (pu)	XG-Zero (pu)
Hydro plant	0.85	0.00009	0.25	0.00009	0.25	0.00009	0.25	0.00009	0.25
Thermal plant	0.85	0.00009	0.2	0.00009	0.2	0.00009	0.2	0.00009	0.2

Source: PSMP Study Team

Machine	Model	T'd0	T"d0	T'q0	T"q0	H	D	Xd	Xq	X'd	X'q	X"d	X1	S(1.0)	S(1.2)
Hydro plant	GENSAL	5	0.05	-	0.06	5.084	1	1.5	1.2	0.4		0.25	0.12	0.03	0.25
Thermal plant	GENROU	6	0.05	1	0.05	3	0	1.4	1.35	0.3	0.6	0.2	0.1	0.03	0.4

Source: PSMP Study Team

Table 9-14 Excitation system

Machine	Model	TA/TB	TB	K	TE	EMIN	EMAX
Hydro plant	SEXS	0.1	10	100	0.1	0	5
Thermal plant	SEXS	0.1	10	100	0.1	0	5

Source: PSMP Study Team

Table 9-15 Governor

Machine	Model	R	r	Tr	Tf	Tg	VELM	Gmax	Gmin	TW	At	Dturb	qNl
Hydro plant	'HYGOV'	0.05	0.5	10	0.05	0.5	0.17	1	0	2	1.2	0.5	0.08
Machine	Model	R	T1	VMAX	VMIN	T2	T3	Dt					
Thermal plant	'TGOV1'	0.05	0.5	1.5	0	1.8	6	0					

Source: PSMP Study Team

(6) Newly installed transmission line and submission facilities

(a) Transmission line

The following are the standard parameters of the newly installed transmission line. The detailed data is shown in AP Table 9-3.

- Quad conductor for 400kV
- Bangladesh specification based on the existing facilities for 132kV and 230kV

(b) Generator

Analyses are carried out with standard data. (Table 9-13 - Table 9-15)

(c) Step-up transformer

The parameters of existing facilities similar to the capacity have been used. Otherwise the standard parameters have been used.

(d) Ttransformer

The parameters of the 230kV/132kV transformer are based on existing facilities. In addition, the standard parameters of the 400kV/230kV transformer are shown in AP Table 9-4.

(7) Construction cost

The construction cost for the power system expansion plan is based on the unit costs provided by PGCB, as shown in Table 9-16. In addition, for the construction cost of the transmission line across the river, it is assumed to be 40 times the standard cost based on information from Japanese concerned parties really involved in the 230kV transmission line construction of the river crossing part in Bangladesh thirty years ago.

Table 9-16 Unit cost for construction of transmission line and substation

		Unit Cost	
Overhead Line	132kV	0.1786	mil. US$/km/2cct
	230kV	0.357	mil. US$/km/2cct
	400kV	0.643	mil. US$/km/2cct
Underground Cable	132kV	0.893	mil. US$/km/2cct
	230kV	1.785	mil. US$/km/1cct
	400kV	3.215	mil. US$/km/1cct
River Crossing OHL[1]	400kV North 10km	257.2	mil. US$/2cct
	400kV Middle 4.5km	115.74	mil. US$/2cct
	400kV South 6km	154.32	mil. US$/2cct
Substation[2]	132/33kV(2x100MW, AIS)	5	mil. US$/station
	132/33kV(2x100MW, GIS)	5.714	mil. US$/station
	230/132kV(2x500MW, AIS)	23.3	mil. US$/station
	230/132kV(2x500MW, GIS)	26.7	mil. US$/station
	230/132kV(2x300MW, AIS)	14.0	mil. US$/station
	230/132kV(2x300MW, GIS)	16.0	mil. US$/station
	400/230kV(4x500MW, AIS)	81.2	mil. US$/station
	400/230kV(3x500MW, AIS)	60.9	mil. US$/station
	400/230kV(2x500MW, AIS)	40.6	mil. US$/station
	400/230kV(1x500MW, AIS)	20.3	mil. US$/station
Switching Station	400kV	20.3	mil. US$/station
BTB	230kV, 400kV	80.0	mil. US$/station
Static Capacitor	132kV	0.017	mil. US$/Mvar
	230kV	0.029	mil. US$/Mvar
	400kV	0.051	mil. US$/Mvar

Source: PGCB, PSMP Study Team

(8) Basic concept of cross border trading

The interconnection transmission line should be designed during the stage of the newly-constructed facilities to adjust the future reinforcement plan and the neighboring power system.

In order to construct such a reasonable interconnection transmission line, not only the immediate necessity of the construction but also the future plan concerning the overall power system should be thoroughly discussed at the stage of the construction plan study by all concerned nations.

In addition, the Back to Back (BTB) system is currently attracting a great deal of attention as an interconnection method. The BTB system has the advantage of being able to ease the power flow

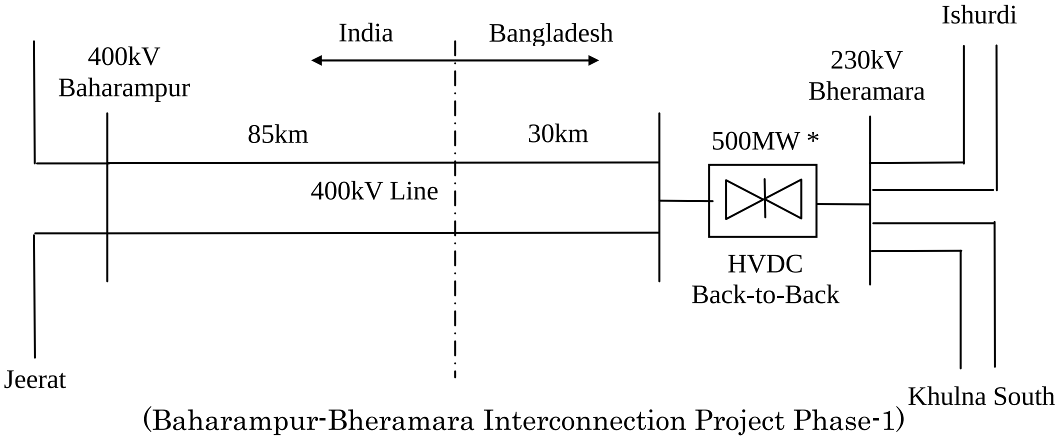
[1] Based on information from the Japanese concerned parties involved in the 230kV transmission line construction of the river crossing part in Bangladesh nearly thirty years ago

[2] The unit cost of the 400/232kV substation will be estimated assuming that the proportion to the number of the banks, the capacity of the single-unit capacity, and the voltage based on that of the 230/132kV substation (2×300MVA, GIS), which is the 16 mil. US$/ station.

control, grasp the solution to a problem concerning power system stability and the short circuit capacity via a large-scale AC power system, and an increase of the transmission capacity between the AC power systems.

(a) Planned project

The cross border trading between Baharampur (India) and Bheramara has been already planned by adopting the BTB system as shown in Fig. 9-15.



Source: BPDB

Fig. 9-15 Power system diagram of Asynchronous interconnection

(b) Other potential projects

For the cross border trading with the neighboring countries, the following candidate points have been considered at present.

- Indian Meghalaya state
  The hilly area of the 2,000m class extends to the Indian Meghalaya state which is adjacent to the northeast of Bangladesh. It is considered that the new transmission line for the interconnection will be difficult due to geographical factors, though there is existing hydro-power potential.

- Pallatana, Indian Tripura state
  Recently the burial of large-scale natural gas has been discovered in the Indian Tripura state which is adjacent to the east of Bangladesh, Pallatana gas power generation project (726.6MW) is planned. It is considered that the majority of the power generation will be consumed by the home country as the solution to power shortages.

- Indian Assam state
  There is potential of coal and hydro-power in the Indian northeastern Assam state. The reinforcement of the power system in India will be necessary because it is far from Bangladesh.

- Bhutan and Nepal
  It is necessary to import the electric power via India as there is large-scale hydro-power potential in Bhutan and Nepal.

- Myanmar
  Discussion between Bangladesh and Myanmar Governments is advancing for power import by Bangladesh from hydro power plant to be developed in Lemro site in Myanmar’s Rakhine State.

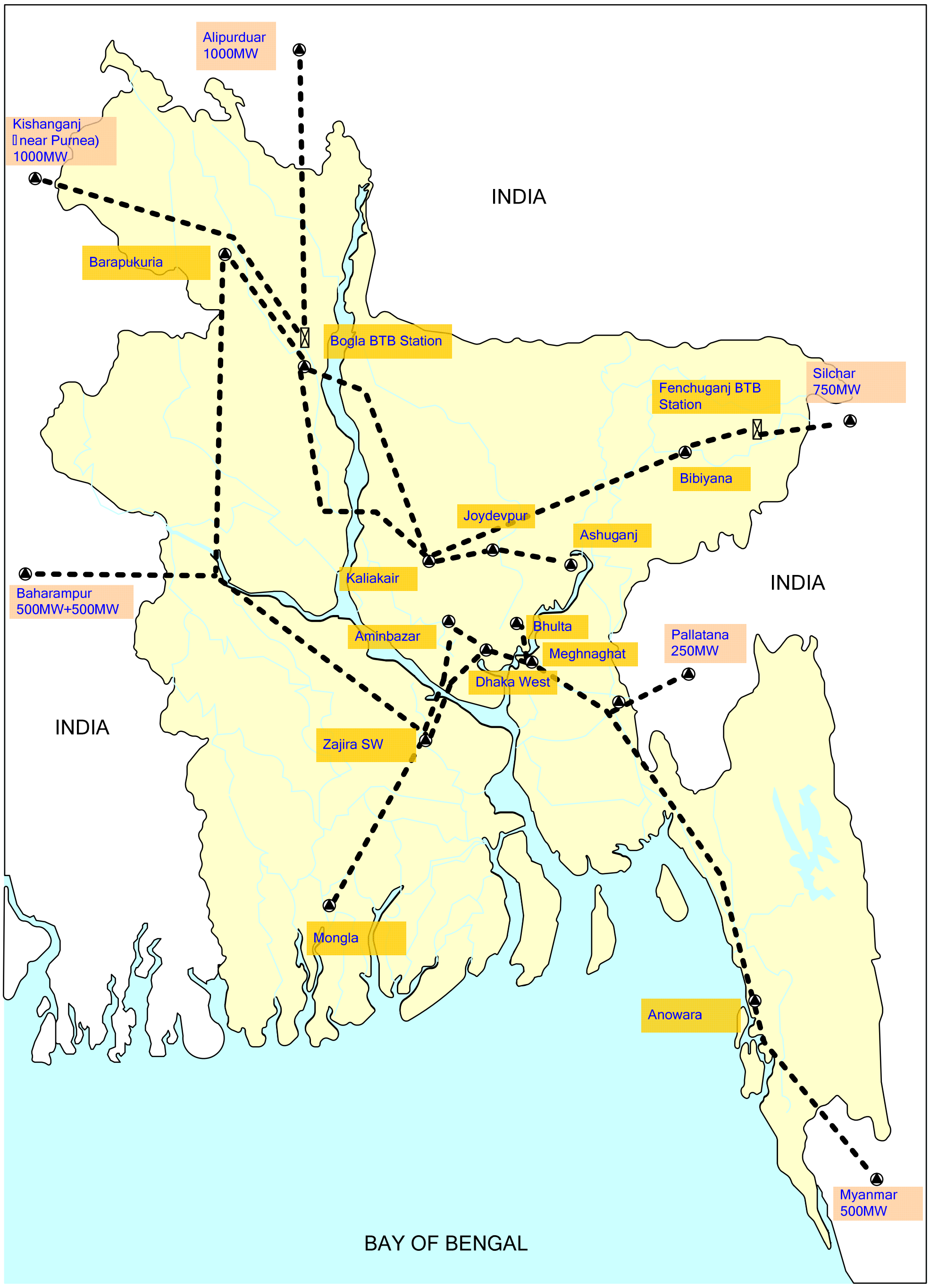
- Other
  Although, it is possible to connect a part of the small demand in South – West Bangladesh to India, it is not considered in this MP.

As for the interconnection in the northwestern region, increasing power flow from the northwest to the Dhaka region together with a rapidly advanced coal power development in the same region in the future should be considered. The number of circuits for the transmission line across the Jamuna River is increased as mentioned in 9.2.3(5)(c). Therefore, it is recommended to reduce the amount of interconnection in the northwestern region from the perspective of minimizing costs.

Moreover, neighboring countries such as India, Nepal, Bhutan, and Myanmar positively focusing on developing large-scale hydro power as renewable energy, and strengthening the wide area interconnection system contribute to power supply reliability improvements and measures for controlling global warming in each country. In conclusion, the interconnection with the neighboring countries was planned including the following two candidate site points with a current possibility as shown in Fig. 9-16.

- Indian Tripura state
  There is the possibility of further gas field development around Pallatana.
- Indian northeastern region
  It is possible to correspond with the system reinforcement in India though it is in a remote place from Bangladesh.

The voltage class for interconnection voltages (400kV or 230kV) will be individually studied, taking into account the amount of interconnection and the power flow conditions in the surrounding area, etc.



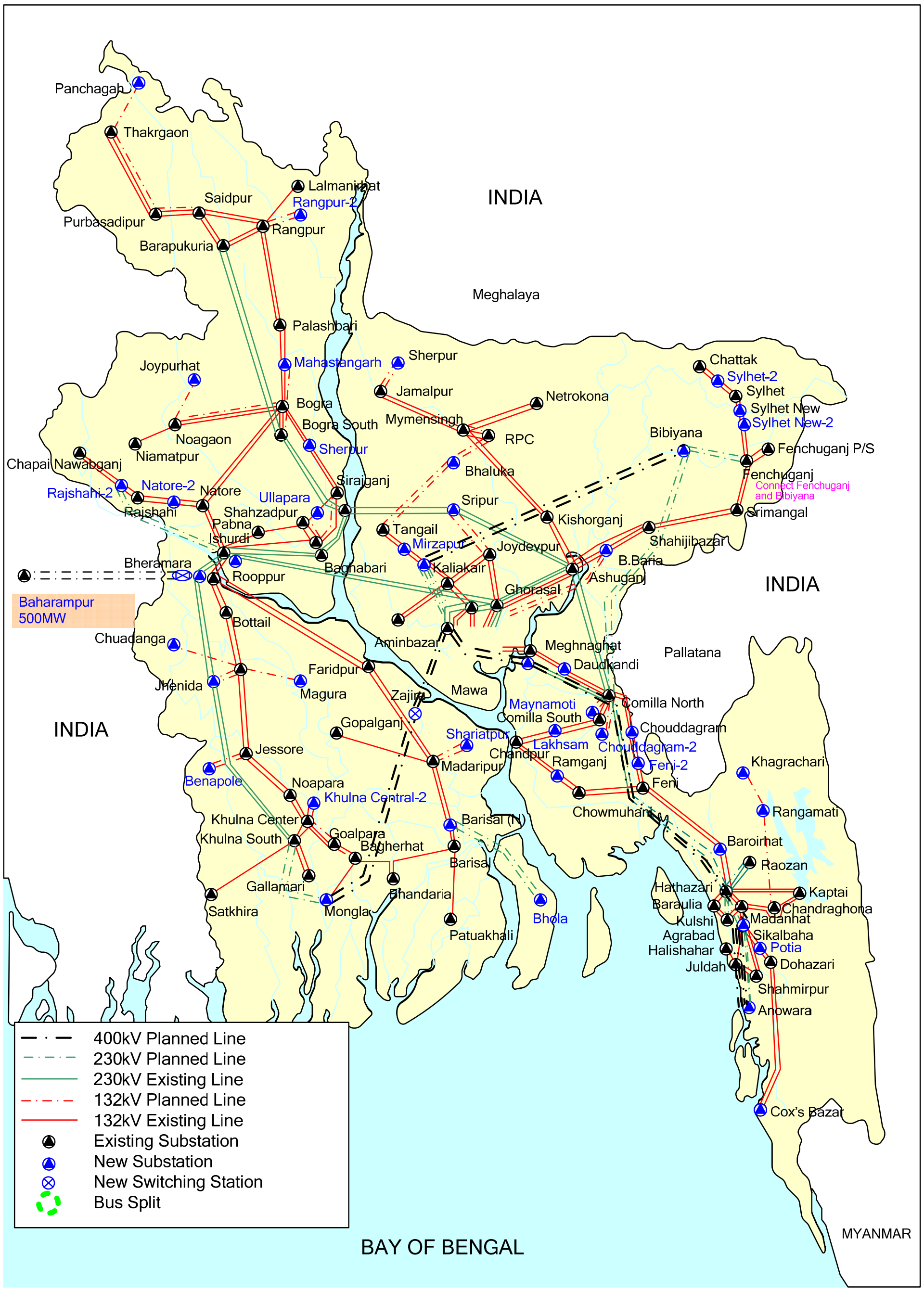
Source: PSMP Study Team

Fig. 9-16 Summary of potential interconnections (2030)

9.4.2 2015 plan

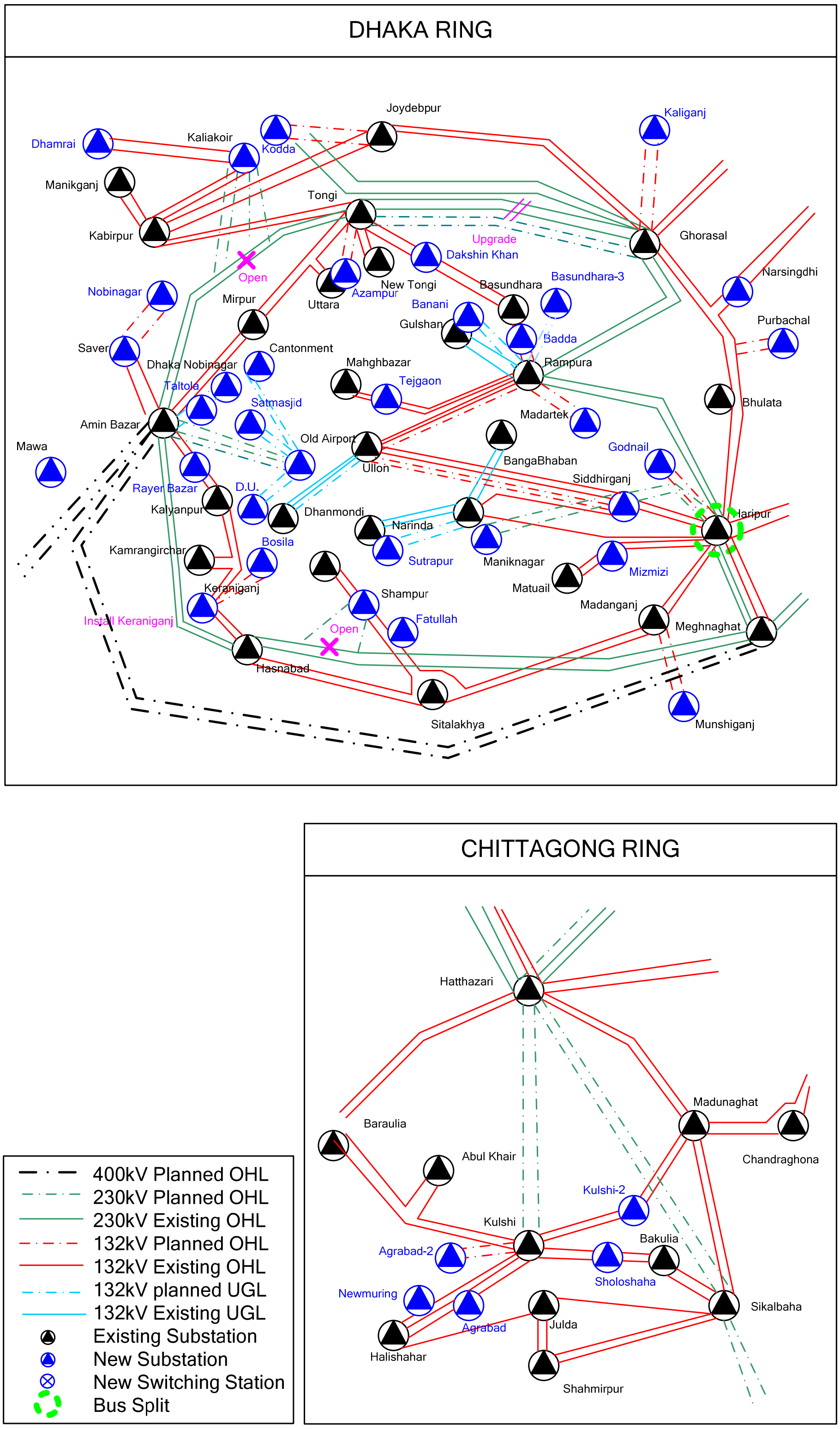
The 2015 power system expansion plan, which satisfies the planning criteria as mentioned in 9.4.1 , are shown in Fig. 9-17 and Fig. 9-18. The power flow is shown in APFig. 9-1 – APFig. 9-12.

System Configuration at 2015 (Grid Demand:10GW)



Source: PSMP Study Team

Fig. 9-17 Power system expansion plan at 2015 (overall system)



Source: PSMP Study Team

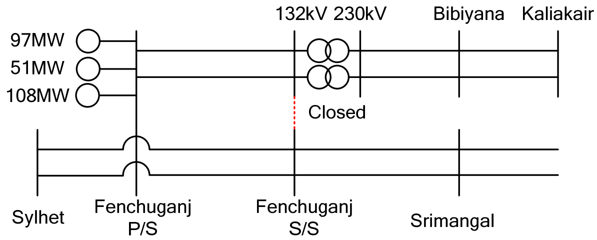
Fig. 9-18 Power system expansion plan at 2015 (Dhaka and Chittagong ring)

(1) Results of power flow and voltage analysis

Special instructions for the results of the power flow and voltage analysis are as follows.

- 230kV Fenchuganj substation

  According to the PGCB's plan, the bus of Fenchuganj 132kV substation will be split, and the power from the Fenchuganj power station will be transmitted to the 230kV Bibiyana substation through the 230kV transmission line, as shown in Fig. 9-19. However, the bus of the 132kV Fenchuganj substation will not be split due to a large voltage drop occurrence around the Fenchuganj substation.



Source: PSMP Study Team

Fig. 9-19 Power system around Fenchuganj substation

- 400kV Mongla-Aminbazar transmission line

  According to the PGCB's plan concerning the 400kV Mongla-Aminbazar transmission line, the transmission capacity will be insufficient in the future, and the amount of the investment for the river crossing where vast funds will be necessary will grow. Therefore, the 400kV switching station will be needs to be constructed at Zajira and a 400kV large capacity (quad-conductor) transmission line will be required.

- 400kV Meghnaghat-Anowara transmission line

  The 400kV large capacity (quad-conductor) transmission line will also be required between Meghnaghat and Anowara.

- 400kVAminbazar – Zajira transmission line

  The 400kV large capacity (quad-conductor) transmission line will also be required between Aminbazar and Zajira.

- 230kV Raozan-Hathazari transmission line

  An additional 230kV Raozan-Hathazari transmission line will not be necessary for the near term due to the 100MW operation of the Raozan power station. After the operation condition of the Raozan power station in the future is ascertained, it will be necessary to study additional line construction.

- Bhola power station

  A large voltage drop occurs when the two generators of the Bhola power station are stopped simultaneously. Therefore, the two generators of the Bhola power station will not be stopped simultaneously under heavy load conditions.

- 230kV Barisal (N)-Bhola transmission line

  The 230kV Barisal (N)-Bhola transmission line will be connected with the Barisal (N) substation without being connected with the Barisal substation because there is a restriction in surplus bay in the Barisal substation.

- 132kV Goalpara-Bagherhat transmission line
  Regarding the N-1 overload condition for the 132kV Bagherhat-Bandaria transmission line, it will be possible to evade it by opening those lines.

- 132kV Barisal-Patuakhali transmission line
  In case of the N-1 fault for the 132kV Barisal-Patuakhali single-circuit transmission line, it will be possible to evade it by opening the 132kV Bagherhat-Bandaria transmission line.

- 230kV Tongi-Ghorasal transmission line
  The construction of an additional 230kV Tongi-Ghorasal transmission line is impossible. Therefore, it will be required to be replaced with a 230kV large capacity transmission line.

(2) Results of the short-circuit and ground-fault current analysis

The bus 132kV splitting in the Haripur power station will be necessary because a large-capacity generator is connected to the 132kV bus of the Haripur power station. It was confirmed that the short-circuit and ground-fault current of all substations became less than 63kA via the aforementioned measures, as shown in the AP Table 9-5.

(3) Results of the system stability analysis

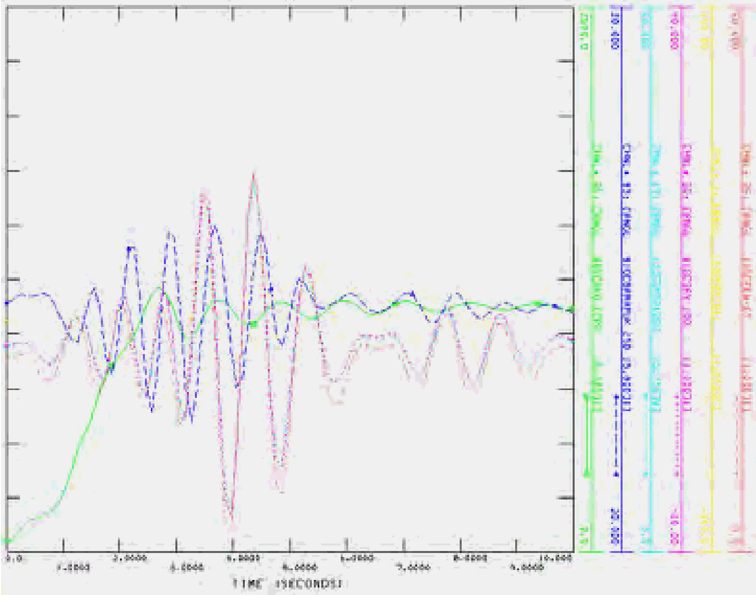
It has been confirmed that the system is unstable in case of the 230kV Bhola – Barisal(N) transmission line contingency. This will be improved by measure such as additional two circuits, 230kV Bhola – Barisal(N) transmission line or connection of two circuits 230kV Barisal (N) - Mongla. The result is shown in Fig. 9-20, Fig. 9-21. Since there exists some inadequate generator data for transient stability, an analysis is carried out with standard data. It is considered that the system stability analysis will be carried out again after data is maintained, and necessary measures are studied. The measures for improving system stability are considered as follows.

- Measures by system configuration
  Multi-route transmission line, system voltage upgrading, and the installation of an intermediate switching station

- Measures by generator and turbine control
  High initial response excitation, PSS (Power System Stabilizer), and turbine high-speed valve

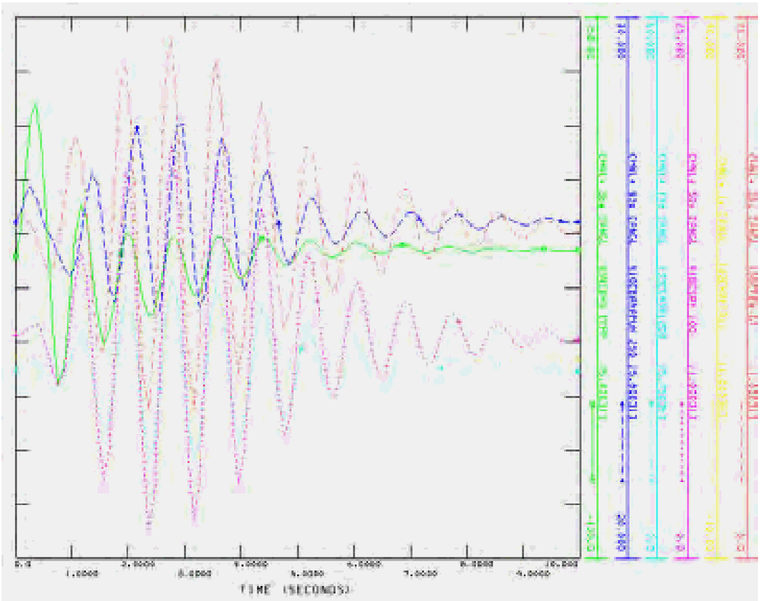
- Measures by relay and control system
  High speed fault clearing, high speed reclosing, and a predictive out-of-phase protection system

- Measures by special equipment
  SVC (Static Var Compensator), series capacitor, and damping resistor



Source: PSMP Study Team

Fig. 9-20 Results of the system stability analysis without measures



Source: PSMP Study Team

Fig. 9-21 Results of the system stability analysis with measures

(4) Light load study condition

The light load condition study has been also carried out. It was confirmed that the bus voltage of all substations remains within the stipulated range. The power flow is shown in APFig. 9-13 - APFig 9-18.

(5) Amount of facilities expansion

(a) Transmission line

The transmission line for which construction is necessary by 2015 is shown in AP Table 9-6. Summary is shown in Table 9-17 The 400kV and 230kV transmission line for which construction is necessary from 2010 to 2015 is shown in Table 9-18 and Table 9-19.

Table 9-17 Summary of transmission line required by 2015

Voltage (kV)	2010		2015		Additional (2015-2010)	
	Length (km)	cct.	Length (km)	cct.	Length (km)	cct.
132	6116.7	194	7384.8	339	1268.1	146
230	2644.8	40	3676.3	73	1031.5	33
400	0	0	1340	10	1340	12

Source: PSMP Study Team

Table 9-18 230kV transmission line required from 2010 to 2015[1]

From Substation	To Substation	CCT.	Length(km)
AMINBZ	KALIAKAIR	2	50.5
AMINBZ	OLDAIRPORT	3	30
ANOWARA	SIKALBAHA	2	40
BARISAL	BHOLA	2	120
BIBIYANA	COMIN	2	320
BIBIYANA	FENCHUGANJ	2	64
HARIPR	SIDDHIRGANJ	2	4
HATHZR	KULSHI	2	40
HATHZR	RAOZN	1	22.5
HATHZR	SIKALBAHA	2	50
ISHRDI	RAJSHAHI	2	140
KALIAKAIR	TONGI	2	50.5
KHULN	MONGLA	2	80
MANIKNAGAR	SIDDHIRGANJ	2	20
		Total	1031.5

Source: PSMP Study Team

Table 9-19 400 kV transmission line required from 2010 to 2015

From Substation	To Substation	cct.	Length(km)
AMINBAZAR	MEGHNAGHAT	2	100
AMINBAZAR	ZAJIRA	2	112.5
ANOWARA	MEGHNAGHAT	2	520
BIBIYANA	KALIAKAIR	2	336
MONGLA	ZAJIRA	2	272
		Total	1340.5

Source: PSMP Study Team

[1] 230kV GHRSL – TONG transmission line upgrade is not included.

(b) Substation

The substation for which construction is necessary by 2015 is shown in AP Table 9-7. Summary is shown in Table 9-20. The 230/132kV and 400/230kV substation for which construction is necessary from 2010 to 2015 is shown in .Table 9-21 and Table 9-22

Table 9-20 Summary of substation required by 2015

<table>
<tr><th>Voltage</th><th>East or West</th><th>Region</th><th colspan="3">Additional Number of Substation</th></tr>
<tr><td rowspan="5">132/33kV</td><td rowspan="3">East</td><td>Central</td><td>6</td><td rowspan="3">51</td><td rowspan="5">65</td></tr>
<tr><td>Dhaka</td><td>29</td></tr>
<tr><td>Southern</td><td>16</td></tr>
<tr><td rowspan="2">West</td><td>Northern</td><td>8</td><td rowspan="2">14</td></tr>
<tr><td>Western</td><td>6</td></tr>
<tr><td rowspan="5">230/132kV</td><td rowspan="3">East</td><td>Central</td><td>1</td><td rowspan="3">8</td><td rowspan="5">12</td></tr>
<tr><td>Dhaka</td><td>5</td></tr>
<tr><td>Southern</td><td>2</td></tr>
<tr><td rowspan="2">West</td><td>Northern</td><td>1</td><td rowspan="2">4</td></tr>
<tr><td>Western</td><td>3</td></tr>
<tr><td rowspan="4">400/230kV</td><td rowspan="3">East</td><td>Central</td><td>1</td><td rowspan="3">5</td><td rowspan="4">6</td></tr>
<tr><td>Dhaka</td><td>3</td></tr>
<tr><td>Southern</td><td>1</td></tr>
<tr><td>West</td><td>Western</td><td>1</td><td>1</td></tr>
</table>

Source: PSMP Study Team

Table 9-21 230/132kV Substation required from 2010 to 2015

Voltage	East or West	Region	Substation
230/132kV	East	Southern	KULSHI
230/132kV	East	Southern	SIKALBAHA
230/132kV	East	Dhaka	KALIAKAIR
230/132kV	East	Dhaka	OLDAIRPORT
230/132kV	East	Dhaka	SHAMPUR
230/132kV	East	Dhaka	SIDDHIRGANJ
230/132kV	East	Dhaka	SRIPUR
230/132kV	East	Central	FENCHUGANJ
230/132kV	West	Western	BARISAL
230/132kV	West	Western	BHERAMARA
230/132kV	West	Western	JHENIDA
230/132kV	West	Northern	RAJSHAHI

Source: PSMP Study Team

Table 9-22 400/230kV Substation required from 2010 to 2015)

Voltage	East or West	Region	Substation
400/230kV	East	Southern	ANOWARA
400/230kV	East	Dhaka	AMINBAZAR
400/230kV	East	Dhaka	MEGHNAGHAT2
400/230kV	East	Dhaka	KALIAKAIR
400/230kV	East	Central	BIBIYANA
400/230kV	West	Western	MONGLA

Source: PSMP Study Team

(c) Switching station

The switching station for which construction is necessary by 2015 is shown in Table 9-23.

Table 9-23 Summary of switching station required by 2015

Voltage	East or West	Region	New Switching Station
400kV	West	Western	Zajira

Source: PSMP Study Team

(d) Capacitor

The capacitor for which construction is necessary by 2015 is shown in Table 9-24.

Table 9-24 Summary of capacitor required by 2015

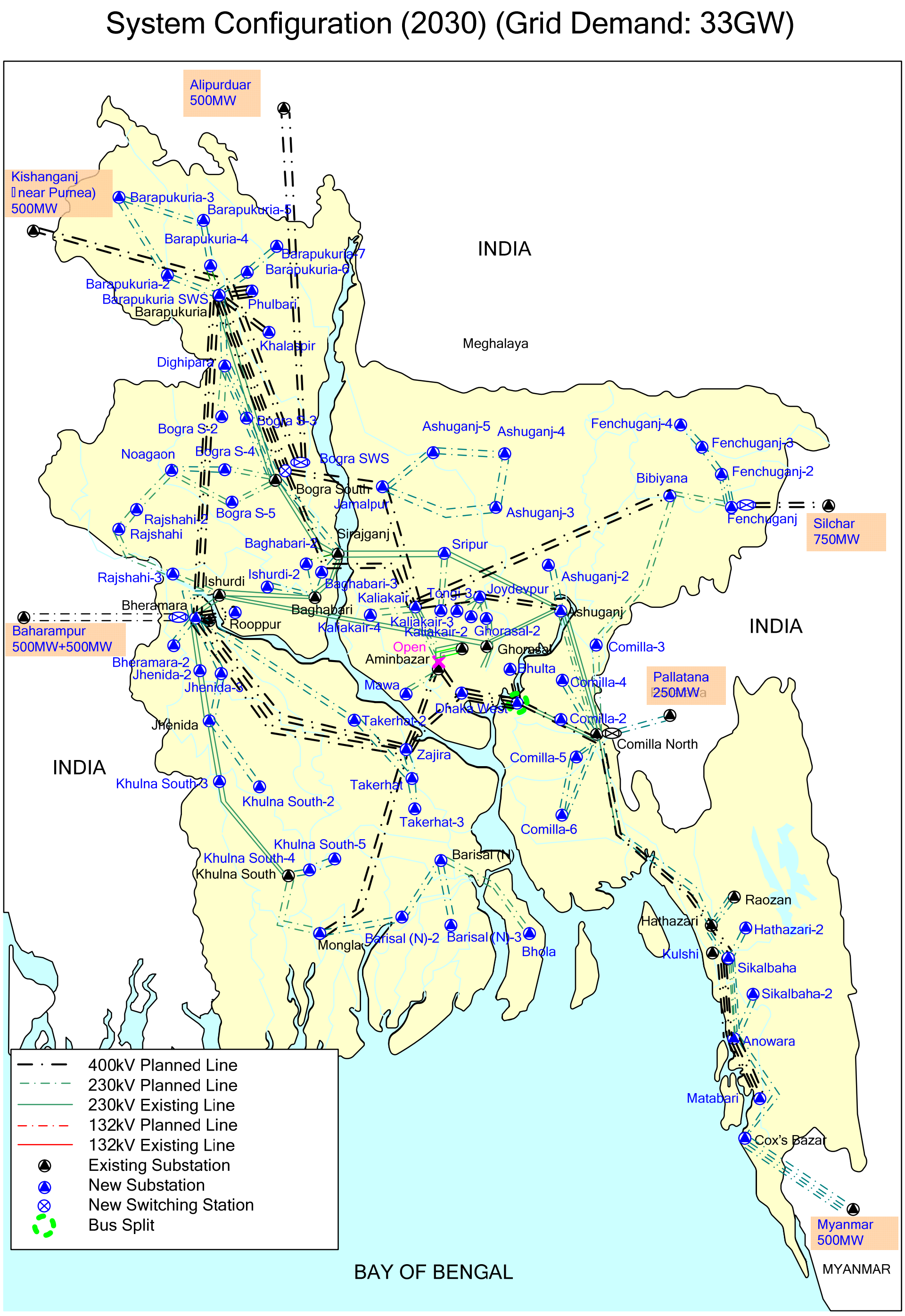
East or West	Region	Voltage	Substation	Capacity (Mvar)
East	Southern	132kV	HATHAZARI	45
East	Southern	132kV	DOHAZARI	45
East	Southern	132kV	BAKULIA	45
East	Southern	132kV	KHAGRACHARI	45
East	Dhaka	132kV	RAMPURA	90
East	Dhaka	132kV	AMINBAZAR	90
East	Central	132kV	JAMALPUR	25
East	Central	132kV	NETRAKONA	12.5
East	Central	132kV	CHHATAK	12.5
East	Southern	33kV	FENI	25
East	Southern	33kV	CHOWMUHANI	25
East	Southern	33kV	COMILLA (S)	50
East	Dhaka	33kV	HASNABAD	25
East	Dhaka	33kV	KALYANPUR	50
East	Dhaka	33kV	KABIRPUR	25
East	Dhaka	33kV	TANGAIL	25
East	Dhaka	33kV	JOYDEBPUR	37.5
East	Dhaka	33kV	BHULTA	25
East	Dhaka	33kV	MANIKGANJ	25
West	Western	132kV	CHUADANGA	12.5
West	Western	132kV	JESSORE	45
West	Western	132kV	JHENAIDAH	12.5
West	Western	132kV	KUSHTIA (BOT	25
West	Western	132kV	MAGURA	12.5
West	Western	132kV	GOPALGANJ	45
West	Western	132kV	MADARIPUR	45
West	Western	132kV	BARISAL	45
West	Western	132kV	BAGHERHAT	25
West	Western	132kV	MONGLA	25

East or West	Region	Voltage	Substation	Capacity (Mvar)
West	Western	132kV	GOLLAMARI	12.5
West	Western	132kV	PATUAKHALI	25
West	Northern	132kV	NIAMATPUR	62.5
West	Northern	132kV	JOYPURHAT	30
West	Northern	132kV	LALMONIRHAT	62.5
West	Northern	132kV	PANCHAGAR	30
West	Northern	132kV	THAKURGAON	45
West	Northern	132kV	RANGPUR-2	45
West	Northern	132kV	BOGRA-3	12.5
West	Western	33kV	SATKHIRA	12.5
West	Northern	33kV	NATORE	25
West	Northern	33kV	RAJSHAHI	25
West	Northern	33kV	CHAPAI NOWAB	25
West	Northern	33kV	SIRAJGANJ	12.5
West	Northern	33kV	NOAGAON	25
West	Northern	33kV	PALASHBARI	12.5
West	Northern	33kV	PURBASHADIPU	50

Source: PSMP Study Team

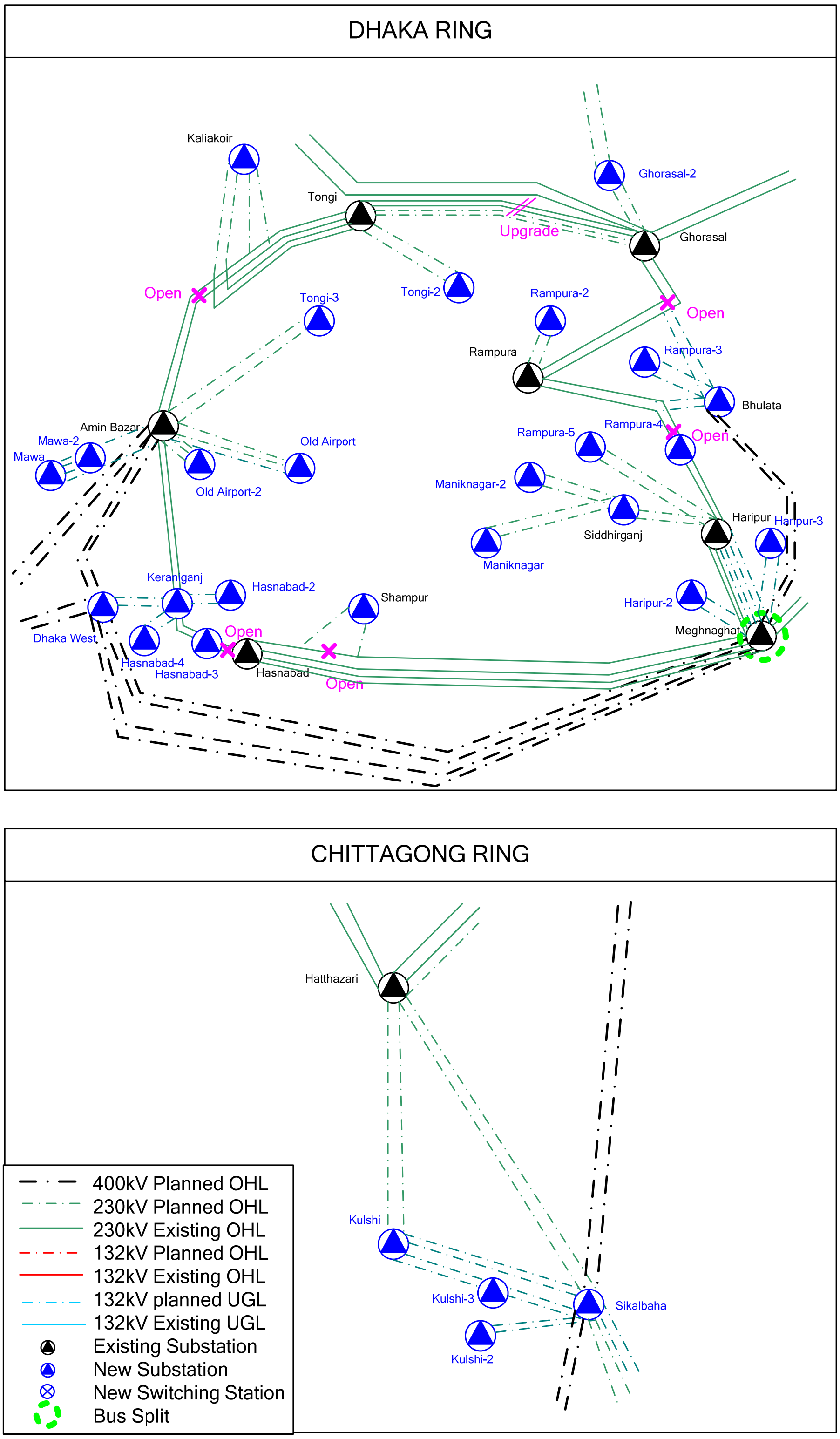
9.4.3 2030 plan

The 2030 power system expansion plan, which satisfies the planning criteria as mentioned in 9.4.1 is shown in Fig. 9-22 and Fig. 9-23. The power flow is shown in APFig. 9-19 and APFig. 9-20.



Source: PSMP Study Team

Fig. 9-22 Power system expansion plan at 2030 (overall system)



Source: PSMP Study Team

Fig. 9-23 Power system expansion plan at 2030 (Dhaka and Chittagong ring)

(1) Results of power flow and voltage analysis

Special instructions for the results of the power flow and voltage analysis are as follows.

- 400kV Bogra switching station
  For the purpose of reducing the short-circuit and the ground-fault current and the system stability, the switching station is constructed at Bogra. In addition, the Bogra switching station contributes to system stability.

- 400kV Bogra switching station-Kaliakair transmission line
  As for the 400kV Bogra switching station-Kaliakair four circuit transmission line, each two circuit is crossing the river at a different point taking into account system security.

- 400kV Aminbazar-Kaliakair transmission line
  Although The connection of the 400kV Aminbazar-Kaliakair transmission line results in an increase of the short-circuit and the ground-fault current around the Dhaka area, .the connection of 400kV Aminbazar-Kaliakai is recommended in the future for reliability and stability improvement.

- Interconnection transmission line connection
  If the interconnection transmission line is connected with the 400kV bus of the 400/230kV substation (Bogra, Bheramara), an additional 400kV/230kV transformer will be necessary because power is supplied to the adjacent demand. Therefore, it is connected with the 230kV bus of substation.

- Myanmar interconnection transmission line
  The construction of the switching station or the substation at Cox's Bazar, the measure by the series capacitor is required for the stability improvement. Detailed planning should be required in FS.

- 230kV Sirajganj – Siripur transmission line
  Although the 230kV Sirajganj – Siripur transmission line is over current (101.5%) when the east plant is maximum, it will be reacted by the operation.

- Installation of the series capacitor
  Although the series capacitor is effective for the improvement of the heavy load voltage drop and the system stabilization of the long transmission lines, it may cause the Sub-synchronous resonance (SSR). Therefore, it has not been adopted in this Study. Recently, the Thyristor Controlled Series Capacitor (TCSC) is being adapted to the worldwide actual system in USA, Brazil, China, India, etc. to prevent the SSR.

(2) Results of short-circuit and ground-fault current analysis

Moreover, for the 400kV Meghnaghat substation, the measures of bus splitting are also necessary. It has been confirmed that the short-circuit and the ground-fault current of all substations becomes less than 63kA via the aforementioned measures, as shown in AP Table 9-8..

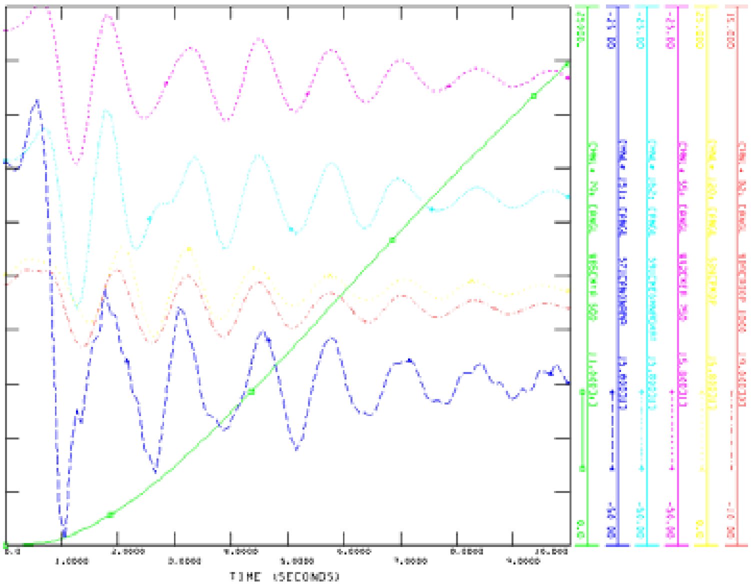
(3) Results of system stability analysis

The result is shown in Fig. 9-24, Fig. 9-25 and Fig. 9-26.

- 400kV Barapukuria – Bheramara 2cct
  400kV Barapukuria - Bheramara reinforce to 4cct.

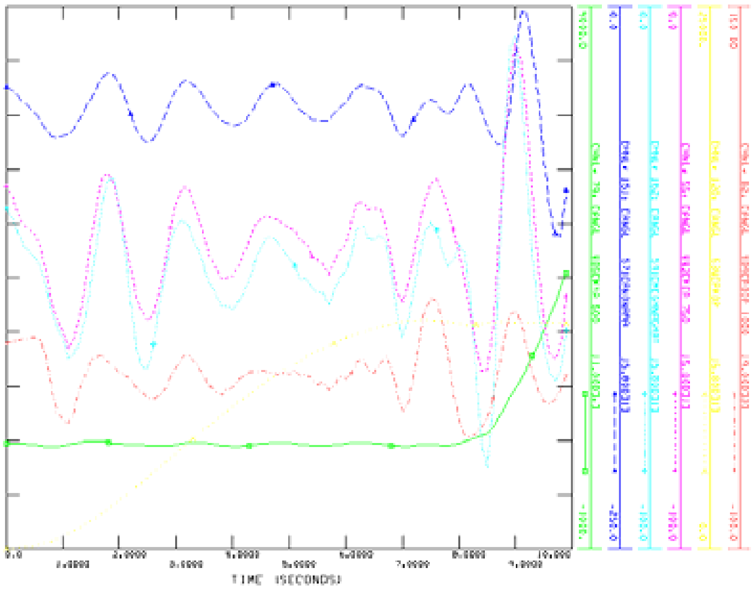
- 230kV Myanmar-Cox's Bazar 2cct
  230kV Myanmar-Cox's Bazar reinforce to 4cct.

Although the system stability improves by adding transmission lines, there are other measures. After data is adjusted, a detailed study will be required.



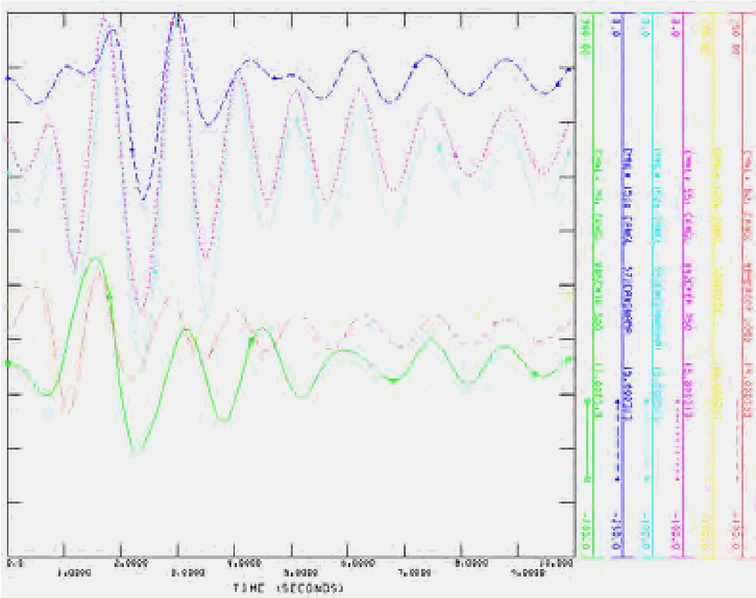
Source: PSMP Study Team

Fig. 9-24 Results of system stability analysis without measures (Myanmar)



Source: PSMP Study Team

Fig. 9-25 Results of system stability analysis with measures (Khalaspir)



Source: PSMP Study Team

Fig. 9-26 Results of system stability analysis after countermeasure

(4) Light load condition

The light load condition study has been also carried out. It has been confirmed that the bus voltage of all substations remains within the stipulated range. The power flow is shown in APFig. 9-21.

(5) Amount of facilities expansion

(a) Transmission line

The transmission line for which construction is necessary by 2030 is shown in AP Table 9-9. A summary is shown in Table 9-25. The 400kV transmission line for which construction is necessary from 2025 to 2030 is shown in Table 9-26.

Table 9-25 Summary of transmission line required by 2030

Voltage	2010		2030		Additional (2030-2010)	
	Length(km)	cct.	Length(km)	cct.	Length(km)	cct.
230	2644.8	40	9360.2	251	6715.4	211
400			4479.3	58	4479.3	58

Source: PSMP Study Team

Table 9-26 400kV transmission line required from 2025 to 2030

From Substation	To Substation	cct.	Length(km)
AMINBAZAR	DHAKA WEST	2	7.5
ANOWARA	MATARBARI	2	90
ANOWARA	SIKALBAHA	2	40
BHERAMARA	PKDP	4	810
BHERAMARA	ZAJIRA	2	337.5
BOGRA	KALIAKAIR	2	270
BOGRA	PKDP	2	225
DHAKA WEST	MEGHNAGHAT	4	59
DHAKA WEST	ZAJIRA	2	81
PHULBARI	PKDP	4	40
		Total	1960

Source: PSMP Study Team

(b) Substation

The substation for which construction is necessary by 2030 is shown in AP Table 9-10. A summary is shown in Table 9-27. The 400/230kV substation for which construction is necessary from 2025 to 2030 is shown in Table 9-28.

Table 9-27 Summary of substation required by 2030

Voltage	East or West	Region	Additional Number of Substation		
230/132kV	East	Southern	23	46	78
		Dhaka	25		
		Central	8		
	West	Western	15	43	
		Northern	17		
400/230kV	East	Southern	2	11	14
		Dhaka	6		
		Central	3		
	West	Western	3	3	

Source: PSMP Study Team

Table 9-28 400/230kV substation required from 2025 to 2030

Voltage	East or West	Region	Substation
400/230kV	East	Southern	SIKALBAHA
400/230kV	East	Dhaka	DHAKA WEST

Source: PSMP Study Team

(c) Switching station

The switching station for which construction is necessary by 2030 is shown in Table 9-29.

Table 9-29 Summary of switching station required by 2030

Voltage	East or West	Region	New Switching Station
400kV	West	Northern	Bogra
400kV	West	Northern	Barapukuria

Source: PSMP Study Team

(d) Capacitor

The capacitor for which construction is necessary by 2030 is shown in Table 9-30.

Table 9-30 Summary of capacitor required by 2030

East or West	Region	Voltage	Substation	Capacity (Mvar)
East	Southern	230kV	HATHZR	100
East	Southern	230kV	COMIN	400
East	Southern	230kV	KULSHI	400
East	Southern	230kV	COXS BAZAR	100
East	Southern	230kV	HATHZR-2	200
East	Southern	230kV	KULSHI-2	200
East	Southern	230kV	COMIN-2	300
East	Southern	230kV	COMIN-3	200

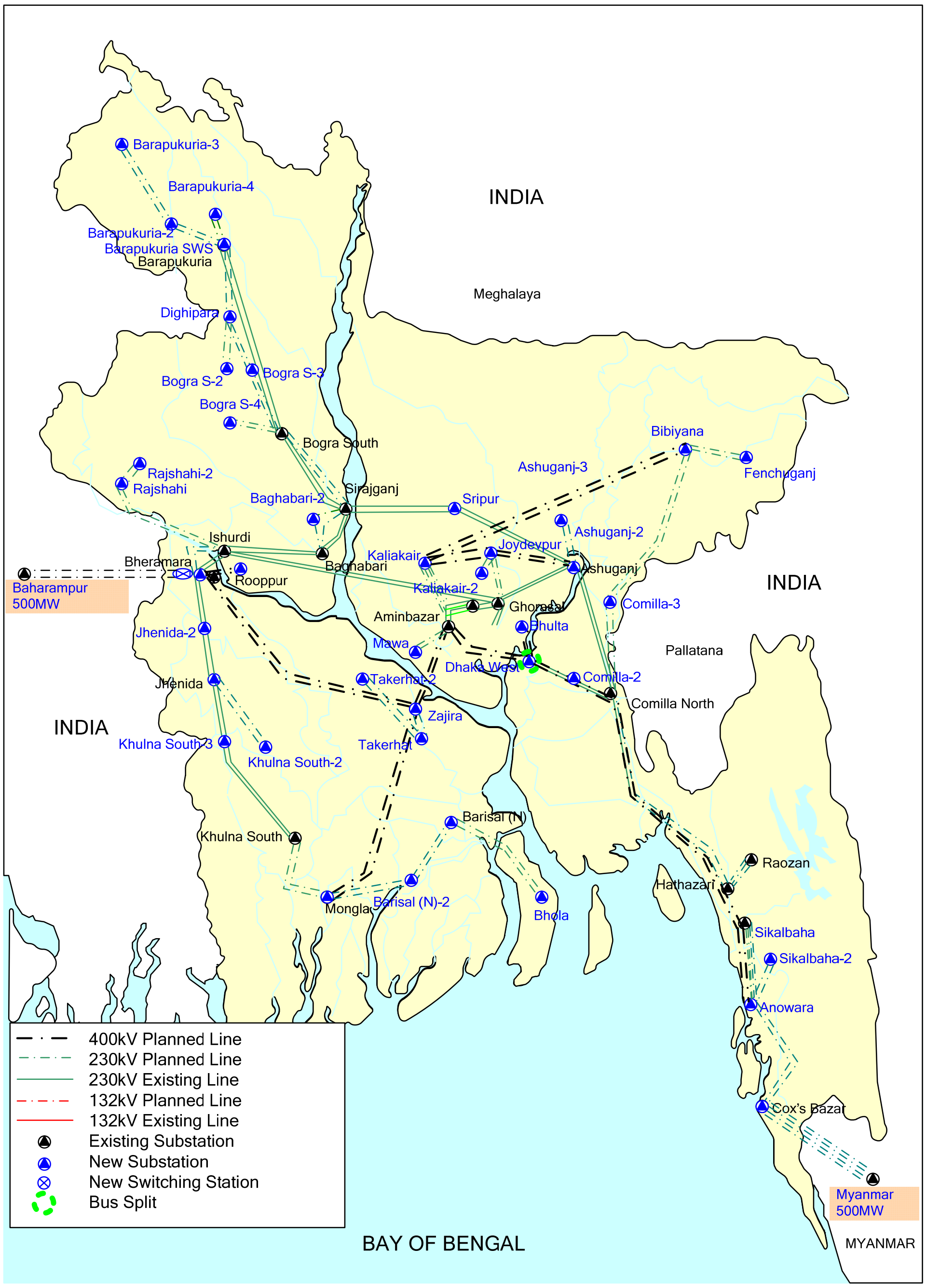
East or West	Region	Voltage	Substation	Capacity (Mvar)
East	Southern	230kV	COMIN-6	200
East	Dhaka	230kV	MANIKNAGAR	500
East	Dhaka	230kV	GHRSL	300
East	Dhaka	230kV	TONGI	100
East	Dhaka	230kV	HARIPR	200
East	Dhaka	230kV	HASNBD	500
East	Dhaka	230kV	OLDAIRPORT	500
East	Dhaka	230kV	SRIPUR	100
East	Dhaka	230kV	HARIPR2	200
East	Dhaka	230kV	RAMPR2	500
East	Dhaka	230kV	TONGI-2	300
East	Dhaka	230kV	TONGI-3	300
East	Dhaka	230kV	HASNBD-2	200
East	Dhaka	230kV	HASNBD-3	200
East	Dhaka	230kV	HASNBD-4	200
East	Dhaka	230kV	OLDAIRPORT-2	500
East	Dhaka	230kV	KALIAKAIR-2	300
East	Dhaka	230kV	KALIAKAIR-3	300
East	Dhaka	230kV	KALIAKAIR-4	300
East	Dhaka	230kV	RAMPR-2	300
East	Dhaka	230kV	RAMPR-3	200
East	Dhaka	230kV	RAMPR-5	200
East	Dhaka	230kV	GHRSL-2	300
East	Central	230kV	FENCHUGANJ	100
East	Central	230kV	ASHUGNJ-2	300
East	Central	230kV	ASHUGNJ-3	200
East	Central	230kV	ASHUGNJ-4	200
East	Central	230kV	ASHUGNJ-5	100
East	Central	231kV	FENCHUGANJ-3	100
East	Central	232kV	FENCHUGANJ-4	200
West	Western	230kV	KHULN	200
West	Western	230kV	JHENIDA	200
West	Western	230kV	KHULN-2	200
West	Western	230kV	KHULN-5	100
West	Western	230kV	BARISAL-3	200
West	Western	233kV	TAKERHAT-2	200
West	Western	234kV	TAKERHAT-3	200
West	Northern	230kV	RAJSHAHI	200
West	Northern	230kV	BAGHA	200
West	Northern	230kV	BOGRS	500
West	Northern	230kV	NOAGAON	200
West	Northern	230kV	BOGRS-3	100
West	Northern	230kV	BOGRS-2	100
West	Northern	230kV	ISHRDI-2	200
West	Northern	230kV	RAJSHAHI-2	100
West	Northern	230kV	BRPUK-3	200
West	Northern	230kV	BRPUK-5	200
West	Northern	230kV	BRPUK-7	200

Source: PSMP Study Team

9.4.4 2020 plan

For the 2020 power system expansion plan, the power flow, the voltage, the short-circuit and the ground-fault current have been only confirmed, and the system configuration is shown in Fig. 9-27 and Fig. 9-28. The power flow is shown in APFig. 9-22 and APFig. 9-23. The 400kV transmission line for which construction is necessary from 2015 to 2020 is shown in Table 9-31 The 400/230kV substation for which construction is necessary from 2015 to 2020 is shown in Table 9-32.

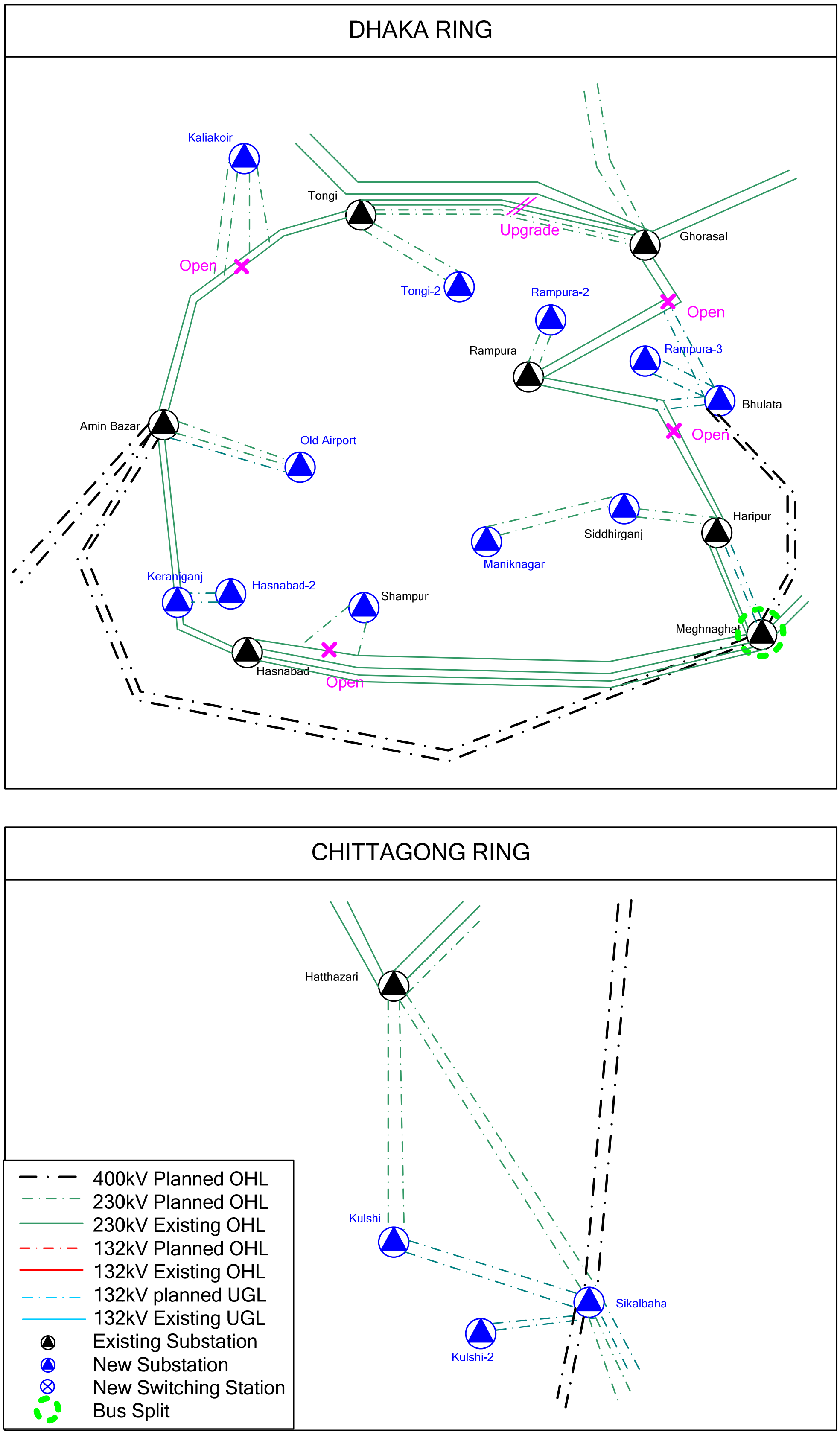
System Configuration (2020) (Grid Demand: 18GW)



Source: PSMP Study Team

Fig. 9-27 Power system expansion plan at 2020 (overall system)

TEPCO



Source: PSMP Study Team

Fig. 9-28 Power system expansion plan at 2020 (Dhaka and Chittagong ring)

Table 9-31 400kV transmission line required from 2015 to 2020

From Substation	To Substation	cct.	Length(km)
JOYDEBPUR	ASHUGANJ	2	56.25
MEGHNAGHAT	BHULTA	2	51.75
KALIAKAIR	JOYDEBPUR	2	56.25
ROOPPUR	BHERAMARA	2	24.75
ZAJIRA	BHERAMARA	2	337.5
		Total	526.5

Source: PSMP Study Team

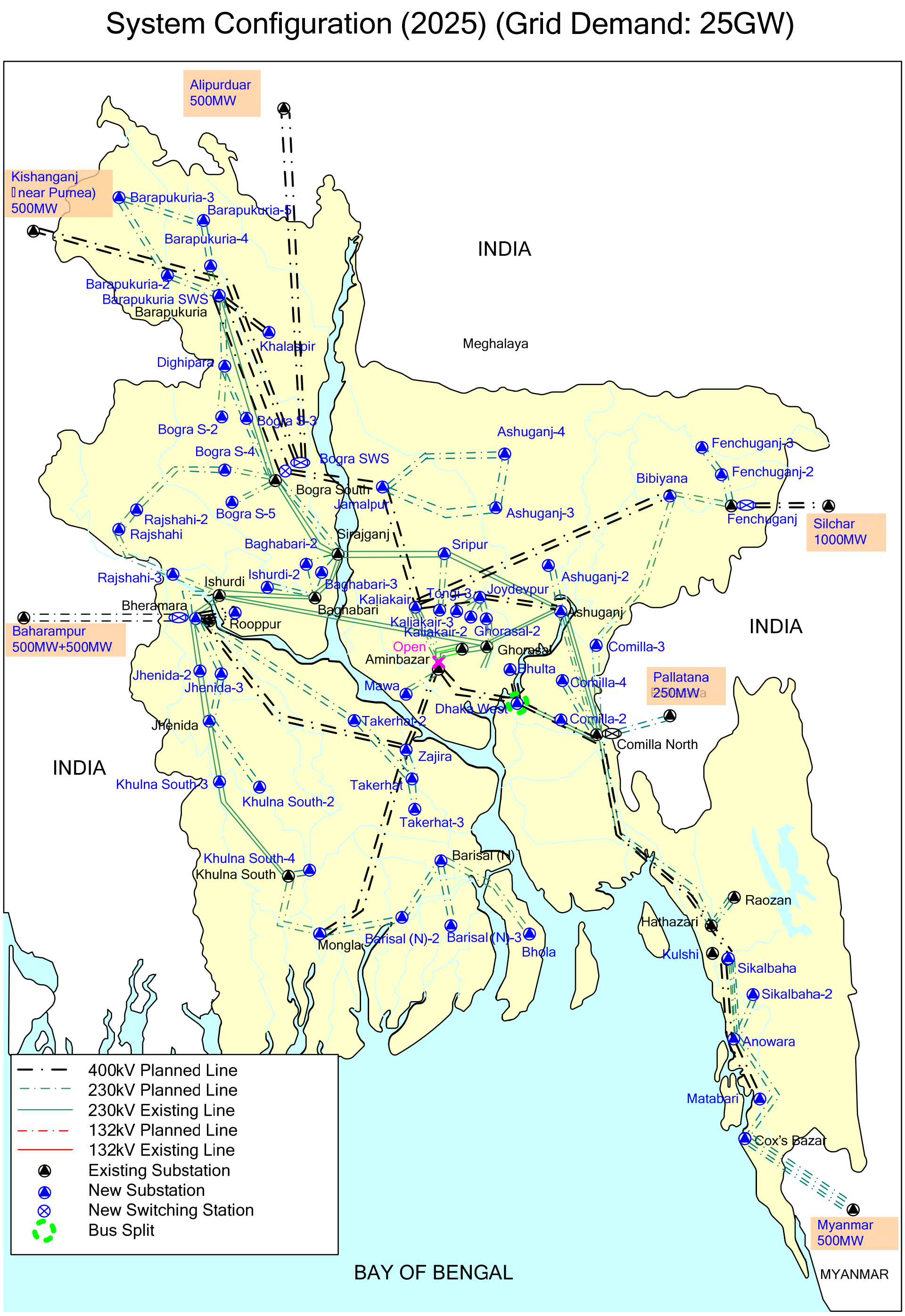
Table 9-32 400/230kV substation required from 2015 to 2020

Voltage	East or West	Region	Substation
400/230kV	East	Dhaka	BHULTA
400/230kV	East	Dhaka	JOYDEBPUR
400/230kV	East	Central	ASHUGANJ
400/230kV	West	Western	ZAJIRA
400/230kV	West	Western	BHERAMARA

Source: PSMP Study Team

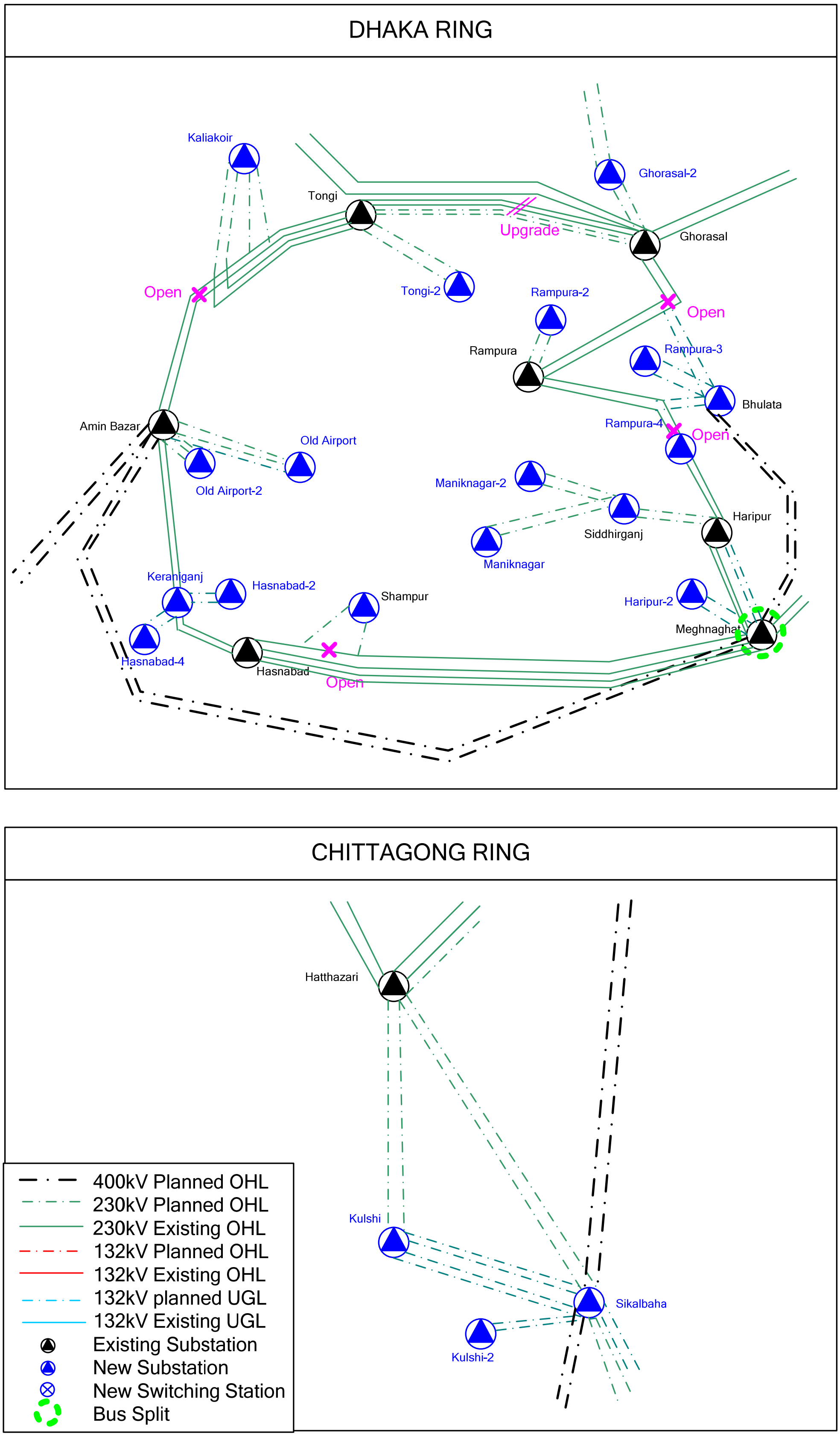
9.4.5 2025 plan

For the 2025 power system expansion plan, the power flow, the voltage, the short-circuit and the ground-fault current have been only confirmed, and the system configuration is shown in Fig. 9-29 and Fig. 9-30. The power flow is shown in APFig. 9-24 and APFig. 9-25. The 400kV transmission line for which construction is necessary from 2020 to 2025 is shown in Table 9-33. The 400/230kV substation for which construction is necessary from 2020 to 2025 is shown in Table 9-34.



Source: PSMP Study Team

Fig. 9-29 Power system expansion plan at 2025 (overall system)



Source: PSMP Study Team

Fig. 9-30 Power system expansion plan at 2025 (Dhaka and Chittagong ring)

Table 9-33 400kV transmission line required from 2020 to 2025

From Substation	To Substation	cct.	Length(km)
ANOWARA	MATARBARI	2	90
BHERAMARA	ROOPPUR	2	24.75
BOGRA	JAMALPUR	2	130.5
BOGRA	PKDP	2	225
JAMALPUR	KALIAKAIR	2	162
KHARASPIR	PKDP	2	20
		Total	652.25

Source: PSMP Study Team

Table 9-34 400/230kV substation required from 2020 to 2025

Voltage	East or West	Region	Substation
400/230kV	East	Central	JAMALPUR

Source: PSMP Study Team

9.4.6 Construction cost

The construction cost based on the analysis results is shown in Table 9-35 and Table 9-36.

Table 9-35 Construction cost for facilities expansion (2010-2015)[1]

		Unit Cost		Required amount	Required Cost	
Overhead Line	132kV	0.1786	mil. US$/km/2cct	606.9	108.4	mil. US$
	230kV	0.357	mil. US$/km/2cct	500.8	178.8	mil. US$
	400kV	0.643	mil. US$/km/2cct	700.0	450.1	mil. US$
Underground Cable	132kV	0.893	mil. US$/km/2cct	54.3	48.5	mil. US$
	230kV	1.785	mil. US$/km/1cct	30.0	53.6	mil. US$
	400kV	3.215	mil. US$/km/1cct	0.0	0.0	mil. US$
River Crossing OHL	400kV North 10km	257.2	mil. US$/2cct	0	0.0	mil. US$
	400kV Middle 4.5km	115.74	mil. US$/2cct	0	0.0	mil. US$
	400kV South 6km	154.32	mil. US$/2cct	1	154.3	mil. US$
Substation	132/33kV(2x100MW, AIS)	5	mil. US$/station	46	230.0	mil. US$
	132/33kV(2x100MW, GIS)	5.714	mil. US$/station	19	108.6	mil. US$
	230/132kV(2x500MW, AIS)	23.3	mil. US$/station	0	0.0	mil. US$
	230/132kV(2x500MW, GIS)	26.7	mil. US$/station	5	133.3	mil. US$
	230/132kV(2x300MW, AIS)	14.0	mil. US$/station	7	98.0	mil. US$
	230/132kV(2x300MW, GIS)	16.0	mil. US$/station	0	0.0	mil. US$
	400/230kV(4x500MW, AIS)	81.2	mil. US$/station	0	0.0	mil. US$
	400/230kV(3x500MW, AIS)	60.9	mil. US$/station	1	60.9	mil. US$
	400/230kV(2x500MW, AIS)	40.6	mil. US$/station	4	162.3	mil. US$
	400/230kV(1x500MW, AIS)	20.3	mil. US$/station	1	20.3	mil. US$
Switching Station	400kV	20.3	mil. US$/station	1	20.3	mil. US$
BTB	230kV, 400kV	80.0	mil. US$/station	1	80.0	mil. US$
Static Capacitor	132kV	0.017	mil. US$/Mvar	1528	25.5	mil. US$
	230kV	0.029	mil. US$/Mvar	0	0.0	mil. US$
	400kV	0.051	mil. US$/Mvar	0	0.0	mil. US$
				Total	1932.7	mil. US$

Source: PSMP Study Team

[1] Cross border transmission line is included. Bheramara 30km

Table 9-36 Construction cost for facilities expansion (2010-2030)[1]

		Unit Cost		Required amount	Required Cost	
Overhead Line	132kV	0.1786	mil. US$/km/2cct	606.9	108.4	mil. US$
	230kV	0.357	mil. US$/km/2cct	3035.2	1083.6	mil. US$
	400kV	0.643	mil. US$/km/2cct	2693.1	1731.7	mil. US$
Underground Cable	132kV	0.893	mil. US$/km/2cct	54.3	48.5	mil. US$
	230kV	1.785	mil. US$/km/1cct	45.0	80.3	mil. US$
	400kV	3.215	mil. US$/km/1cct	0.0	0.0	mil. US$
River Crossing OHL	400kV North 10km	257.2	mil. US$/2cct	1	257.2	mil. US$
	400kV Middle 4.5km	115.74	mil. US$/2cct	1	115.7	mil. US$
	400kV South 6km	154.32	mil. US$/2cct	2	308.6	mil. US$
Substation	132/33kV((2x100MW, AIS)	5	mil. US$/station	46	230.0	mil. US$
	132/33kV((2x100MW, GIS)	5.714	mil. US$/station	19	108.6	mil. US$
	230/132kV(2x500MW, AIS)	23.3	mil. US$/station		0.0	mil. US$
	230/132kV(2x500MW, GIS)	26.7	mil. US$/station	31	826.7	mil. US$
	230/132kV(2x300MW, AIS)	14.0	mil. US$/station	47	658.0	mil. US$
	230/132kV(2x300MW, GIS)	16.0	mil. US$/station		0.0	mil. US$
	400/230kV(4x500MW, AIS)	81.2	mil. US$/station	6	487.0	mil. US$
	400/230kV(3x500MW, AIS)	60.9	mil. US$/station	5	304.3	mil. US$
	400/230kV(2x500MW, AIS)	40.6	mil. US$/station	3	121.7	mil. US$
	400/230kV(1x500MW, AIS)	20.3	mil. US$/station		0.0	mil. US$
Switching Station	400kV	20.3	mil. US$/station	2	40.6	mil. US$
BTB	230kV, 400kV	80.0	mil. US$/station	3	240.0	mil. US$
Static Capacitor	132kV	0.017	mil. US$/Mvar	1528	25.5	mil. US$
	230kV	0.029	mil. US$/Mvar	13300	386.2	mil. US$
	400kV	0.051	mil. US$/Mvar	0	0.0	mil. US$
				Total	7162.6	mil. US$

Source: PSMP Study Team

[1] Cross border transmission line is included.
400kV Kishanganj 240km, Alipurduar 170km, Fenchuganj 40km, Bheramara 30km
230kV Commila 20km, Cox's Bazar 30km

9.5 Road map and action plan for realization of Master Plan

In this clause, domestic power system expansion according to the power demand increase was summarized from short, mid and long-term perspectives aspect as shown in Table 9-37.

Table 9-37 Road map and action plan for realization of Master Plan

Aspect	Power demand milestone in Master Plan	Issue	Action plan
Short-term	10GW for 2015	Power system expansion according to the power demand increase	■ Construction of new sixty nine 132/33kV substations ■ Construction of a transmission line across the river adjacent to Padma Bridge ■ Domestic power system expansion for interconnection with Beharampur
Middle-term	18GW for 2020	Power system expansion according to the power demand increase	■ Domestic power system expansion for interconnection with Myanmar
Long-term	33GW for 2030	Power system expansion according to the power demand increase	■ Construction of a transmission line across the river adjacent to Jamuna Bridge and Bogra District ■ Domestic and international power system expansion for interconnection with Alipurduar, Kishanganj, Baharampur, Silchar, and Pllatana

Source: PSMP Study Team

9.6 Distribution system

Distribution system should be developed in line with the power generation expansion plan and transmission expansion plan contained in the Master Plan in order to match the power supply and demand. Distribution utilities must have their own Distribution Expansion Plan in conformity with this Master Plan to realize the vision to provide access to electricity to all by 2021.

9.7 Recommendations

The following items should be taking into account for reviewing this PSMP-2010.

(1) Design of the transmission line across the river
The 400kV transmission line across the river has been studied by adopting the quad conductors to secure a large capacity. As another option, the 765kV design should also be taken into account in order to cope with the ultra-long-term increasing power flow of the east-west interconnection.

(2) Promotion of underground transmission system in urban area
In the urban area, the promotion of the underground transmission system will be a key consideration because the procuring of the transmission line right-of-way and the substation site becomes more difficult as the year passes.

(3) Additional data maintenance for system analysis
There is some inappropriate data for the system analysis. In particular, as recommended in PSMP-2006, the owners of the generation facilities and PGCB will need to make a considerably greater and better coordinated effort of the data maintenance.

(4) Adoption of N-2 criteria
The adoption of N-2 criteria should be evaluated for the grid connection of large-scale power generation such as nuclear power plants on a case-by-case basis.

(5) Strengthening of human resources development for system analysis
The system analysis is a technology necessary to form a power system with high efficiency and reliability. Additionally, a technology with a high degree of specialization

peculiar to each power utility is requested, and it is an urgent issue that the human resources development for system analysis in the future be strengthened.

(6) Distribution expansion plan based on this Master Plan

Distribution system also needs to be expanded commensurate to the generation and transmission expansion plans.

Chapter 10 Financing for Materialization of the Master Plan

10.1 Total investment required and funding sources

10.1.1 Capital cost

(1) Generation and transmission plants

For the construction of new generation and transmission plants constituting the Master Plan, the total investment costs are estimated to be as follows;

Table 10-1 Generation and transmission plants and cost estimates (FY 2010 constant price)[1]

Fuel Type	Capacity	Investment Cost (Tk Billion)	Investment Cost (US$ million)
Coal			
Domestic Coal	11,050 MW	1,094	15,721
Imported Coal	8,400 MW	935	13,436
Gas	8,956 MW	531	7,630
Furnace Oil	3,817 MW	300	4,311
Diesel Oil	500 MW	39	560
Hydro	100 MW	10	144
Renewable Energy	111 MW	25	359
International Connection	3,500 MW		
Transmission	—	524	7,530
Total	36,434 MW	3,458	49,691

Source: PSMP Study Team

(2) Related facilities

The Master Plan requires the following facilities to be developed along with the development of the generation and transmission plants;

Table 10-2 Related facilities required for the Master Plan (FY 2010 constant price)[2]

Facility	Particulars	Investment Cost (Tk Billion)	Investment Cost (US$ million)
Domestic Coal Mines	4 mines at BCMC, Khalaspir, Dighipara & Phulbari	585	8,406
Domestic Gas Fields		446	6,409
Coal Center for Imported Coal	4 centers at Chittagong South, Mongla, Matarbari & Sonadia	115	1,653
Gas Transmission		87	1,250
LNG Terminal		19	273
Single Point Mooring		5	72

[1] The plants listed in the table contain the ones that will expire prior to 2030 due to a short life span and the total capacities do not tally with the net increase of capacities under and at the end of the Master Plan. The investment cost for the transmission of electricity through the international connection is included in the transmission cost. Aside from the plants listed, the government of Bangladesh maintains a plan to develop 4,000 MW of nuclear power generation. The exchange rate applied for calculation is US$1=Taka 69.59 (the actual average rate for FY 2010).

[2] Out of the plants listed, domestic gas development, gas transmission, LNG terminal, oil refinery, ports will serve their purposes including the ones other than the power supply. The cost expressed in the table indicates the cost of the portion that serves the power supply only. The exchange rate applied is the same of that of the preceding table.

Facility	Particulars	Investment Cost (Tk Billion)	Investment Cost (US$ million)
Oil Refinery		35	503
Railroad	4 lines of Mongla-Khulna, Cittagong-Chittagong South, Matarbari & Sonadia	18	259
Deep Sea Port	2 ports at Matarbari & Sonadia	140	2,012
Total		1,449	20,822

Source: PSMP Study Team

10.1.2 Aggregated amount of investment

The aggregated amount of investment for the development of the generation, transmissions and the related facilities are estimated to be as follows;

Table 10-3 Aggregated amount of investment

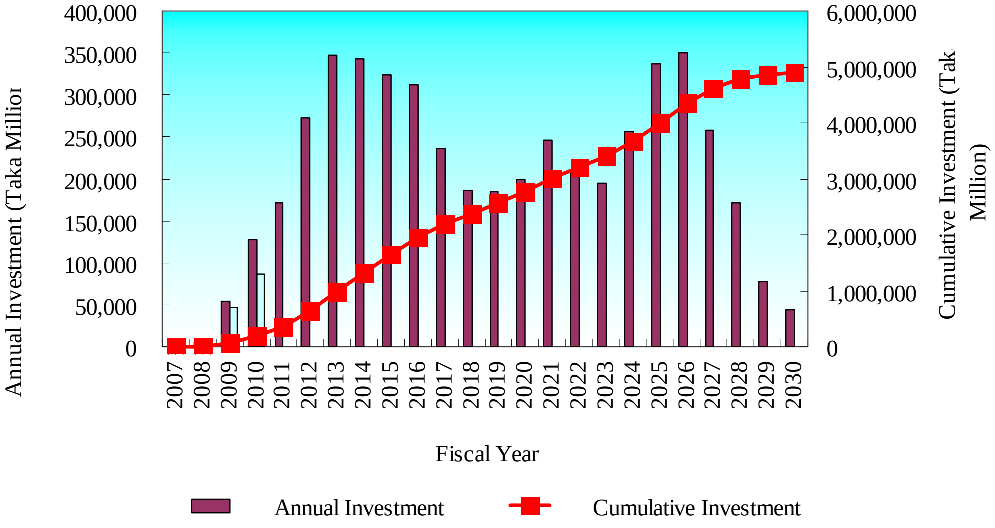
Executing Agency	Generation Capacity	Total Investment (Taka Billion)	Annual Averega of Investment (Taka billion)	ditto (US$ million)
Generation & Transmission				
Public Sector	5,787 MW	947	47.4	681
Private Sector	9,436 MW	710	35.5	510
Pub/Priv Unclassified	17,600 MW	1,776	88.8	1,276
Renewable Energy[1] & Intl Connection	3,611 MW	25	1.3	19
Sub-total	36,434 MW	3,456	172.8	2,483
Related Facilities		1,449	72.5	1,042
Total	36,434 MW	4,905	245.3	3,525

Source: PSMP Study Team

The aggregated investments for the development of the generation, transmission and related facilities are found to be at Taka 4.9 trillion (US$ 70.5 billion). The annual average of the investment amounts to Tk 245 billion (US$ 3.5 billion). The peak of the investment will be reached in FY 2013 for the amount of Tk 347 billion (US$ 5.0 billion) while the bottom will be found during the final couple of years. The amount will be Tk 78 billion (US$ 1.1 billion). The year wise investment and its cumulative total appear in the figure below.

The graph presents the twin peaks of annual investments, the first one of which is during the fiscal years of 2012 and 2017, while the second one is during FY 2024 and FY 2027. The first peak is formed by a concentration of investments that are intended to cope with the prevailing power shortage while the second one is formed by the concentration caused by the retirements of plants with shorter life spans that have been constructed during the first peak period. The issue of financing is critically important for meeting the financial needs during the first peak period, in particular. The underlying reason is found in the fact that the entire first peak of investments is the new investments that need to be identified with financing sources from scratch. The second peak, on the other hand, should be less difficult in terms of financing as the expiring plants accompany the accumulated depreciation that can be re-invested for the replacing of investments.

[1] Hydro power is excluded from renewable energy, included in "Generation & Transmission, Public Sector".



Source: PSMP Study Team

Fig. 10-1 The aggregated investment under the Master Plan (FY 2010 constant price)

10.1.3 Source of funds

(1) Government budget

The national budget is comprised of the development budget and non-development budget. The government introduced the Medium Term Budget Framework (MTBF) System in FY 2005-06 under which the government allocates all of the central ministries and agencies a pre-determined amount of budget within which the ministries and agencies are authorized to compile the development as well as the non-development budget. The MTBF is compiled every year by the Ministry of Finance, discussed and approved at the National Diet together with the annual budget.

In order for the government to cope with the acute power shortage, the government has announced the power sector as the priority sector and established a Power Generation System Development Plan[1]. The plan focuses on new development efforts in the three thronged approaches of public, private and public-private partnership efforts through which the government plans to complete the new generation capacities of ; 792 MW; 920 MW; 2,269 MW; 1,675 MW; 1,170 MW; 2,600 MW annually with an aggregate capacity of 9,426MW from the fiscal years of 2010 to 2015. Through the plan's implementation, the government intends to resolve the deficient power supply gap. The annual budget has been compiled to achieve the target incorporated in the plan. MTBF indicates the levels of the budget required up till the fiscal year of 2013 as follows;

[1] Ministry of Finance, "Towards Revamping Power and Energy Sector: A Road Map", June 2010

Table 10-4　Estimated level of expenditure under MTBF[1]

(Taka Billion)

Fiscal Year	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
Nominal GDP	6,906	7,803	8,834	10,030	11,407	12,942
GDP Growth（Nominal）	12.3%	13.0%	13.2%	13.5%	13.7%	13.5%
GDP Growth（Real）	6.0%	6.7%	7.2%	7.6%	8.0%	8.0%
Total Budget（Total Expenditure）	943	1,138	1,295	1,500		
Total Budget／GDP (%)	16.0%	16.9%	17.2%	17.4%	17.8%	18.1%
Power Sector	27	50	45	54		
Power Sector／Total Budget (%)	2.9%	4.4%	3.5%	3.6%		

Source:　Ministry of Finance, "Medium Term Budget Framework", June 2010

Meanwhile, the actual records of the national budget between FY 2006 through FY 2011 and their annual development budget (ADP：Annual Development Programme) are acknowledged to be as follows;

Table 10-5　Performance of government budget[2]

(Taka Billion)

Fiscal Year	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Total Budget	611	668	861	941	1,105	1,322
ADP	215	216	225	230	285	385
Current Expenditure Budget	396	452	711	711	820	937
Power Sector（ADP + Non -ADP）	34	29	31	27	27	50
Power／Total Budget(%)	5.6%	4.3%	3.6%	2.9%	2.4%	3.8%

Source:　Ministry of Finance, "Medium Term Budget Framework", June 2010

During the past several years, investment for power sector development has been stagnant and its result has been reflected into the actual performance records of the budget. The actual amounts expended during the fiscal years between FY 2006 through FY 2010 have averaged at Tk 30 billion (=US$ 430 million) annually. It has been observed during those years that despite the budgets that were allocated with the amounts exceeding the levels of the preceding years' expenditures, the original budgets were found to be un-expendable due to delays in their implementation resulting in the reduction of the budget at the stage of compiling the revised budget. As a result, the actual records of ADP allocation for each year was found at the same level which is similar to the level of the total commitments of the three major donors to be analyzed later. This fact indicates that the constraint in the budget allocation was not the cause of delay in the development of the power sector but that the slow implementation of development caused the budgetary allocation to be halted. This reveals the prevailing fact connected to the delay in development and its implementation.

The budget allocation for FY 2010-11 amounts to Tk 50 billion which is acknowledged to cover a mere 20% of the total investment estimated for the Master Plan, indicating that the

[1] Fy 2009-10 is the revised budget,　FY 2010-11 is the original budget and FY 2011-12 is the estimate by Ministry of Finance.
[2] Years up till FY 2009-10 are the revised budgets and FY 2010-11 is the original budget.

implementation of the Master Plan is by far not possible with the sole funding from the national budget. What is indicated clearly is that the only measure to cope with the situation can be found in the promotion and accelerated tapping of the private sector source for funds. It should be noted here that there exists a difference in the scopes encompassed by the Master Plan and the one for the national budget. The Master Plan includes the infrastructure required for the generation and transmission as the Related Facilities while it excludes the distribution from its scope. On the other hand, the national budget includes the distribution within its allocation for the power sector while the budget for the Related Facilities of the Master Plan are to be placed for the budget allocation under other sectors than the power.

10.1.4 Government schemes for promotion of private sector investment

The reigning government which assumed power in early 2009 resolved to achieve 8% and 10% economic growth in 2013 and 2017 respectively to be maintained thereafter. The government fully recognizes the fact that public sector investment alone is not sufficient to achieve its target and has aimed at mobilizing resources from the private sector and its investments. The government has been promoting the development of infrastructure through the promotion of Public-Private Partnership (PPP) as the policy to develop public services via private sector investment. The target sector conceived by the government for PPP lies in the sectors such as; power and energy; transportation infrastructure; water supply and sewerage; civil aviation and tourism; manufacturing; education; health care; housing, etc[1]. The governing rule for PPP is found in the “Private Sector Infrastructure Guidelines of 2004 (PSIG)”[2] There is no specific PPP definition though it is generally conceived as the ones having the following features[3];

(1) The private sector arranges resources to build infrastructure;
(2) The private sector bears the cost of building the infrastructure;
(3) The private sector bears both the fiduciary and safety related risks related to the construction;
(4) The government and public avail themselves of the service by paying appropriate prices or fees;
(5) The private sector cannot raise the prices, fees or charges unilaterally; and
(6) PPP initiatives are usually long term (15-30 years) in nature.

Since 1997, the government has established the following three institutions to promote PPP;

(1) Infrastructure Development Company Ltd. (IDCOL)[4]

IDCOL was established in 1977 under the Economic Relations Department of Ministry of Finance. The growth of its financial activities has accelerated since 2006. IDCOL has managed to arrange financing for 22 projects totaling Tk 13 billion as of June 2009, out of which IDCOL lends from its own source Tk 3.0 billion. In an annual average, the number of projects arranged is five for the financed amount of Tk 3.0 billion out of which IDCOL has lent Tk 0.8 billion from its own resources. By arranging syndicated loans, IDCOL has successfully arranged a large scale financing scheme for large projects materializing large leverage effects while using a relatively smaller amount of its own resources. IDCOL owes its primary source of funds to such organizations as; IDA; ADB; KfW; SNV-Netherlands Development Organization; GTZ; Islamic Development Bank, etc. The projects that have been arranged by IDCOL in the power sector are listed in the following table;

[1] Ministry of Finance, “Invigorating Investment Initiative Through Public Private Partnership: A Position Paper”, June 2009
[2] Cabinet Division, “Bangladesh Private Sector Infrastructure Guidelines of 2004”
[3] Bangladesh Bank, “Annual Report 2008-09”
[4] Ministry of Finance, “Invigorating Investment Initiative Through Public Private Partnership: A Position Paper”, June 2009

Table 10-6 List of power sector projects of IDCOL

(Taka Million)

Sector	Project	Type of PPP	Total Investment
Power	Meghnaghat 450 MW Power Plant	BOO	21,000
	Summit Power 33 MW Power Plant	BOO	1,250
	Summit Uttaranchal Power Company 44 MW Power Plant	BOO	1,970
	Summit Purbanchal Power Company 66 MW Power Plant	BOO	3,000
	VERL 34 MW Power Plant at Bhola	BOO	1,200
	BEDL 51 MW Power Plant at Sylhet	BOO	1,830
	34 MW Malancha Holdings Power Plant at Dhaka EPZ	BOO	1,650
	Shah Cement 11.6 MW Power Plant	Captive	590
Renewable Energy	IDCOL Solar Energy Program	NGO	20,060
	250 kW Biomass Gasification Based Power Plant	BERC License	25
	50 kW Biogas Based Power Plant	Govt License	5

Source: Ministry of Finance, "Invigorating Investment Initiative Through Public Private Partnership: A Position Paper", June 2009

(2) Investment Promotion and Financing Facility (IPFF)

IPFF was established in 2007 under the purview of Central Bank. IPFF provides the funds to promote PPP projects that will be implemented by the private sector. The target projects are selected in accordance with the guidelines and rules established by the World Bank (WB) but are required to be commercially viable. The total amount of funds originally provided was Tk 4.18 billion (US$ 47.5 million from IDA and US$ 10 million from GOB). The Facility has arranged finances to five power sector projects for the total capacity of 178 MW up till June 2009. The aggregate total amount of investments of the five projects was Tk 8.67 billion out of which IPFF financed Tk 4.41 billion while the private investors invested Tk 2.51 billion and the private sector financial institutions lent Tk 1.46 billion. WB acknowledges in its project evaluation report that IPFF attained a leverage effect exceeding 100% of the amount invested in successfully mobilizing the aggregated sum of no less than US$ 120 million[1]. The following table lists the projects in the power sector that are financed by IPFF;

[1] World Bank, "Investment Promotion and Financial Facility Project", April, 2010

Table 10-7 List of power sector projects of IPFF

(Taka Million)

Sector	Project	Type of PPP	Total Investment
Power	Three 22 MW Doreen Power Generation & System Ltd. (2 in Tangail & 1 in Feni)	BOO	3,430
	11 MW Doreen Power House & Technologies Limited at Mahipal, Feni	BOO	564
	22 MW Regent Power Limited	BOO	1,108
	Malancha Holdings Ltd. (44 MW Captive Power Plant at CEPZ)	BOO	1,919
	Malancha Holdings Ltd. (35 MW Captive Power Plant at CEPZ)	BOO	1,649

Source: Ministry of Finance, "Invigorating Investment Initiative Through Public Private Partnership: A Position Paper", June 2009

IPFF has used up almost all of the funds initially provided and, in May 2010, WB has approved a new facility amounting US$ 257 million through the IDA. Given the injection of the new funds, it is now capable for the IPFF to finance PPP projects amounting to approximately US$ 40-60 million (Tk 2.8-4.2 billion) annually[1].

(3) Bangladesh Infrastructure Finance Fund Ltd. (BIFF)

BIFF was established in September 2010 through a 100% investment by the government with an initial capital injection of Tk 16 billion. The Company aims at providing equity and loans to infrastructure projects including the power sector. The government is now soliciting equity participation to private sector and oversea investors.

(4) PPP funds of national budget

Aside from the aforementioned independent institutions, the government sets aside an allotment of special funds for PPP promotion. The current budget carries Tk 30 billion of such an allocation. The execution of the budget is decided by an independent organization under the purview of cabinet. The government is reported to be undergoing the selection and evaluation of the projects for financing though their details are not yet publicly disclosed. The size of the funds appears to be a potentially powerful financial source. Assuming that a portion of the funds are mobilized to the power sector to an extent similar to the resource allocation plan of IPFF, 39%, a significant amount of Tk 11.7 billion would be allocated to the sector. Should such an allocation bring about a 100%leverage effect, the combined total of potential financing of the budget and the private sector financing would be as large as Tk 23.4 billion annually.

10.1.5 Assistance by Donors

(1) Official development assistances

Significant providers of financial assistance to the power sector are the Asian Development Bank (ADB), the WB and Japan International Cooperation Agency. The assistance provided by these three donors during the past five years are listed in the following table;

[1] ditto

Table 10-8 Financial assistances provided by three major donors[1]

	JICA		ADB		WB	
	Project	Amount (JPY million)	Project	Amount (US$ million)	Project	Amount (US$ million)
2005-06	Grid S/S & Transmission	4,642			(PPP Invest Promotion)	(50)
2006-07			West Zone Power Devt	199		
			Sustainable Power Devt	400		
			Sustainable Power Devt	60		
2007-08	Haripur Power	17,767			Power Sector Devt Policy Cr.	120
2008-09	Central Zone Distribution	9,715			Siddirganj Peaking Plant	350
	Haripur Power (II)	22,210				
2009-10	Rural Area Distribution	13,241			Addl Financing for Rural Elect.	130
	Bheramara Gas CC (E/S)	2,209			(PPP Invest Promotion)	(257)
Total		69,784 (= US$ 813 mill)		659		600

Source: Websites of the respective institutions

The amounts committed to each fiscal year have been summarized as below;

Table 10-9 Year-wise commitment by the three donors

(US$ million)

	2005-06	2006-07	2007-08	2008-09	2009-10	Total	Ann. Ave.
JICA	54		208	373	181	816	163
ADB		659				659	132
WB			120	350	130	600	120[2]
Total	52	659	317	705	302	2,035	415 (=Tk 29 billion)

Source: Websites of the respective institutions

(2) Assistance for promotion of private sector investment

In addition to the official development assistance to the government, the WB has been providing financial assistances for the promotion of private sector investment to institutions such as IDCOL and IPFF through IDA or GEF. ADB is following the same track with WB for promoting private sector investment. The following are the typical cases of private sector investments for which both of the organizations extended direct assistances;

[1] Exchange Rate between JPY and US$: US$ 1=JPY 85.50

[2] In addition to what is listed here, World Bank extended financial assistances to IPFF for US$ 50 million in April 2006 and US$ 257 million in April 2010.

(a) Haripur 360 MW Combined Cycle Power Station Project (World Bank committed in 2000)[1]

The Haripur Power Station was initiated as a BOO project and awarded to AES Corporation through competitive bidding. The project raised the total funds of US$ 183 million from the sponsor, IFC and private financial institutions. The equity raised was US$ 68 million and the remaining US$ 115 million was raised from debt, out of which the IFC provided a loan for US$ 54 million (repayment in 10 to 15 years) and private financial institutions provided US$ 61 million. For the portion of the private financial institutions' lending (repayment in 10-15 years with the rate of interest at LIBOR + 2.00-2.25% p.a.), IDA provided a partial risk guarantee for US$ 61 million. The partial risk guarantee (for 15 years) issued by IDA contained such assurances as ; (i) non-compliance on the part of government institutions of PPA and GSA; (ii) political force majeure (forced acquisition); (iii) convertibility of currency; (iv) changes of laws and regulations; (v) natural calamities and force majeure, etc. based on the counter guarantee rendered by GOB. In addition to the partial risk guarantee, a financing package included, among others; (i) Implementation Agreement to be signed by Ministry of Power, Energy and Mineral Resources (MPEMR); (ii) Power Purchase Agreement (PPA) for 22 years; (iii) Gas Supply Agreement (GSA) for 22 years; and (iv) a Land Lease Agreement.

(b) Meghnaghat 450 MW Power Station Project (ADB committed in 2000)[2]

Meghnaghat Power Station was initiated as a BOO project and awarded to AES Corporation through a competitive bid. The project raised an amount of funds totaling US$ 290 million from the sponsor, ADB and private financial institutions. The equity raised was US$ 75 million and the remaining US$ 220 million was raised from debt, out of which ADB provided a direct loan of US$ 50 million and private financial institutions provided US$ 80 million. For the portion of the private financial institutions' lending, ADB provided a partial risk guarantee for US$ 70 million. The amount of the partial risk guarantee covered only 32% of the total debt portion, while the remaining part of the debt was provided by domestic financial institutions including IDCOL who were not eligible for the risk guarantee. Such experience implies that as early as in 2000, there existed domestic financial institutions that were capable of providing long term financing for the development of the power sector if the terms and conditions of such financing meet the requirements of the lender institutions. In addition to the partial risk guarantee, the financing package included among others an; (i) Implementation Agreement to be signed by MPEMR; (ii) Power Purchase Agreement (PPA) for 22 years; (iii) Gas Supply Agreement (GSA) for 22 years; and (iv) a Land Lease Agreement.

10.1.6 Probability for expansion of fund raising

(1) Conventional sources of funding

Thus far, the PSMP Study Team has reviewed the sources of funds that can be tapped into by the power sector for the implementation of the Master Plan and examined the amount of funds potentially available for the development of the power sector. The following table summarizes the sources of funds, present level and potentially available level in the near future;

[1] World Bank, "Syndicated Commercial Loan to AES Haripur (Private) Ltd. for the Haripur Power Project in Bangladesh", May 2000

[2] Asian Development Bank, "Extended Annual Review Report: Loan and Political Risk Guarantee Bangladesh: Meghnaghat Power Project", March 2008

Table 10-10 Funding source and volume of available funds

(Tk billion)

Funding Source	Allocation to Power Sector (Ann. Ave.)	Potential Allocation (in 2-3 years; Ann. Ave.)	Leverage Effect[1] (Ann. Ave.)	Particulars
National Budget (Power Sector)	50	+ 28.4	0	To grow along with GDP and donors' commitment
IDCOL	0.8		0.8	To expand by contribution of GOB and donors
IPFF	1.5	+ 0.8	2.3	IDA committed 2nd loan for US$ 257 million in 2010. The PSMP Study Team assumes the funds to be consumed in 3 years while 39% will be allocated to power sector. Leverage effect is assumed based on WB's evaluation report on IPFF[2].
PPP Fund within National Budget	0	+ 9.0	9.0	The PSMP Study Team assumes 30% to be allocated to power sector
Infrastructure Finance Fund	0	+ 1.6	+ 1.6	Initial funds of Tk 16 billion. The PSMP Study Team assumes the funds to be consumed in 3 years and 30% of the funds to be allocated to power sector.
Donor Loans[3]				
JICA	(11.3)	-	0	
ADB	(9.2)	(+ 5.7)	0	Country Operation Business Plan (2011-13) projects total commitment for US$ 3,205 million. COBP plans to allocate 30% to energy sector[4]. The PSMP Study Team assumes 20% to be allocated to generation and transmission.
WB	(8.4)	(+ 14.4)	0	Country Assistance Strategy 2011-14 plans total commitment for 3 years: US$ 6,550 million[5]. The PSMP Study Team assumes 15% of the funds to be allocated to generation and transmission.
China				Assisted Barapukuria Coal PowerStation (commissioned in 2006)
India				Agreed in 2010 to assist

[1] The leverage effect refers to the economic effects that realize in mobilizing the third party capital in addition to the investor's own equity investment. The leverage effect in the table is defined as the investment and loans to be made by the private sector to development projects while deeming the public sector investment and loans as the equity.

[2] World Bank, "Investment Promotion and Financial Facility Project", April, 2010

[3] Execution of donor assistance is carried out by being incorporated into the national budget. To avoid duplication with ADP budget, the volumes of donor's commitment are not counted here but is shown as a reference only.

[4] Asian Development Bank, "Bangladesh: Country Operations Business Plan FY 2011-13", July 2010

[5] World Bank, "Country Assistance Strategy for Bangladesh FY 2011-2014", July 2010.

Funding Source	Allocation to Power Sector (Ann. Ave.)	Potential Allocation (in 2-3 years; Ann. Ave.)	Leverage Effect[1] (Ann. Ave.)	Particulars
				Baharampur to Bheramara Power Transmission and construction of two coal based power stations.
Russia				Assisted Ghorassal Power Station (2X210 MW) and agreed in 2010 to assist nuclear power stations.
Donor Assistance to Private Sector Investment1				
ADB		+ 2.5	+ 6.8	The PSMP Study Team assumes ADB to assist IPPs similar to Meghnaghat Power Station by one plant each for three years.
WB		+ 2.5	+ 6.8	Same with for ADB
Rental Power	18	▲ 18	0	
Total	70.3 (US$1.0 B)	+ 26.8 (US$0.4 B)	+ 27.3 (US$0.4 B)	Total funds incl. leverage: Tk 122 billion (US$ 1.7 billion)

Source: PSMP Study Team

The above can be summarized in the following table;

Table 10-11 Funding source and fund volume for the Master Plan

(Taka Billion)

	Present Level of Fund Volume	Fund Volume Expected in 2-3 Years[2]	Annual Average Investment under Master Plan
National Budget (incl. ODA assistance by donors)	50	78.4	
Government Schemes for PPP Promotion	2.3	25.1	
Donors' Assistance to IPPs	-	18.6	
Rental Power	18	0	
Total	70.3	122.1	245.3

Source: PSMP Study Team

The volume of funds currently available from the identified sources of funds stands at Tk 70 billion (US$ 1.0 billion) annually. In the 2-3 years to come, the PPP funds in the national budget and commitments by donors are expected to increase. In addition to those mentioned and for the sake of analysis, the PSMP Study Team assumes that WB and ADB extend their assistance of direct loan and partial risk guarantees to one IPP plant for each three year period. Given these assumptions, the annual allocation to the power sector will increase by Tk 27 billion (US$ 0.3 billion) which will then be added by the leverage effect of Tk 27 billion (US$ 0.4 billion). The total volume that can be financed in consideration of those effects will amount to Tk 122 billion (US$ 1.7 billion). The Master Plan as a whole requires an annual allocation of Tk 245 billion and the amount calculated for future availability covers only 50%

[1] The hypothetical project is assumed to be: 400 MW in capacity, US$ 400 million in total cost which is financed by 40% in equity, 60% in borrowings. Donors are assumed to lend 45% of the total borrowing.
[2] Includes leverage effects

of the total requirement, while the remaining 50% has yet to be identified in its funding source. It is imperative that the funding source needs to be expanded and efforts should be made to increase the funding volume from each of the funding sources to fill the gap.

In the meantime, although the realization of the Master Plan requires painstaking efforts to secure the sufficient amount of funds required, it is needed to be considerate before hastily concluding that the prevailing conditions constitutes an insurmountable barriers which could endanger the implementation of the Master Plan. In general, the funds float in search of better investment opportunities while scrutinizing the risks and returns involved. The fact that power sector was not able to receive sufficient funds for development buttresses the underlying fact that the projects have not yet been formulated which is sufficiently attractive for risk-taking and investment. What is important is to carefully prepare the projects, while developing an environment conducive to investments including the assurance of a sufficient return which is matched against the risks to be taken on the investment, diversify the funding source, pursuing the expansion of funding through which the Master Plan grows as the plan assuring a high probability of funding support.

(2) Funding sources in consideration of the global climate change

In addition to what has been described of the conventional sources of funds, funding can be sought to the mechanisms such as Global Environment Facility (GEF) and Clean Development Mechanism (CDM) established for protection of the global climate. GEF is jointly managed by the WB, UNDP and UNEF and provides the developing countries in implementing the projects purported to the issues of global environment protection with the grant funds for the projects' incremental portion of the total costs. The funds have been contributed by the participating governments to the trust fund established at the WB and are utilized by the managing institutions for implementation of the projects in developing countries. As of present, an approximate number of 10 projects have been implemented in Bangladesh including one project in the power sector which is Rural Electrification and Renewable Energy Development Project in 2002.

CDM, on the other hand, is the mechanism established by Kyoto Protocol and others for protection from the global climate change. The developed countries can earn merits in implementing projects purported to the reduction of the emission of greenhouse gas (GHG), a portion of which can be credited to the donor country. The project owner is required to prepare a Project Design Document which is to be scrutinized by the Designated National Authorities of the donor and the recipient counties and be validated by the Designated Operational Entity of the system. The amount of the reduction is approved by the Executive Board as Certified Emission Reduction (CER). CER can be traded internationally and the parties obtained CER thus benefit from the investment made. The eligibility and criteria for the mechanism is stipulated under the Approved Consolidated Baseline and Monitoring Methodology (ACM). As of present, 18 categories of ACMs have been identified and rules are established for each of them that remain in force, out of which the ones that are closely related to the Master Plan are as follows;

- ACM 0002: the Consolidated Baseline and Monitoring for Grid-connected Electricity Generation from Renewable Sources,
- ACM 0007: the Methodology for Conversion from Single Cycle to Combined Cycle Power Generation, and
- ACM 0013: the Consolidated Baseline and Monitoring Methodology for New Grid Connected Fossil Fuel Fired Power Plants Using a Less GHG Intensive Technology.

Out of the 18 categories of ACMs, a large number of projects have been approved under ACM 0002 among various countries but the number of projects approved under ACM 0007 and ACM 0013 are reported to be very minimal. In particular under ACM 0013 which is relevant for the coal fired power generation, only one example of registration is reported while a relatively large number of projects are reported to be under validating assessment. The registered project is reported to be as Adani Power Ltd. in India with the generation capacity of 1,320 MW. ACM 0013 specifies the eligibility criteria as follows;

(1) Eligible project is the activity of the construction and operation of a new fossil fuel fired grid-connected electricity generation plant that uses more efficient generation technology than what would otherwise be used with the given fossil fuel. The project activity is not a co-generation power plant;
(2) The identified baseline fuel is used in more than 50% of total generation by utilities in the geographical area within the country, as defined later in the methodology, or in the country.

The conditions set out above should be relatively easier for the countries such as China or India to clear as those countries are traditionally heavily dependent on the coal fired power generation and easy to clear the threshold of 50% rule while situations are different in Bangladesh. For Bangladesh, in order to effectively benefit from the mechanisms, a proactive approach should be made to the mechanism for relaxation of the baseline rule and/or to search options that are available in other areas that are not limited to the coal fired generation plants. In the process of materialization of the Master Plan, the formulation of individual projects should take into consideration of the mechanisms that would be potentially available so as to adjust those projects to the requirement of the mechanisms and thereby enhance the probability of those advanced finance sources.

10.1.7 Promotion of private sector investment

At around 2000, the private sector development in the power sector used to be in a full swing but has lost its momentum since then. Since 2003, there has been no large scale development of IPPs. The development has been on stall for a considerable time period. The following underlying reasons behind the stagnant development are frequently referred to;

- Unfavorable business environment for investments owing to the global financial crisis and economic slump,
- Low and inadequate levels of electricity tariffs and gas tariffs,
- Vulnerable financial standing of the single power purchasing entity, BPDB,
- Unstable supply of gas for long term supply and commitment by contracts,
- Constraints of implementation capability of government institutions,
- Lack of transparency in the government processes, lack of timely decision-making and enforcement of government commitment, and
- The spreading of a skepticism among private sector investors against the government handling of private investment.

The government, on the other hand, launched a series of promotion policies and proceeded in their implementation. The following are some of the policy measures launched by the government;

- Exemption and alleviation of income taxes, import duties and value added taxes by virtue of the Private Power Generation Policy,
- The purchasing of electricity generated by captive generation plants by virtue of the Captive Power Generation Policy
- Establishment of PPP Guideline and special fund allocation for PPP within the national budget,
- Introduction of rental power generation and quick rental power generation as the emergency measures to cope with the power shortage.

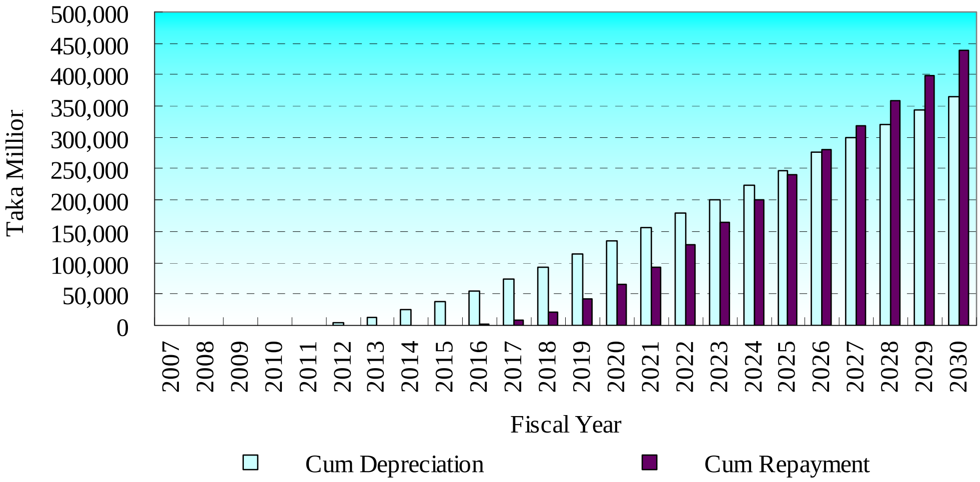
The policy measures adopted by the government directly address the improvement of investment returns and the alleviation of the shortage of funds over a shorter time span. On the other hand, the long term and fundamental elements such as protection from country risks, improvement of fundamental risk/return correlations, improvement of the financial strength of the single power purchasing entity, revision of electricity tariffs, long term assurance of fuel supply, capacity building of government institutions engaged in the power sector development, etc. have yet to be addressed and remain insufficient.

The new political regime, having assumed the power in early 2009, has started tackling the problems in the power sector by introducing and promoting a rental power generation system while launching a road-show to induce the private sector to invest in power sector development. These events are demonstrating the government attitude changes and their willingness to confront power sector issues. Such changes of the government attitude are acknowledged to have drawn positive responses from private investors. The new government has taken over from the previous government large IPPs that the previous government made repeated but abortive attempts for competitive bidding over several years in the past but has successfully approved the bidding results lately. It is imperative to capture the momentum being created and to make such changes and momentum a solid path for development. The PSMP Study Team is of the opinion that each of the aforementioned constraints needs to be addressed and measures need to be implemented for improvement, revision, alleviation and strengthening. For an individual investor facing the risk of long term investment, any one of the issues mentioned poses to be a vital factor for making his/her investment decision. The government is urged to address and resolve the following hurdles and solidify an environment conducive to investment by any means;

(1) To develop an environment which is conducive and allows for a sufficient return amount matched against the risks of long term investment,
(2) To alleviate the risks involved for the recovery of investment (strengthening of the financial health of BPDB, assurance of the government for bill collection, arrangement by the government for protection from the country risk),
(3) To revise the electricity tariffs and gas tariffs,
(4) To strengthen the financial strength of the power purchasing entity, BPDB,
(5) To promote the development of fuel and to enable a stable long term supply of fuel under a long term supply contract, and
(6) To establish a transparent process in the government handling of private investment, to proceed with a timely decision-making and its enforcement, and the due delivery of commitments.

10.2 Debt service

The above has so far delved into the fundraising for the Master Plan. For the portion of the borrowed funds, it is vital to check and confirms that the debt repayment and interest payments can be properly handled over time. With respect to the debt servicing of the principal portion, the comparison between the cumulative amount of depreciation and cumulative amount of repayment of loans provides an efficient tool for verifying that the project generates a sufficient amount cash to meet the maturities of loan installments. The relation between the depreciation and repayment in their cumulative amounts can be seen in the following figure;



Source: PSMP Study Team

Fig. 10-2 Depreciation and loan repayment (FY 2010 constant price)

The figure above illustrates that during the years under the Master Plan up till FY 2025, the cumulative depreciation stands bigger than the cumulative repayment clearly indicating that there will be no deficiency of funds for repayment of the loans borrowed during the period. During FY 2026 through FY 2030, the positions will be reversed. The depreciation will be short of the cumulative amount of repayment which will require the loans to have longer maturities than assumed in the presumption. It should be noted that, in order for the depreciation to be appropriated for the repayment, there need to be sufficient earnings that enable the depreciation to be fully accounted. The pre-requisite conditions for such earning power are connected to the sufficiency of the electricity tariff covering the cost of supply.

For all of the loans, the repayment terms have been set at 20 years[1], whereas the depreciation periods for most of the plants extend longer than the repayment period. Consequently, after 20 years has elapsed, for instance, a plant with a 30 year depreciation life shall produce 60% of the initial investment through depreciation, whereas the whole amount of the loan, being 82% of the initial investment, needs to be repaid. The situation can be easily coped with by allowing for the extension of the re-lending term of donor loans to the extent of the terms of the original donor loans. It may be argued that a longer repayment term will entail an increase of interest payments and will affect the overall generation cost. The issue can be addressed by softening the on-lending rate of interest to the extent but not lower than those of the original loans from the donors. Based on the assumption that the repayment shall be accommodated within the cumulative depreciation and the overall supply cost of electricity shall be covered by the power tariff, the interest accruing to the borrowed funds should be managed out of the current revenue of electricity sales in maintaining the healthy financial status of the power supply system as a whole. The scenario provides explicit assurance that there shall be no problems with respect to the due performance in debt servicing under the Master Plan.

10.3 Cost of input

The Sub-Chapter deals with the next issue of analyzing the overall generation cost of the country as a whole through the implementation of the Master Plan and subsequently how the electricity tariff should be adjusted in line with the Master Plan. The analysis, first, reviews the cost

[1] Ministry of Finance, "Lending and Relending Terms of Local Currency and Foreign Loans", March, 2004 establishes the standard terms and conditions for government providing funds to publicly implemented projects. The individual project can be discussed and approved for different terms and conditions with flexibility.

elements of the inputs with exception of the capital cost that has been seen before, to the power system for the implementation of the Master Plan.

10.3.1 Construction cost and O&M expense

For all generation and transmission, standard costs are contemplated for different type and size of the plants based on the latest market and technology information. In addition to the estimate of the construction cost, the O&M expense is estimated in two parts, namely; the fixed expense and the variable expense to develop analytical model that is fit for changing operational environment. For the generation plants, the following standard schedule has been applied in estimating the expense;

Table 10-12 Standard O&M expense for generation plants (FY 2010 constant price)[1]

Capacity Class & Type	Fuel	Plant Construction Cost (US$/kW)	Fixed Expense (US$/kW/yr)	Variable Expense (US$/MWh)
120 MW CT	Gas	530	10.6	0.6
120 MW CT	Furnace Oil	600	16.0	0.9
150 MW CT	Gas	500	10.0	0.6
150 MW CT	Furnace Oil	500	13.3	0.9
140 MW CC	Gas	1,170	23.4	1.3
350 MW CC	Gas	950	19.0	1.1
450 MW CC	Gas	860	17.2	1.0
450 MW CC	Furnace Oil (Dual Fire with Gas)	980	26.1	1.5
750 MW CC	Gas	660	13.2	0.8
600 MW ST USC	Coal (Imported)	1,600	53.3	3.0
600 MW ST USC	Coal (Domestic)	1,500	50.0	2.9
1000 MW ST USC	Coal	1,350	45.0	2,6
-	Hydro	1,400	2.3	4.7

Source: PSMP Study Team

10.3.2 Fuel cost

The fuel cost is derived from the ones that have been adopted by the long term development planning of the Master Plan. The system tool utilized for the long term development analyzed and obtained the optimal solution that realizes the least cost development planning, given the pre-determined assumptions. The financial analysis needs to synchronize the same terms and conditions adopted in such a planning phase to make the output of the analysis valid and relevant. The Master Plan has adhered to the following scenario of estimates;

[1] CC: Combined Cycle, ST: Steam Turbine, USC: Ultra Super Critical Generation

Table 10-13 Fuel cost scenario (FY 2010 constant price)[1]

FY	Domestic Coal		Imported Coal		Furnace Oil		Diesel Oil		Gas	
	US ¢/ MM kcal	Taka/ Ton	US ¢/ MM kcal	Taka/ Ton	US ¢/ MM kcal	Taka/ liter	US ¢/ MM kcal	Taka/ liter	US ¢/ MM kcal	Taka/ 10^3 cft
2010	1,400	5,941	1,454	5,135	4,761	31.63	7,300	45.50	3,571	595
2011	1,467	6,229	1,539	5,435	4,843	32.17	7,425	46.28	3,632	605
2012	1,530	6,497	1,618	5,713	4,925	32.71	7,551	47.06	3,693	615
2013	1,595	6,771	1,698	5,999	5,007	33.26	7,677	47.85	3,755	626
2014	1,655	7,025	1,773	6,263	5,089	33.80	7,802	48.63	3,816	636
2015	1,715	7,280	1,848	6,526	5,171	34.35	7,928	49.41	3,878	646
2016	1,773	7,527	1,921	6,785	5,330	35.40	8,172	50.93	3,997	666
2017	1,830	7,768	1,992	7,036	5,489	36.46	8,416	52.45	4,116	686
2018	1,885	8,002	2,061	7,279	5,648	37.52	8,660	53.97	4,236	706
2019	1,940	8,236	2,130	7,523	5,807	38.57	8,904	55.49	4,355	726
2020	1,992	8,457	2,193	7,752	5,966	39.63	9,148	57.01	4,474	745
2021	2,044	8,678	2,260	7,982	6,055	40.23	9,285	57.87	4,541	757
2022	2,096	8,899	2,323	8,212	6,145	40.82	9,422	58.72	4,609	768
2023	2,147	9,113	2,388	8,434	6,234	41.41	9,559	59.58	4,676	779
2024	2,196	9,320	2,449	8,650	6,324	42.01	9,696	60.43	4,743	790
2025	2,244	9,528	2,510	8,866	6,413	42.60	9,834	61.29	4,810	801
2026	2,293	9,735	2,571	9,081	6,503	43.20	9,971	62.14	4,877	813
2027	2,339	9,929	2,628	9,283	6,592	43.79	10,108	63.00	4,944	824
2028	2,386	10,130	2,687	9,492	6,682	44.39	10,245	63.85	5,011	835
2029	2,432	10,324	2,745	9,694	6,771	44.98	10,382	64.71	5,078	846
2030	2,478	10,518	2,802	9,896	6,861	45.58	10,520	65.56	5,145	857

Source: PSMP Study Team

The fuel cost adopted here is all based on international price levels and its widely acknowledged future estimate with the exception of domestic coal which the Study Team values with certain discount of the imported price. As a result of such an estimation process, the price of gas, whose domestic price is maintained at a level that widely deviates from international standards remains at a level that is approximately seven times higher than prevailing domestic prices.

10.3.3 Financing cost

The government establishes the standard terms and conditions under which the government provides the funds from the national budget and from the donor assistances[2]. For the projects to be implemented as public undertakings, the Study applies the standard conditions established by the government. For the private sector undertakings, the following terms and conditions are assumed for analytical purposes. The existing plants, whether they are public or private, are incorporated into the review based on the actual financing costs so long as relevant data or information is made available.

[1] The exchange rate applied is US$1=Taka 69.59, (the actual average rate for FY 2009).
[2] Ministry of Finance, "Lending and Relending Terms of Local Currency and Foreign Loans", March, 2004

Table 10-14 Financing terms and conditions

	Public Undertaking	Private Undertaking
Equity Ratio[1]	18%	30%
Debt Ratio[2]		70%
Donor Loan	70%	
Government Loan	12%	
Loan Period		15 years
Donor Loan	20 years	
Government Loan	20 years	
Rate of Interest		8% p.a.
Donor Loan	4.0% p.a.	
Government Loan	3.0% p.a.	
Return on Equity[3]	6.0% p.a.	15% p.a.
Depreciation[4]	Straight line method with residual value of 10%	Straight line method with no residual value

Source: PSMP Study Team

10.4 Generation cost and purchasing cost of power

The capital costs, O&M expenses, fuel costs and financing costs are integrated into calculation of the overall cost of generation and purchasing cost of electricity from which the following table is obtained. As has been mentioned before, those costs assumed in the preceding analysis are used for the new plants, whereas the existing plants are analyzed utilizing the actual cost of depreciation and O&M expenses under prevailing operational conditions. However, for both the new and existing plants, the fuel costs are incorporating the costs described in the above scenario.

[1] The debt/equity ratio is predominantly determined based on the appraisal of donor. The government guideline stipulates that the government provides the portion of the funds that is not funded by the donors at the proportion of the debt equity at 40%:60%.
[2] ditto
[3] The government guideline does not contain any regulation on the return of equity. The guideline established by BERC for approving the electricity stipulates that the power entities may be allowed for counting the return of equity at the rate equivalent to the yields of two-year treasury bonds. There exists no recent issue of two-year treasury bond in the country. The Study Team assumed such rates to be 6% here based on the yield curve.
[4] For public undertaking, the depreciation methodology of BPDB is adopted. Private undertaking assumed zero residual value at the end because the power purchase agreement to be concluded between the generation company and the single buyer might reasonably spread out the portion of the residual value evenly into the annual fixed payments.

Table 10-15 Generation cost and purchasing cost of power (FY 2010 constant price)[1]

(Taka/kWh)

	New Plants[2]	Existing Plants	Power Purchase[3]	Overall Cost
2010		7.66	6.86	7.30
2011	7.17	7.80	9.76	8.59
2012	8.45	7.84	9.91	8.84
2013	7.52	8.13	9.51	8.63
2014	7.03	8.29	9.36	8.42
2015	7.25	8.32	7.99	7.97
2016	7.44	8.55	7.72	7.96
2017	7.39	8.37	6.90	7.53
2018	8.32	8.65	6.62	7.55
2019	7.33	8.83	6.71	7.36
2020	7.89	8.81	6.42	7.27
2021	7.51	8.91	6.33	7.08
2022	7.80	8.76	6.21	7.04
2023	7.66	8.85	6.16	7.06
2024	7.78	8.65	5.94	6.91
2025	7.94	8.46	5.66	6.70
2026	7.64	8.02	5.65	6.67
2027	7.24	7.73	5.63	6.63
2028	7.06	7.51	5.60	6.57
2029	6.91	6.71	5.39	6.44
2030	6.88	6.33	5.38	6.44
Levelized Cost[4]	6.91	8.17	7.84	7.83

Source: PSMP Study Team

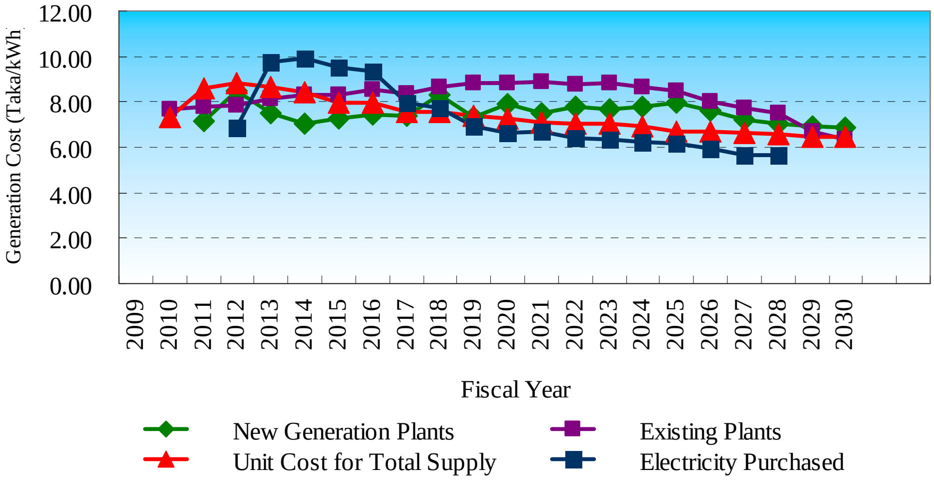
The following is a birds' eye view of the generation cost in its yearly trend;

[1] The generation costs expressed herein do not tally with those presented earlier as the outputs from PDPAT calculation. The reasons of deviations stem, primarily, from the facts such that the PDPAT outputs deal with the generation plants only whereas this Table deals with transmission facilities, and that some parameters are processed with simplified methodologies in PDPAT Calculation whereas this Table treats the depreciation costs in precise and accurate data.

[2] The cost incurred at the new generation plants, transmission plants and related facilities. The cost includes the transmission cost of the electricity generated domestically and purchased from neighboring countries through international trade.

[3] The purchasing cost of electricity acquired from private sector IPPs, small IPPs, rental power producers, nuclear generated power, power purchased from neighboring countries through cross border transactions, etc. The cost estimates are provisional ones as they involve presumptions and preliminary projections by the Study Team.

[4] The levelized cost of generation is calculated as the value at which the aggregated sum of the present value of the net annual sales (annual sales volume of the electricity sold multiplied by the levelized cost minus O&M cost) equals the aggregated sum of the present values of the capital investment. The analysis here has adopted a discount rate of 12% in calculating the levelized cost.



Source: PSMP Study Team

Fig. 10-3 Overall generation cost – base case- (FY 2010 constant price)

The table above and the figures reveal the phenomenal features of the generation and purchasing cost of electricity throughout the Master Plan as follows;

(1) Generation cost stays at a high level.
Irrespective of whether the plants are new, existing or power purchasing, the electricity costs stay at high levels throughout the Master Plan period. The overall cost which includes all of the power sources starts the Master Plan period at Tk 8.59/kWh in FY 2011, reaches its all time high of Tk 8.84 in FY 2013 and decreases in succeeding years towards the end when the cost becomes Tk 6.44/kWh in FY 2030. The levelized cost throughout the Master Plan is calculated as Tk 7.83/kWh.

(2) The generation cost of the new plants is high at the initial period and decreases gradually.
The generation cost of the new plants records high levels of exceeding Tk 8.45/kWh in FY 2012 and Tk 8.32/kWh in FY 2018 since the cost will subside gradually to Tk 6.88/kWh in FY 2030. The levelized cost stays at Tk 6.91/kWh being the lowest among the three categories.

(3) The generation cost of the existing plants remains at a high level.
The existing plants are less in terms of the capital cost in comparison with the new plants but inferior in terms of fuel efficiency. The generation cost (levelized cost: Tk 8.17/kWh) remains at the highest among the three categories.

(4) The purchasing cost of electricity varies and is uncertain.
During the initial phases of the Master Plan, power purchases come primarily from IPPs and rental power producers and purchasing costs from those sources remain at the highest level among the three alternative sources. In the latter half of the Master Plan, the cross border acquisition of power and the purchasing from nuclear power sources are assumed to take over the major role. The cost for the latter is not clearly identifiable at this moment and may be volatile depending on development in the international market. The levelized cost stands at Tk 7.84/kWh

Behind the scene of high generation costs, there obviously lies the adoption of international prices for gas. The present level of the gas prices for the power sector in Bangladesh is set and managed by the government at a level which is approximately one seventh of the international level and this causes prevailing power costs at a low level. The Master Plan, however, anticipates that gas prices will eventually be adjusted to the international level as a matter of time and resolved to adopt international prices for developing the long term power development plan. The Study above describes the analysis conducted based on the assumption of international fuel prices. In the reality of life, the adjustment of fuel prices, wherever it happens to take place, will be accompanied with shock mitigating steps and measures.

The PSMP Study Team gives thought to such practical changes in the scenario in which it attempts a simulating analysis under the assumption that the gas prices will be gradually adjusted during the FY 2011-2015 five year period. The following table shows the generation costs during the transitional phase;

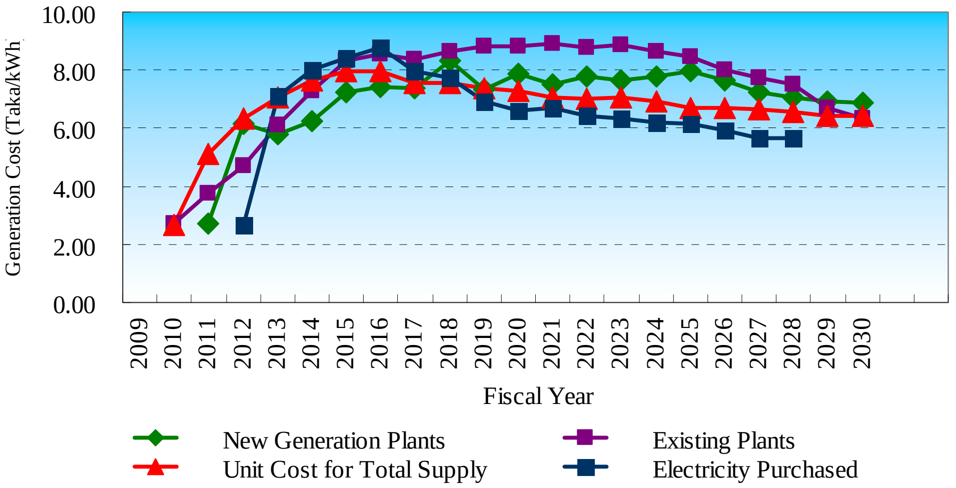
Table 10-16 Generation cost and purchasing cost of power (FY 2010 constant price)

(Taka/kWh)

	Base Case ＜Overall Cost＞		Gas Price Adjustment Case ＜Overall Cost＞		Difference
	Price of Gas (Tk/MM kcal)	Gen. Cost (Tk/kWh)	Price of Gas (Tk/MM kcal)	Gen. Cost (Tk/kWh)	
2010	2,485	7.30	333	2.68	▲4.62
2011	2,528	8.59	772	5.13	▲3.46
2012	2,570	8.84	1,228	6.35	▲2.49
2013	2,613	8.63	1,701	7.08	▲1.55
2014	2,656	8.43	2,191	7.65	▲0.77
2015	2,699	7.97	2,699	7.97	-
Levelized Cost (20 Years)		7.83		6.39	▲1.44

Source: PSMP Study Team

Under the gas price adjustment scenario, the generation cost starts the adjustment period at Tk 2.68/kWh assumed for FY 2010, the base year. It climbs to Tk 5.13/kWh in FY 2011 (increase by 91.4% from the preceding year), Tk 6.35/kWh in FY 2012 (by 23.8% similarly), Tk 7.08/kWh in FY 2013 (by 11.5%), Tk 7.65/kWh in FY 2014 (by 8.1%) and reaches to the level of international cost in FY 2015. The adjustment period will have to accompany an adamant increase of electricity tariff. The generation cost of the power sources when the gas price is adjusted gradually during the five years is illustrated in the following figure;



Source: PSMP Study Team

Fig. 10-4 Generation costs – gas price adjustment case – (FY 2010 constant price)

10.5 Master Plan and the electricity tariff

10.5.1 Pursuit for the electricity tariff in due reflection of the generation cost

The levelized costs during the Master Plan period turns out to be; Tk 6.91/kWh for new plant generation ; Tk 8.17/kWh from existing plants; and Tk 7.84/kWh for purchased power from third parties. The overall cost integrating all of the three is identified as Tk 7.83/kWh which is the value expressed in the FY 2010 constant price without including the inflation and levelization[1] for the whole term of the Master Plan.

The preceding sub-sections reviewed the generation cost of the generation plants and related plants together with the overall cost of generation including the purchasing costs of electricity. The cost derived indicates the total cost to be incurred to the power system of the country and the level of tariffs to be satisfied. The cost obtained stays at a high level and implies that the revision of the power tariff is required for a significant margin from the prevailing level. By all means, the tariff needs to be adjusted to a level that sufficiently covers the overall cost for the power. The prevalent bulk tariff adhered to by BPDB is Tk 2.37/kWh[2]. For the power tariff to reach the overall cost of power under the Master Plan at Tk 7.83/kWh, the bulk tariff needs to be raised to 3.3 times the prevailing level. Assuming that the gas price is adjusted to the international level in five years, the bulk tariff needs to be raised to 330%, equivalent to an annual increase of 27%. As indicated before, the overall power cost starts the Master Plan period at a high level from its very beginning and remains stagnant in the middle to latter part of the period. The start at the high level stems from the fuel cost adopting international prices, in particular, the gas price is set up at a level that is significantly higher than the prevailing price. According to the calculation, the overall cost records a peak of Tk 8.84/kWh in FY 2012. The overall cost tends to gradually decline from the year towards the final end of the Master Plan. Should it happen that the gas price is adjusted towards the international level, the storyline articulated above will become the reality in which, unless the tariff is drastically adjusted, the bulk selling business of power by BPDB will end up becoming a loss-making operation.

[1] The analysis here has adopted a discount rate of 12% in calculating the levelized cost.
[2] Based on the hearing at BPDB and BERC at the time of the revision of bulk tariff taken place in 2008.

10.5.2 Recommendation for tariff revision

As of FY 2009, the structure of the power source of BPDB, the single buyer of the power in the country, consists of; 41% from its own generation; 19% from public generation entities (government/BPDB owned); 34% from IPP purchases; and 5% from rental power producers. The costs of electricity for each of the sources are Tk 2.53/kWh for its own generation; Tk 1.21/kWh for the publicly owned generation entities; Tk 2.70/kWh for IPPs; and Tk 5.20/kWh for rental power producers. The overall acquisition cost of BPDB for all the power sources stands at Tk 3.07/kWh for the year. The average billing rate of BPDB, on the other hand, stands at Tk 2.56/kWh including its retail selling to certain designated consumers[1]. The acquisition and selling prices leave BPDB with a negative margin of Tk 0.51/kWh[2]. Of particular mention is the increase of rental power which expanded its shares among the total acquisition of BPDB from 0.2% in FY 2008 to 5.2% in FY 2009, is creating significant losses in the single buyer operation.

The purchasing of power by BPDB from the rental power producers is conducted under government initiatives and is supposed to be supported by the government in its financial outcome. The remedy assistance provided by the government remains in the provision of funds in the form of loans with interest. BPDB, though it is helped by the funds for tiding over cash flow deficiencies but is of no help in terms of profit and loss accounting in ending up with the accumulation of losses in its profit and loss statement. For BPDB, there hardly exists a source of funds for repaying the funds provided through lending by the government. The financial standing of BPDB has been placed in very weak and vulnerable position for a long time with the accumulation of losses in its balance sheet and that fact has been one of the key elements that have constrained the development of IPP market. The situation is being further aggravated in line with the promotion of the rental power generation system. The weakness and fragility of BPDB’s financial position has caused long lasting and fundamental problems such as the weak capacity for power development; lack of proper maintenance activities of existing plants; constraints in the purchasing of power generated by the private sector entities; anxieties spreading about the capability for contract performance; and constraints in new investment for the development of power both in the public and private sectors. The government is urged to take immediate steps for coping with the situations and resultant issues.

In concluding this Chapter, the PSMP Study Team stands resolved to face the issues needing rectifying and recommends that the government take the necessary steps in the following specific recommendations;

(1) Subsidy to cover the deficit Incurred by rental power

Rental power is a system that has been initiated and promoted by the government as an immediate measure to cope with the critical shortage of power. With the exception of several plants whose contracts runs for a relatively long term of 15 years, most of the contracts are short term ones of three to five years in which the per unit cost of power inevitably becomes expensive as the rental power producers try to absorb the depreciation of the plant within such limited short times. BPDB is obligated to purchase the rental power produced at such high cost and to sell the power at the regulated bulk tariff with no effective means to avoid the loss creation in the dealing operation. The negative margin incurred at BPDB needs to be recognized as the cost of the policy implementation initiated by the government and there exists a legitimate reason for the government to bear such cost. The present assistance of the government through the extension of loans to BPDB should be replaced by the grant for the purpose of alleviating the burden of loss creation at BPDB. Such actions of the government, if

[1] BPDB, “Annual Report 2008-2009”
[2] ditto

honored, are recommended to be made retroactive to the starting year of the rental power system (FY 2008), in theory.

(2) Revision of bulk selling tariff

The preceding subsection argued that the electricity tariff should be revised to reflect the overall power cost under the Master Plan. The fundamental policy of the government for setting the electricity tariff stipulates the achievement of the cost reflective tariff in Bangladesh. In actuality, the principle has not been duly met and the history of the tariff revision has been reputed as the ones of “too little, too late”. The fundamental principle laid down appears to be becoming dormant. The prevailing insufficient tariff has caused the power sector of the country problems such as the delay in development; the delay in energy saving activities; while not meeting the growing demand which is ending in the acute and aggravating shortage of power. The revision of tariffs to reflect costs is vital to develop an environment conducive to private sector investment and to activate demand side management. The power shortage issue needs to be addressed from both sides of the demand and the supply. The establishment of a cost reflective tariff is one of the indispensable steps to be taken. It is unfortunate to know that, while arguments are occurring between the government agencies and officials concerned that the cost reflective tariff is a non-negotiable must, there is no clear initiative or indicative actions for the realization of such a tariff.

The government and BERC should take strong leadership in establishing and launching an action plan to materialize the cost reflective tariff. The power cost observed in the preceding sub-chapter has been based on the international fuel prices and its wide deviation from the current tariff prevailing in the country has been observed. The first phase of the action plan should focus on achieving the cost reflective tariff based on domestic fuel prices and in the second phase to proceed to adjust the fuel price and the electricity tariff to international levels. Should it happen that the fuel price be adjusted in the nearer future, it would be necessary to execute the two phases of actions simultaneously.

(3) Raising of funds through power development surcharge

In concluding the chapter, the PSMP Study Team recommends that the government introduce a “Power Development Surcharge” System for the purpose of raising the funds for power development and moving toward the self sustaining power system in the country. The fundamental principle for the electricity tariff is laid on the cost recovery which limits the power entities to collect electricity bills only to the extent that they recover the costs invested. There is no system where the power entities gain the funds for expansion through bill collection. The funding for expansion is virtually limited to relying on government and/pr donor funding only. The following recommends that the government establish a new channel for accumulating investment funds enabling the power sector to become financially self sustainable.

【Outline of the system】

(a) Background

During the process of aggravating power shortages, it has been generally perceived that fund raising constraints have bottlenecked stagnant development. On the other hand, power demand has continually expanding in the low tariff environment resulting in a chronic supply shortage. Some of the consumers in searching for a remedy on their own found alternative supply sources through captive generation. Those consumers paid costs and expenses higher than public power tariffs for captive diesel generation while demonstrating their preparedness for bearing higher electricity costs. The PSMP Study Team finds a rational reason to request that the consumers bear a part of the development cost of power and accelerate the development process through which the returns will be given back to the consumers in the form of less expensive power cost in comparison with that of captive generation.

(b) Scheme

As an integral part of the electricity tariff, a power development surcharge shall be established. The surcharge shall be in the range of two to three percent of the retail tariff and charged to all of the electricity consumers as a part of the electricity bill. The rate of the surcharge can be adjusted in respect of the demand and supply conditions, in particular, the power shortage, progress of overall development of the power sector, etc. The funds collected through the surcharge shall be deposited into a separate fund account and managed by an independent organ to be established for that purpose. The accumulated funds shall be invested and/or loaned to the project to be implemented by the government and/or by the private investor for the purpose of power development or energy saving activities. The funds should not be used as a replacement source of funds for the national budget for expenditures that should be born by the budget in such as the counterpart funding arises with the new donors' commitments of assistance, etc.

(c) Effect expected

As an assumption, it is said that the volume of electricity sales will be 53,000 GWH, equivalent to the volume anticipated for FY 2015 under the Master Plan Scenario, the surcharge levied at Tk 0.10/kWh generates the total fund revenue of Tk 5.3 billion per year. The revenue will expand as the volume of consumption increases. The funds will accumulate in two years to about Tk 11 billion. Assuming that the construction costs of a 400 MW class power station is about US$ 400 million, the funds collected in two years might be sufficient enough to cover the equity investment for plant construction (Equity: US$ 16 million=Tk 11 billion). The project invested/financed by the funds should be made available to public visits though which the consumers and general public can enhance their awareness for power development participation, consumption and energy saving. The awareness enhanced shall be the driving force for further future development.

(d) Rationale

1) The system is as rational as;

The consumers paying high cost and expense for operation of captive generation will be able to lessen their costs for power in the long run;

2) The system is equitable as;

The surcharges shall be born by the consumers equitably in proportion to their volume of consumption. The surcharge born by the consumers shall be rewarded with the solution of power shortages and lower costs. The relation between the cost bearing and benefits is straight forward and transparent;

3) The system is stable as;

The electricity consumption is not much vulnerable to the economic fluctuation and grows steadily. The system can generate the funds with stability. The stabilized inflow of revenue enables steady power development.

4) The system needs consideration as:

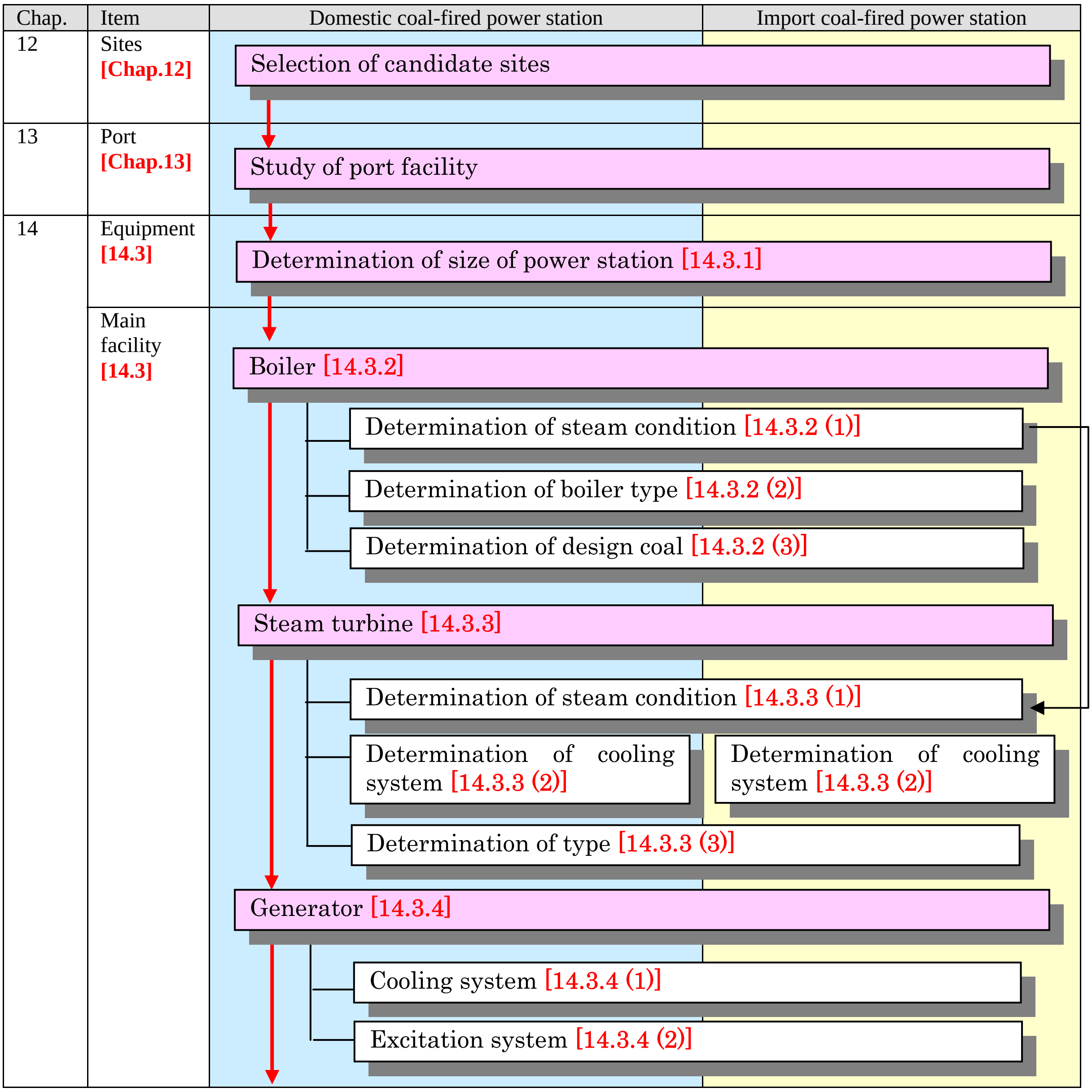
It will take a long time after the consumers start paying the surcharge before the returns materialize due to the long gestation period for development. The surcharge system might include the low income class to whom the surcharge might be a relatively heavy burden. The consumers who are not able to afford additional captive power generation costs or surcharges might deserve special consideration. Small consumers should be given due consideration when formulating the system.

Volume 2 Technical Study for the Construction of Coal-Fired Power Stations

Chapter 11 Viewpoints and Objectives towards Realization of the Most prioritized Projects

11.1 Study flow

Volume 2 considers the technical study for the construction of coal-fired power stations of most prioritized projects, the study consists of the selection of candidate sites on Chap.12, the study of the port facility on Chap.13, the conceptual study for the construction of power stations on Chap.14, the construction schedule and cost on Chap.15, economic and financial analysis on Chap.16, the study of operations and maintenance formation on Chap.17, and the environmental and social examination of Chap. 18. The following figure shows the study flow of volume 2.



Chap.	Item	Domestic coal-fired power station	Import coal-fired power station
14	Environ-mental Facility [14.3]	Environmental facility [14.3.5] Determination of type of electrostatic precipitator [14.3.5 (1)] Determination of type of desulfurization [14.3.5 (2)] Determination of type of denitrification [14.3.5 (3)]	
	Utility equipment [14.3]	Utility equipment [14.3.6] Determination of capacity of water treatment facility [14.3.6 (1)] Coal stock & handling facility [14.3.6 (2)] Determination of type of ash treatment facility [14.3.6 (3)]	
	Equipment transpor-tation [14.4]	Study of equipment transportation [14.4]	
15	Construc-tion sche-dule, cost	Study of construction schedule [15.1] Study of construction cost [15.2]	
16	Economic and financial analysis	Economic and financial analysis of high prioritized projects [Chap.16]	
17	O & M formation	Study of operation and maintenance formation of high prioritized projects [Chap. 17]	
18	Environment & social consideration	Environmental and social examination on most prioritized projects [Chap.18]	

Source: PSMP Study Team

Fig. 11-1 Study flow for technical study for the construction of coal-fired power stations on the most prioritized projects

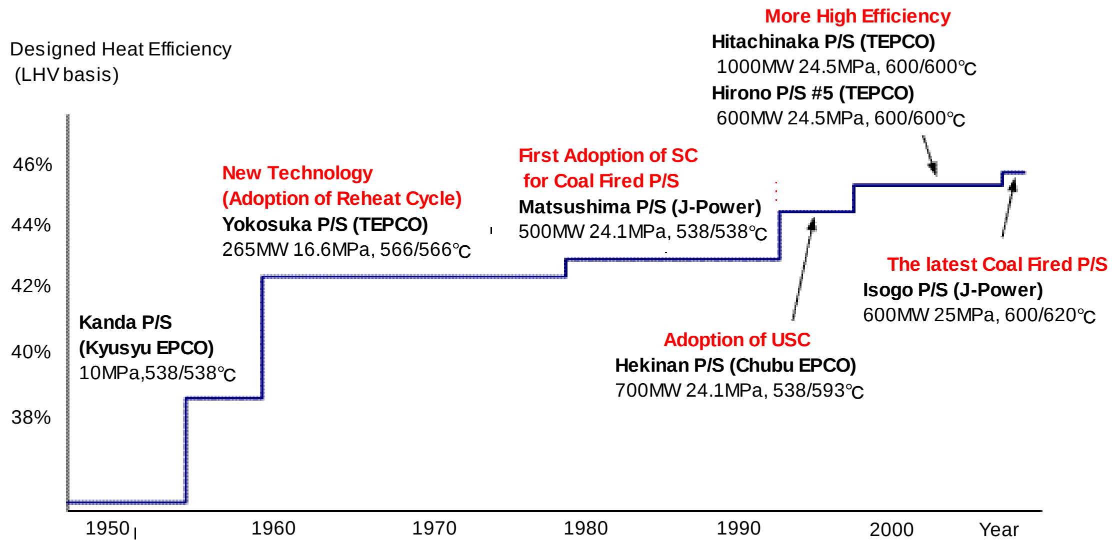
11.2 Viewpoints and objectives

As shown in Chapter 2, it is obvious that coal would play a major role in the primary energy or power sector for the long time. Under such circumstances, when coal-fired power stations are developed, the objective is that, for the "coal" which emits more CO_2 than other fuels, by adopting "Clean Coal Technology" higher efficiency is realized and the environmental load is reduced by adopting environmental facilities, and allows for the contribution to global warming prevention by exploiting the economical merits.

11.3 Study about efficiency level which could be adopted in Bangladesh

11.3.1 Application of high efficiency coal-fired power station

The thermal efficiency of thermal power stations has been improved, as it was about 30% in the 1950's but currently the state-of-the-art gas-fired combined cycle plant with an efficiency of nearly 60% is already in under commercial operations. At the same time, the efficiency of coal-fired power stations has been improved by higher temperatures and higher steam pressure. For example, it is about 43% by the Super Critical (SC) equipment already widely utilized, and it reaches 45% via the new Ultra Super Critical (USC) equipment. Such improvement of thermal efficiency refers to a decrease in the amount of fuel, which decreases the amount of CO_2 emissions contributing to prevent global warming.

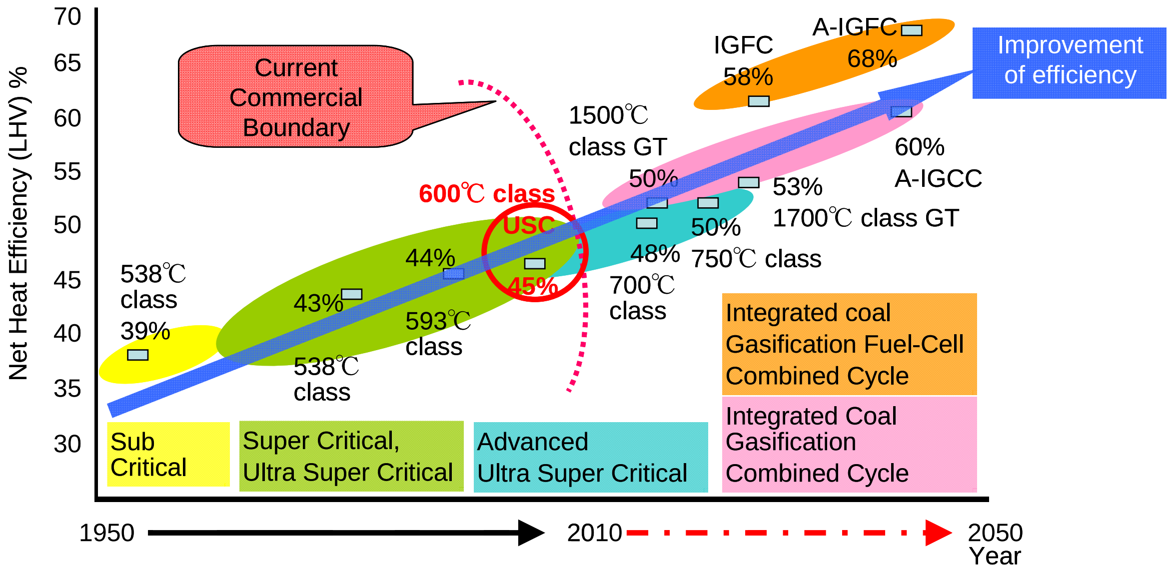


Source: "Thermal and Nuclear Power" 2006.10

Fig. 11-2 Heat Efficiency of coal-fired power stations in Japan

11.3.2 Study about efficiency level which could be adopted in Bangladesh (Target of high efficiency)

In Japan, for the purpose of the efficient utilization of coal, not only the Clean Coal policies in the formation organized by the Ministry of Economy, Trade and Industry (METI), but the private companies are proceeding with many technical developments. The following figure shows the perspective of technical development regarding coal-fired power stations.



Source: Arranged by PSMP Study Team from "Cool-Earth 50"

Fig. 11-3 Improvement of efficiency on coal-fired power stations

Regarding the development of IGCC, currently the verification test by 250MW demonstration plant is proceeding under the "Clean Coal Power Institute" which was established by power companies. By reflecting its results, a commercial level facility would be developed;, however, the procedures depend on the results of the verification test.

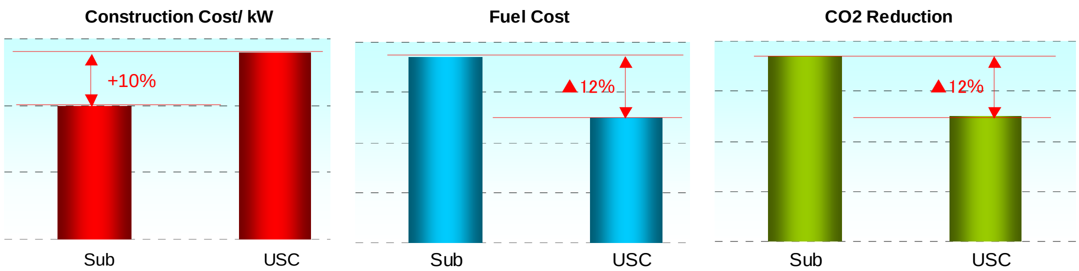
Regarding advanced USC (A-USC), although the basic system is the same as the conventional type, it needs new developed materials which can endure very high pressure and temperature conditions, so that it takes a long time even after the developed new materials in order to achieve sufficient reliability.

Therefore, although USC technology is not at a "state-of-the-art" level compared with other new technology which is currently at the development stage, it is at the highest level at the commercial stage which has sufficient reliability, so that it is the best choice to adopt in this master plan. In this master plan, USC technology would be adopted and its target thermal efficiency is 45%.

As a facility which would be adopted in Bangladesh, the A-USC or IGCC technology which currently is under development could be one of the options in the future. However, a detail study for reliability and economy should be conducted in the stage of adoption of available technology.

11.4 Verification of economic priority by adopting high efficiency technology

The following figure shows the relationship between the construction costs, fuel costs, and CO_2 emissions comparison image between the sub-critical power station and the USC power station.



Source: PSMP Study Team

Fig. 11-4 Comparison between sub-critical facility and USC facility (image)

As explained in Chapter 2, the construction costs of the USC plant, especially those connected to the materials for high pressure and high temperature are higher than the sub critical plant which became widely used throughout the world. However, fuel consumption is lower because of high efficiency; it leads to lower fuel costs, so the increase of construction costs would be recovered via a certain period of operation. Moreover, CO_2 emissions could be reduced.

11.5 Highest level environmental equipment in the world（measure for NOx, SOx, Particle Matter, Vibration, Noise, Coal Dust）

Though there is a difference of characteristics depending upon the area of production, the coal which is the main fuel in coal-fired power station which is proposed in this Master Plan contains more nitrogen content, sulfur content, and ash content than other thermal power fuel (gas and oil etc) with in comparison, there are more NOx, SOx, Particle Matter generation due to combustion of coal. In addition, the coal dust occurs by handling of coal, it is said that environmental impact by using coal is higher including health and safety aspect. Therefore, it is important to make environmental impact minimized by introduction of the highest-level environmental equipment in the world, which is described below.

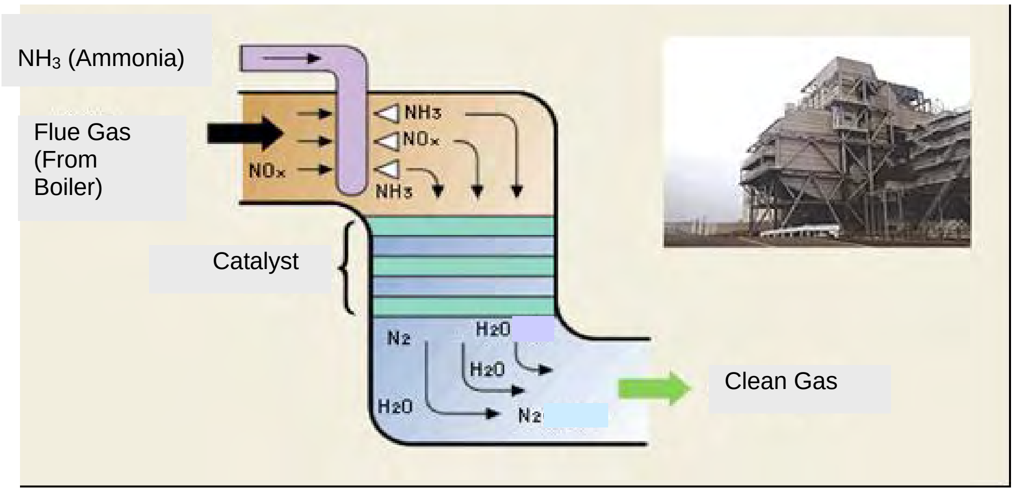
11.5.1 Flue gas denitrification equipment

There are two types of nitrogen oxide by combustion (NO_X). One of them is the Fuel NO_X which is generated from being oxidized nitrogenous substance which is included in the fuel when combustion. The other is the Thermal NO_X which is generated from being oxidized nitrogenous substance which is included in the combustion air. Ratio of Thermal NO_X with the coal combustion is from 10% to 20 %. Measure for flue gas denitrification is executed combining below three measures.

- Usage of low nitrogen content fuel
- Improvement of combustion
- Application of flue gas denitrification equipment

With the NO_X control by improvement of combustion, mainly thermal NO_X generation is controlled by reducing the flame temperature inside the boiler. Equipments which used for improvement of combustion are over fire air duct (two-stage combustion), gas-mixture-fan and additional duct（flue gas recirculation） and low NO_X burners.

It is possible to roughly classify type of flue gas denitrification equipment to dry method and wet method, various systems are developed in principle. Among those systems, selective catalytic reduction (SCR) which is one of dry method and uses ammonia as the reducing agent is main denitrification equipment for power boiler. This system can make NO_X disassemble to harmless nitrogen and water, and it is suitable for large amount flue gas treatment since the system composition is simple. Following shows the mechanism of SCR.



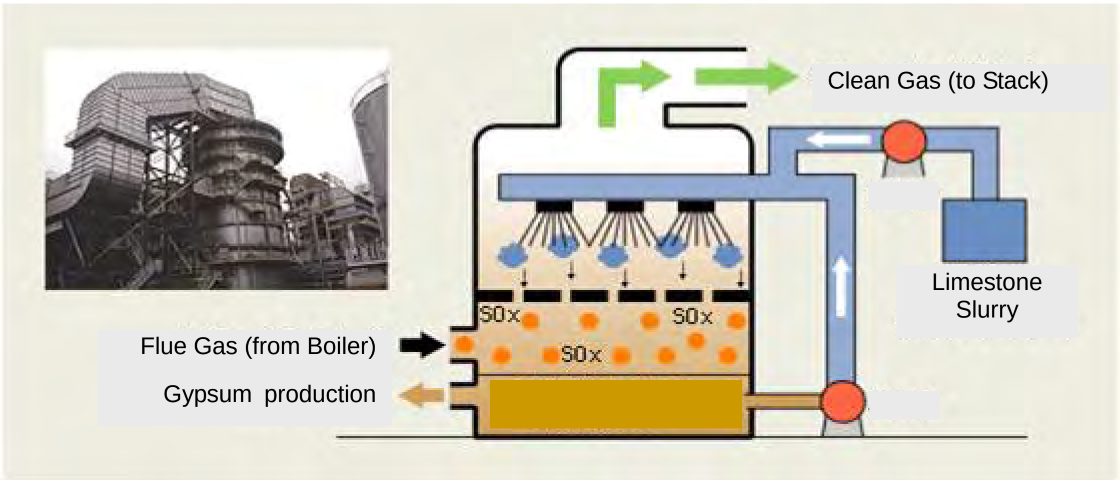
Source: TEPCO website

Fig. 11-5 Flue gas denitrification equipment (SCR)

11.5.2 Flue gas desulfurization equipment

Sulfur oxide (SO_X) is generated by being oxidized sulfur content which is included 0.3 to 2.6 weight percent in fuel due to combustion. In coal-fired power plant, SO_X is reduced by introduction of the flue gas desulfurization equipment. The flue gas desulfurization equipment can be roughly classified to wet method and dry method. Most of flue gas desulfurization equipment for current large power boiler is limestone gypsum FGD, wet method. In limestone gypsum method, HCO_3- from slaked lime is used for the absorbent.

There are past record of seawater scrubber type desulphurization equipment which has almost same component configuration and is simplified the system by using HCO_3- in seawater for absorbent. And it is effective to use dry process activated carbon absorption method at inland area where is difficult to acquire industrial water. Following shows the mechanism of limestone gypsum FGD, wet method.



Source: TEPCO website

Fig. 11-6 Flue gas desulfurization equipment (limestone gypsum FGD, wet method)

11.5.3 Dust collection

Ash from coal-fired boiler can be roughly classified as following table.

Table 11-1 Classification of coal ash

Classification of coal ash	Meaning	Part	Distribution(%)
Fly ash	The fine grain ash which is formed by combustion	Dust collector	Circa 80～90
Cinder ash	The grain ash which is formed by combustion	Air heater, economizer	Circa 5
Clinker ash	Massive form ash which is formed by combustion	Boiler bottom	Circa15～5

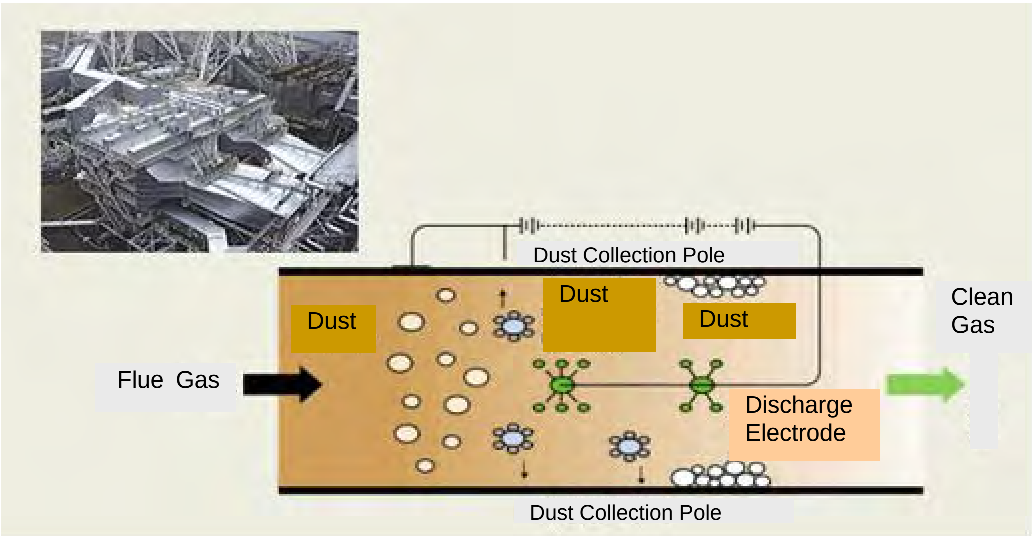
Source : Thermal and Nuclear Power Engineering Society

Dust collector collects the fine grain ash. The way of dust collection is roughly classified physical method (gravity, inertial forces, centrifugal force, and spreading force) and electrical method (electric force). Bag filter and Cyclone separator are typical physical methods and Dry Electrostatic precipitator (Dry ESP) and Wet Electrostatic precipitator (Wet ESP) are typical electrical methods. Dry ESP is common in especially large-sized thermal power boiler.

Fly ash from coal-fired boiler has features like below, and up-to-date ESP is designed corresponds to these ash qualities.

- Medium diameter (dp50) is circa from 13 to 40 micro meter and that is larger than fly ash from oil-fired power boiler
- Adhesion is strong
- Dust layer resistivity is high and tends to occur back corona

In this master plan, it has been determined to adopt EP which is suitable for coal quality in order to reduce air pollution to a minimum level. The following shows the mechanism of the EP.



Source: TEPCO website

Fig. 11-7 Electrostatic precipitator (EP)

11.5.4 Measure for coal dust

Table 11-2shows measure for coal dust according to coal handling.

Table 11-2 Measure for Coal dust

Equipments	Area	Note
Sprinkler	Coal storage yard	Measure for self-ignition
Windbreak fence	Coal storage yard	-
Sealed conveyer	Coal conveyer	Measure for foreign object
Dust collector for coal conveyer	Transfer point of coal conveyer, entrance of coal banker etc	Measure for explosion protection

Source: PSMP Study Team

11.5.5 Target by adopting environment facilities

The merits via adopting the above environmental facilities is assumed to be as follows,

- To lead the preventive measure of pollution problem
- To improve social understanding that leads to smooth development
- To improve technical levels that lead to the adoption of new technology minus future difficulties

11.6 Contribution to the social and economic by mutual collaboration with local communities

Generally, the power station is one of the national important facilities so that there is no contact with normal citizens. However, this engenders bad feelings among citizens resulted in hindered development.

In Japan, on the contrary, the power stations have a good relationship with local communities because it is based on the concept of “mutual collaboration with local communities” . It results in limited objections from local communities concerning power development and the social position of the power company is to maintain and lead smooth power development.

That concept should be adopted in Bangladesh. The following concepts are proposed in this master plan concerning the construction of coal-fired power plants,

- To increase the “green ratio” of the power plant, to make a “Green Power Plant.“
- To create some public space like a park, ground that is open to the public.
- To create a staff residence area, and to create a power plant town.

Through the development of power stations under the concept of “mutual collaboration with local community”, it is accepted that this will create new employment opportunities for the local population that would contribute to poverty reduction.

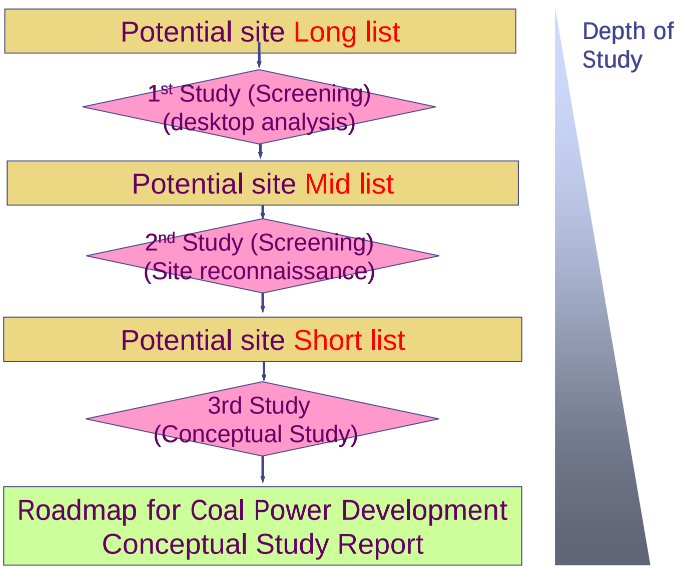
There are co-products from the environmental facilities of the coal-fired power station, such as coal ash, gypsum from desulfurization equipment, and sludge from the wastewater treatment facilities. The beneficial utilization for these co-products should be conducted. Currently, the most common usage is the material for cement. The demand of cement for buildings and infrastructure would increase in concert with the development of the economy in Bangladesh, the supply of material would help the demand, this means coal-fired power plants would contribute to the economic development in Bangladesh.

Chapter 12 Selection of Most Prioritized Projects

In this chapter, most prioritized projects were selected from potential candidate sites for development via the AHP method. In conclusion, the B-K-D-P site as the domestic coal-fired power plant, and Chittagong, Meghnaghat as the import coal-fired power plant were selected as most prioritized projects in this study.

12.1 Selection flow for most prioritized projects

Potential candidate sites for coal-fired power plants were identified in advance to materialize the optimum power development Master Plan, which is called as long-list.
Out of the long-list, the more promising sites are selected according to the major selection criteria, which are called middle-list. Middle-list selection was implemented by basically lap-top evaluation, which was used to identify the project where the PSMP Study Team conducted site survey.
After the site survey at 2nd mission, each expert evaluated the middle-list to nominate the first priority projects in view of higher feasibility according to the detailed selection criteria and the results of site survey, which is called short-list. The selection criteria were established by discussion with CP. Selection flow diagram is shown as follows;



Source: PSMP Study Team

Fig. 12-1 Selection flow for prioritized projects

12.2 Selection result

This Study formulates the optimum power development master plan for twenty years from year 2010, targeting whole country of Bangladesh. Coal power development plays key role to materialize this Master Plan. The most prioritized coal development projects are selected, prioritized and finally short-listed by screening from potential development sites from technical, economic & financial, and environmental and social point of views, with consideration of funding from overseas like Japanese Yen loan. Short-listed projects regarded as the most feasible will be further investigated from technical, economic & financial, and environmental and social point of views, and then implemented more detailed outline study for technical support to materialize the projects.
Based on the discussion with CP, following sites were nominated as potential coal development sites as Long-list. For the points mentioned in Long List, the PSMP Study Team conducted evaluation according to pre-determined major and detailed selection criteria to narrow down to Mid-list and then Short-list.

Table 12-1 Selection of most prioritized project

No.	Site Name	Planned Use Coal	Long List	Middle List	Short List
1	Barapukuria	Domestic		1st screening (desktop evaluation)	2nd screening (site survey)
2	Phulbari	Domestic			
3	Kharaspir	Domestic			
4	Dighipara	Domestic			
5	Jamalgonj	Domestic			
6	Kuchma	Domestic			
7	Bheramara	Domestic/Import			
8	Chittagong	Import			
9	Cox's Bazar	Import			
10	Mongla	Domestic/Import			
11	Khulna	Import			
12	Meghnaghat	Import			
13	Zajira	Import			
14	Maowa	Import			
15	Chandpur	Import			
16	Matarbari	Import			

Source: PSMP Study Team

12.3 Selection by AHP method

12.3.1 Selection standards

In the process for the selection of projects, in order to weigh objectively the evaluation items and evaluations between all projects, the AHP (Analytic Hierarchy Process) Method was adopted. The most important point in adopting the AHP Method for decision-making is the selection of evaluation standards. It is important that the items are selected independently of each other (one item should not influence another). Next, it is imperative that the importance in comparison between each evaluation is weighed as a basis for determining the level of importance for evaluation items. From the Long List which is a list of potential candidate site for coal power development, based on the following selection standards, Middle List and Short List are selected.

Table 12-2 Selection standards (major item and detail item)

Major Item		Detail Item	
A	Fuel Security	1	Fuel Transportation
		2	Port Facility
B	Feasibility Factor for Construction	1	Securing the Necessary Amount of Ground Space
		2	Transportation of Facilities
		3	History of Flood
		4	Topography / Geology
C	Operational Conditions	1	Securement of Cooling Water
		2	Ash Treatment
D	Economic Conditions	1	Distance with Existing Power System
		2	Project Cost
E	Local Demand-Supply	1	Advantage on Power System Viewpoint
F	Needs of Bangladesh	1	Needs Level of Bangladesh
G	Donor	1	Plan and Priority of WB,ADB Finance
H	Environmental Influence	1	Air Pollution
		2	Water Contamination
		3	Soil Pollution
		4	Bottom Sediment
		5	Noise and vibration
		6	Offensive Odor
		7	Waste
		8	Ground subsidence
		9	Geographical feature
		10	Biota and Ecosystem
		11	Water usage
		12	Accidents
		13	Global warming
I	Social Considerations	1	Involuntary resettlement
		2	Local Economy such as employment and livelihood etc.
		3	The poor, indigenous and ethnic people
		4	Misdistribution of benefit and loss
		5	Local conflict of interests
		6	Gender
		7	Children's right
		8	Land use and utilization of local resources
		9	Social institutions such as social infrastructure and local decision making institutions
		10	Existing social infrastructures
		11	Cultural heritage
		12	Infectious diseases such as Human Immunodeficiency Virus and Acquired Immune Deficiency Syndrome (HIV/AIDS) etc

Source: PSMP Study Team

12.3.2 Weighting of evaluation items by the AHP method

The greatest characteristic of the AHP Method is a "pair comparison". In this stage which judges importance, a one-to-one comparison is conducted instead of a comparison of all the items at one time.

Because every judgment measures the importance and level of only one item from two, it is easy to make comparisons, and weigh importance.

Therefore, in this study, the weighting of an evaluation item is preceded by the AHP method as follows.

Table 12-3 Result of evaluation by AHP method for major items

	Major Items	A	B	C	D	E	F	G	H	I	Geometric Average	Level of Importance	Point Allocation
A	Fuel Security	1	2	2	2	2	2	2	1	2	1.7145	0.1818	18.15
B	Feasibility Factor for Construction	1/2	1	1	1	1	1	1	1/2	1	0.8572	0.0909	9.10
C	Operational Conditions	1/2	1	1	1	1	1	1	1/2	1	0.8572	0.0909	9.10
D	Economic Conditions	1/2	1	1	1	1	1	1	1/2	1	0.8572	0.0909	9.10
E	Local Demand-Supply	1/2	1	1	1	1	1	1	1/2	1	0.8572	0.0909	9.10
F	Needs of Bangladesh	1/2	1	1	1	1	1	1	1/2	1	1.7145	0.1818	18.15
G	Donor	1/2	1	1	1	1	1	1	1/2	1	0.8572	0.0909	9.10
H	Environment al Influence	1	2	2	2	2	2	2	1	2	0.8572	0.0909	9.10
I	Social Considerations	1/2	1	1	1	1	1	1	1/2	1	0.8572	0.0909	9.10
Summary													100

Source: PSMP Study Team

12.4 1st screening (desktop evaluation)

Table 12-4 shows the result of selection from long list to mid list (1st screening). After judging and comparing each view totally,16 sites with over 5 points, that are Barapukuria, Phulbari, Khalaspir, Dighipara (as the candidate for domestic coal), Chittagong, Cox's Bazar, Mongla, Khulna, Meghnaghat, Zajira, Maowa, Matarbari (as the candidate for import coal) was narrowed down to Mid-List.

Table 12-4 Evaluation result of 1st screening by AHP method

		A	B	C	D	E	F	G	H	I	Total	Ranking
		Fuel Security	Feasibility Factor for Construction	Operating Conditions	Economic Conditions	Local Demand and Supply	Needs of Bangladesh	Donor	Environmental Influence	Social Considerations		
No	Site Name	18.15	9.10	9.10	9.10	9.10	18.15	9.10	9.10	9.10		
1	Barapukuria	0.0516	0.0939	0.0250	0.0625	0.0960	0.0627	0.0417	0.0696	0.0306	5.8892	11
2	Phulbari	0.0516	0.0939	0.0425	0.0625	0.0960	0.0627	0.0417	0.0696	0.0306	6.0485	9
3	Khalaspir	0.0890	0.0939	0.0425	0.0625	0.0960	0.0627	0.0417	0.0696	0.0583	6.9801	5
4	Dighipara	0.0516	0.0939	0.0425	0.0625	0.0960	0.0627	0.0417	0.0696	0.0583	6.3010	6
5	Jamalgonj	0.0144	0.0939	0.0425	0.0625	0.0960	0.0627	0.0417	0.0188	0.0306	4.9122	13
6	Kuchima	0.0144	0.0939	0.0425	0.0625	0.0960	0.0627	0.0417	0.0188	0.0306	4.9122	14
7	Bheramara	0.0144	0.0120	0.0250	0.0625	0.0516	0.0627	0.0417	0.0214	0.0583	3.8792	16
8	Chittagong	0.0906	0.0512	0.0820	0.0625	0.0287	0.1210	0.1250	0.1217	0.1713	9.6864	1
9	Cox's Bazar	0.0529	0.0512	0.0820	0.0625	0.0287	0.0319	0.0417	0.0235	0.1047	5.1279	12
10	Mongla	0.0906	0.0512	0.0820	0.0625	0.0516	0.0319	0.0417	0.0650	0.0583	5.9760	10
11	Khulna	0.0906	0.0512	0.0820	0.0625	0.0516	0.0627	0.1250	0.1247	0.1047	8.2580	2
12	Meghnaghat	0.0906	0.0512	0.0820	0.0625	0.0516	0.0627	0.1250	0.1288	0.0583	7.8737	3
13	Zajira	0.0906	0.0512	0.0820	0.0625	0.0516	0.0627	0.1250	0.0643	0.0583	7.2869	4
14	Maowa	0.0906	0.0512	0.0820	0.0625	0.0516	0.0627	0.0417	0.0643	0.0306	6.2761	7
15	Chandpur	0.0270	0.0147	0.0820	0.0625	0.0287	0.0627	0.0417	0.0188	0.0583	4.4188	15
16	Matarbari	0.0890	0.0512	0.0820	0.0625	0.0287	0.0627	0.0417	0.0514	0.0583	6.1738	8

Source: PSMP Study Team

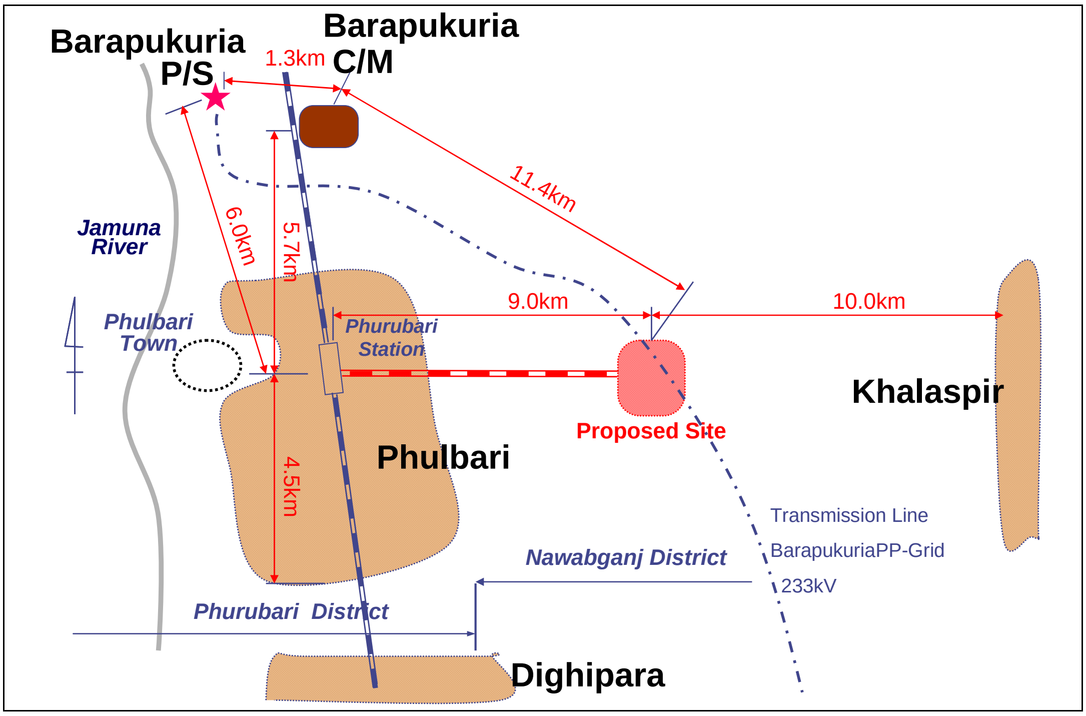
12.5 2nd screening (site survey)

The site survey was conducted for the purpose of the 2nd screening from the 12 sites of the long list which have been selected from the 16 sites by the 1st screening.

12.5.1 Site survey

(1) Candidate site for the domestic coal-fired power plant

Barapukuria, Phulbari, Karaspir and Dighipara are treated as one single domestic coal candidate site where designates particular area located from nearly equal distance from each potential sites (hereinafter B-K-D-P site).



B-K-D-P site		
		
Candidate site	Neighbor river	Barapukuria coal mine

Source: PSMP Study Team

Fig. 12-2 Location and site photos of B-K-D-P site

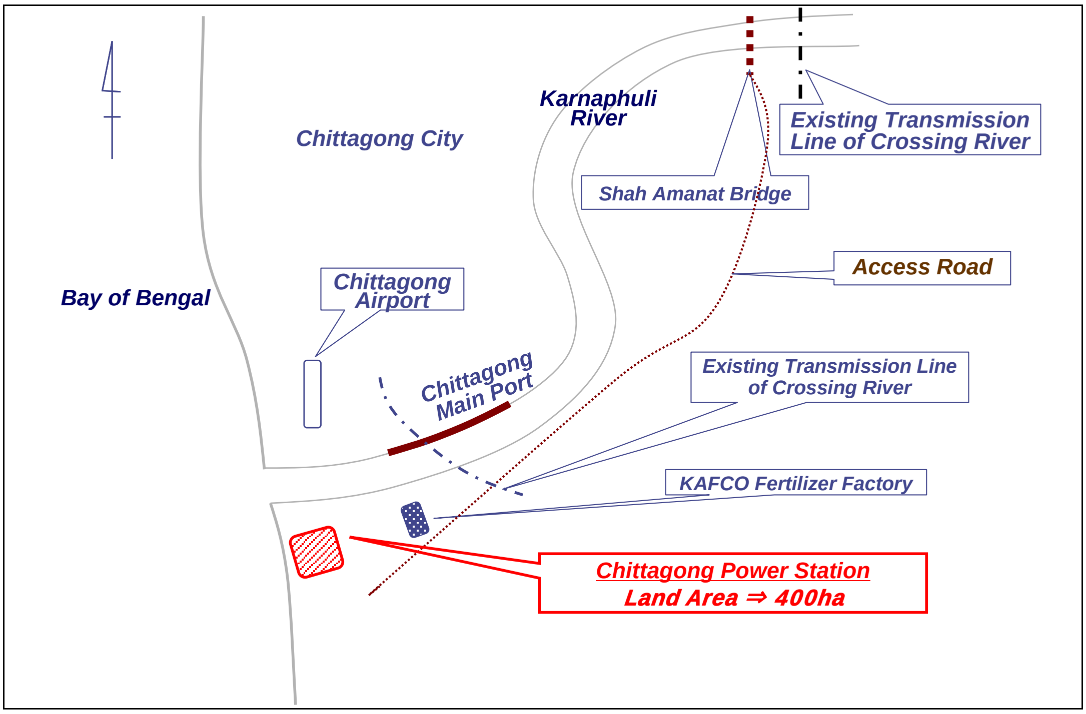
While Barapukuria is the only coal mine in operation, the other 3 sites are hopeful points for the future production of coal. As these sites are close each other, it would be ideal that coal power station is constructed on the point at the same distance from these sites.

(2) Candidate site for the import coal-fired power plant

The site survey was conducted for 8 sites, Chittagong, Cox's Bazar, Mongla, Khulna, Meghnaghat, Zajira, Maowa, and Matarbari.

(a) Chittagong

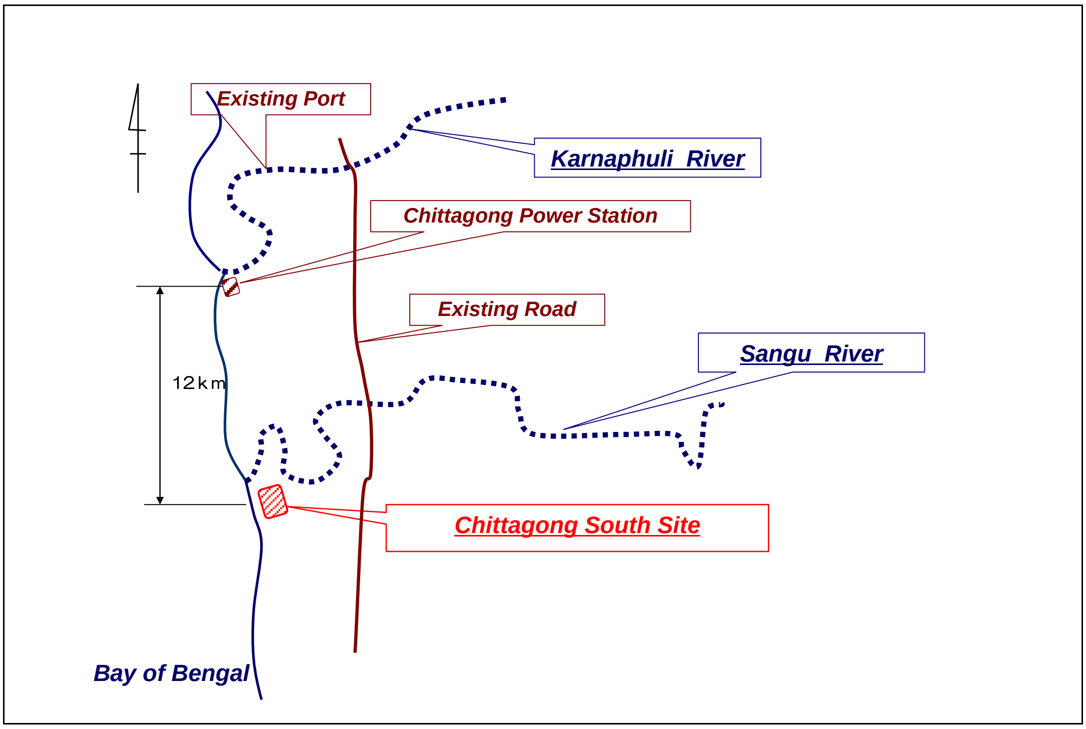
There is a biggest port facility in Bangladesh, it would be the most prioritize site for import coal power station. Needs of Bangladesh is also high.



Chittagong site		
		
Candidate site	Candidate site and neighbor factory	Chittagong port

Source: PSMP Study Team

Fig. 12-3 Location and site photos of Chittagong site



Chittagong South site		
		
Sangu River	Candidate site	Candidate site

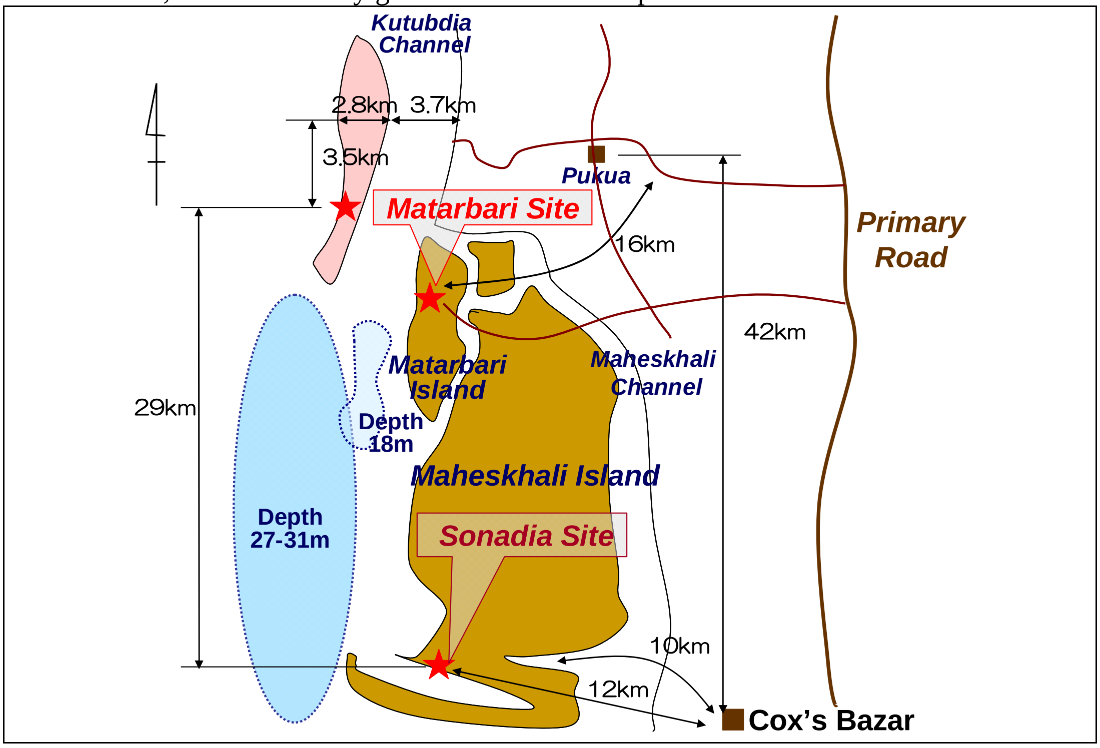
Source: PSMP Study Team

Fig. 12-4 Location and site photos of Chittagong South site

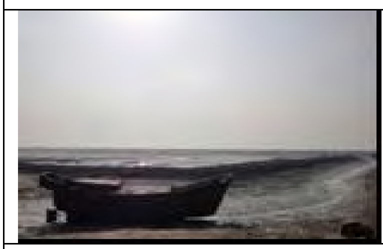
As candidate site points for Chittagong, one is Anwara which is closed to the existing international port, and another is Sangu which is about a 20km distance to south. For the Anwara site, the government of Bangladesh is already planning to carry out the FS for a coal-fired power plant, so that the Sangu site is determined to be candidate site as the Chittagong South“ for avoiding redundancy.

(b) Cox's Bazar, Sonadia, Matarbari

Cox's Bazar is a resort spot with the longest beach in the world. Sonadia Island which is located on the opposite side has a deep sea area and it is a candidate site of deep sea port development, so that it has a potential for economic development. Matarbari is located about 20km north of Sonadia Island, where relatively good access to the deep sea area as well.



Cox's Bazar site		
		
Beach	Road near beach	Identification of location

Matarbari site		
		
Candidate site	Candidate site	Candidate site

Source: PSMP Study Team

Fig. 12-5 Location and site photos of Cox's Bazar, Matarbari, Sonadia sites1

Sonadia site		
		
View from Cox's Bazar	DSP development site	Residence

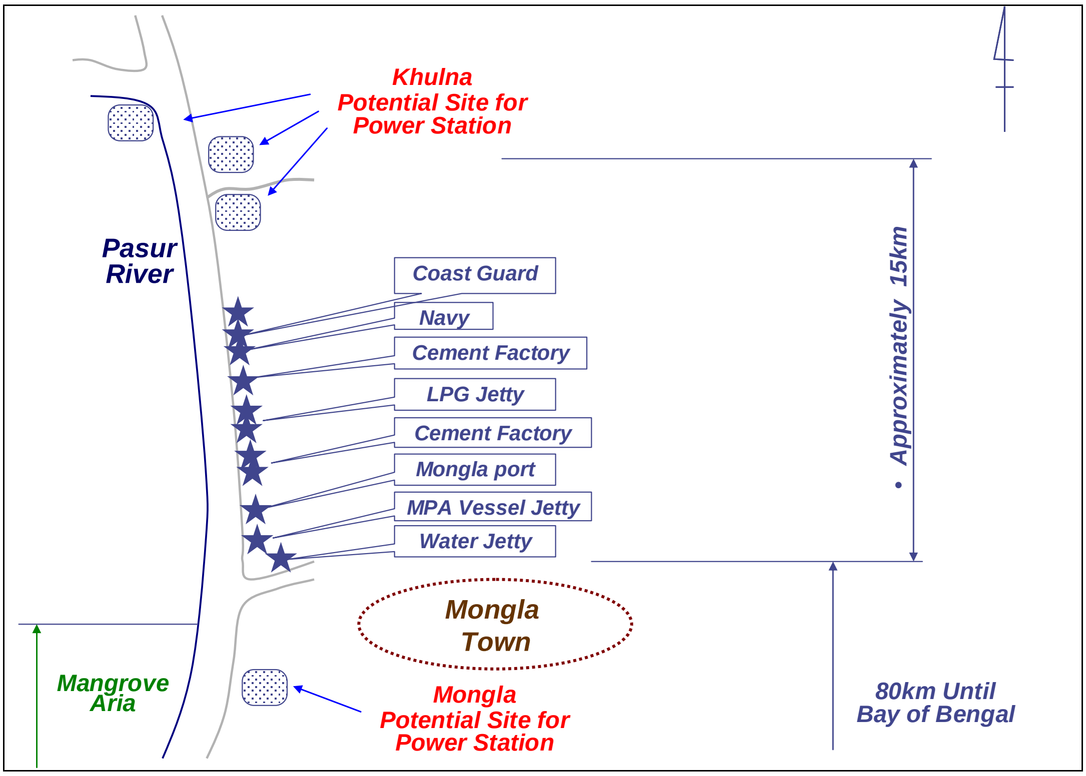
Source: PSMP Study Team

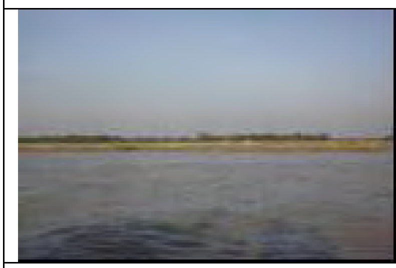
Fig. 12-6 Location and site photos of Cox's Bazar, Matarbari, Sonadia sites2

Cox's Bazar in not only a resort spot but also an environmental protected zone by the government, so it is difficult to develop a power station.
Sonadia and Matarbari has a deep sea area, so it is good for the development of a deep sea port, It is also capable to secure enough space in the land, so it leads to the efficient handling of coal by developing power stations and the coal center. However, Sonadia is not suitable for power station installation because it is near Cox's Bazar, environmental protected zone.

(c) Khulna, Mongla sites

Khulna is located about 15 km from Mongla which is the second biggest international port. Therefore, it uses import coal to come to the Mongla port.



Khulna, Mongla sites		
		
Khulna candidate site	Mongla port	Mongla Port Authority

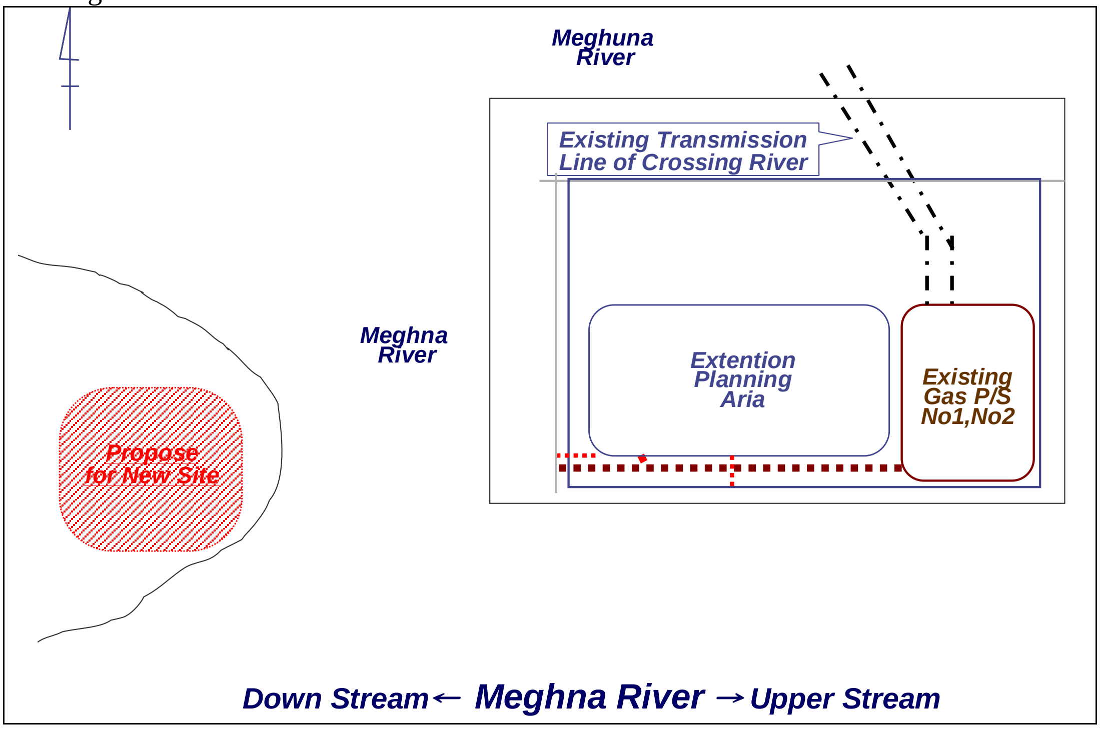
Source: PSMP Study Team

Fig. 12-7 Location and site photos of Khulna, Mongla sites

Because Khulna doesn’t include a world heritage area which is different from Mongla, it is easier to develop. It is easier to secure coal by import than using domestic transportation. It should be under consideration as a prioritized site. Therefore the government of Bangladesh is already planning to develop a coal-fired power plant with a target to commence commercial operations in 2016.

(d) Meghnaghat site

As it is near Dhaka, which is only 20 km away, it is good for a power plant for the load center. The gas-fired power station (IPP 450MW) is already in operation. The transmission conditions are also good.



Meghnaghat site		
		
Existing transmission line	Existing IPP power plant	Meghna River

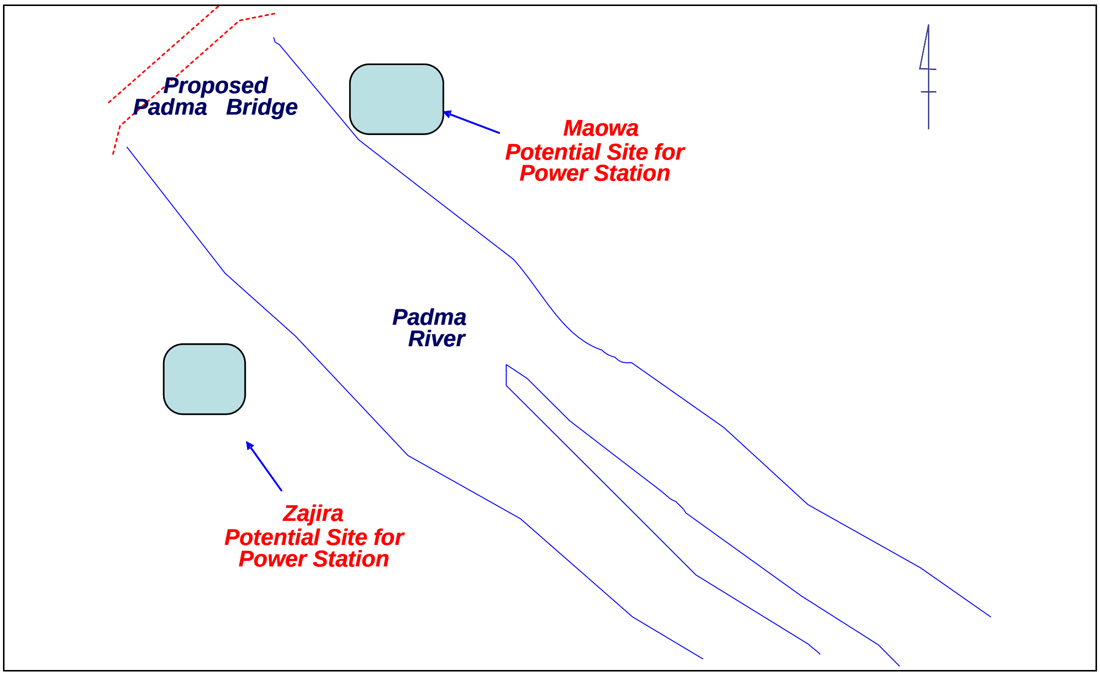
Source: PSMP Study Team

Fig. 12-8 Location and site photos of Meghnaghat site

It would be possible to secure land near an existing IPP power station. Enough water for cooling could be secured from river as the same as existing IPP. A plan for expand power system line is existing. Even though coal have to be transported by small ship, it can be developed quickly.

(e) Zajira, Maowa sites

They are located near the proposed Padma Bridge on the Padma River. Coal is to be transported by domestic vessels.



Maowa site		
		
Candidate site	Candidate site	Candidate site

Zajira site		
		
Candidate site	Candidate site	Candidate site

Source: PSMP Study Team

Fig. 12-9 Location and site photos of Maowa, Zajira site

These two sites are located on both banks of the Padma River, currently there is a jetty for a ferry. Area development is also needed in order to develop the power station, but the land could be secured.

12.5.2 Screening result

The following shows the results of the 2nd screening by a site survey.
Further, it shows the characteristics about fuel secure.

Table 12-5 Result of 2nd screening (According to priority)

Priority	Site	Domestic coal	Import coal	
			Import vessel	Domestic vessel (from Coal Center)
1	Chittagong		○	
2	Khulna		○	
3	Meghnaghat			○
4	B-K-D-P	○		
5	Matarbari		○	
6	Zajira			○
7	Maowa			○
8	Cox's Bazar		○	

Source: PSMP Study Team

12.5.3 Selection of most prioritized project

The results of the 2nd screening shows that the ranking of sites is Chittagong, Khulna, Meghnaghat, B-K-D-P, Matarbari, Zajira, Maowa, Mongla, and Cox's Bazar. When a most prioritized project in this study is selected, based on the concept that it is for the basic of future development of coal power by Bangladesh itself, the following concept was adopted without using a simple selection from the ranking.

- Based on the national policy that domestic resources should be developed preferentially, one site which mainly used domestic coal should be selected.
- From the sites for using import coal, each site has a different type of fuel transportation (means one has coal center capability and another needs domestic transportation).

Based on above concept, the following sites were selected as Most prioritized Projects in this study.

- Chittagong : It has a 1st ranking, and it is capable of maintenance for import coal port, it is selected as a site with a coal center
- Meghnaghat : It is as high as a 3rd ranking, and has a 1st ranking for the sites which are not capable of receiving imported ships directly. It is a site selected for its internal transportation capabilities of import coal.
- B-K-D-P point : It is ranked as 4th, so it has been selected as a site for domestic coal

Table 12-6 Result of 2nd screening

Item		Point Allocation	1	2	3	4	5	6	7	8	9
			K-D-P	Chittagong	Cox's Bazar	Mongla	Khulna	Meghnagh at	Zajira	Maowa	Matarbari
			Domestic	Import	Import	Import	Import	Import	Import	Import	Import
A Fuel Security											
1	Fuel Transportation	12.1	0.1200	0.1200	0.0400	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200
2	Port Facilities	6.05	0.0276	0.1793	0.0638	0.1793	0.1793	0.0638	0.0638	0.0638	0.1793
B. Feasibility Factor for Construction											
1	Securing the Necessary Amount of Ground Space	3.03	0.1065	0.1150	0.0550	0.1065	0.1065	0.1910	0.1065	0.1065	0.1065
2	Transportation of Facilities	1.52	0.0625	0.1250	0.0625	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250
3	History of Flood	1.52	0.1538	0.0769	0.0769	0.0769	0.0769	0.1538	0.1538	0.1538	0.0769
4	Topography / Geology	3.03	0.1043	0.1043	0.1043	0.1043	0.1043	0.1656	0.1043	0.1043	0.1043
C Operational Conditions											
1	Securement of Cooling Water	6.8	0.0588	0.1176	0.1176	0.1176	0.1176	0.1176	0.1176	0.1176	0.1176
2	Ash Treatment	2.3	0.1561	0.1561	0.0691	0.0393	0.1147	0.0631	0.1338	0.1338	0.1338
D Economic Conditions											
1	Distance with Existing Power System	6.07	0.1361	0.1361	0.0703	0.1361	0.1361	0.1361	0.1361	0.0426	0.0703
2	Project Cost	3.03	0.2172	0.1195	0.1195	0.1195	0.1195	0.0617	0.0617	0.0617	0.1195
E Local Demand-Supply											
1	Advantage on Power System Viewpoint	9.1	0.1251	0.1251	0.0422	0.0422	0.1251	0.2214	0.0688	0.1251	0.1251
F Needs of Bangladesh											
1	Needs Level of Bangladesh	18.15	0.1898	0.1898	0.0396	0.0396	0.1898	0.1107	0.0649	0.0649	0.1107
G Donor											
1	Plan and Priority of WH,ADB Finance	9.1	0.0588	0.1765	0.0588	0.0588	0.1765	0.1765	0.1765	0.0588	0.0588
H Environment Influence											
1	Air Pollution	0.91	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
2	Water Contamination	0.91	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
3	Soil Pollution	0.45	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
4	Bottom Sediment	0.45	0.2727	0.0909	0.0909	0.0909	0.0909	0.0909	0.0909	0.0909	0.0909
5	Noise and Vibration	0.48	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
6	Offensive Odor	0.41	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
7	Waste	0.48	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
8	Ground Subsidence	0.96	0.0244	0.1220	0.1220	0.1220	0.1220	0.1220	0.1220	0.1220	0.1220
9	Geographical Feature	0.77	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
10	Biota and Ecosystem	0.96	0.1304	0.1304	0.0435	0.0435	0.1304	0.1304	0.1304	0.1304	0.1304

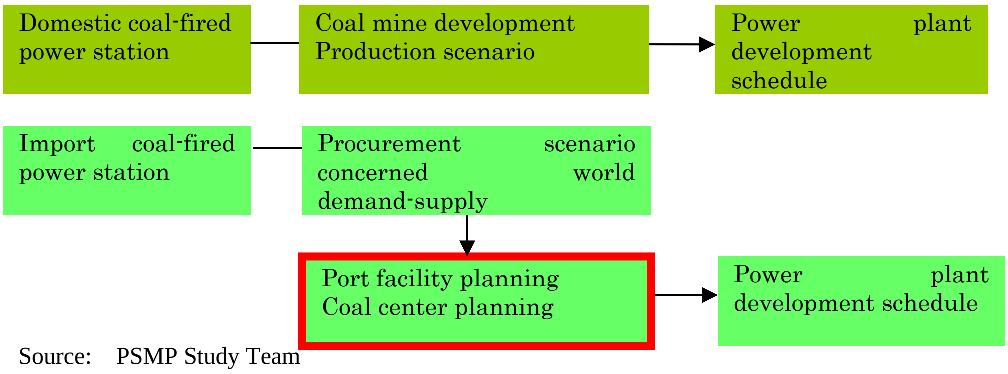
Item		Point Allocation	1	2	3	4	5	6	7	8	9
			K-D-P	Chittagong	Cox's Bazar	Mongla	Khulna	Meghnaghat	Zajira	Maowa	Matarbari
			Domestic	Import	Import	Import	Import	Import	Import	Import	Import
11	Water Usage	0.96	0.0244	0.1220	0.1220	0.1220	0.1220	0.1220	0.1220	0.1220	0.1220
12	Accidents	0.45	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
13	Global Warming	0.91	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
I Social Issues											
1	Involuntary Resettlement	0.98	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
2	Local Economy Such as Employment and Livelihood etc.	0.78	0.0769	0.1538	0.1538	0.1538	0.1538	0.0769	0.0769	0.0769	0.0769
3	The Poor, Indigenous and Ethnic People	1.04	0.0769	0.1538	0.1538	0.1538	0.1538	0.0769	0.0769	0.0769	0.0769
4	Misdistribution of Benefit and Loss	0.59	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
5	Local Conflict of Interests	0.59	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
6	Gender	0.52	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
7	Children's Right	0.52	0.0400	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200
8	Land Use and Utilization of Local Resources	0.83	0.2000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
9	Social Institution such as Social Infrastructure and Local Decision Making Institutions	0.65	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
10	Existing Social Infrastructures	0.93	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
11	Cultural Heritage	0.93	0.2603	0.0879	0.0879	0.0475	0.1649	0.0879	0.0879	0.0879	0.0879
12	Infectious Diseases such as HIV/AIDS etc	0.74	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
Total			12.0090	14.1490	6.9717	9.1832	14.0996	12.8948	10.3968	9.2700	11.0259
Ranking			4	1	9	8	2	3	6	7	5

Source: JICA Study Team

Chapter 13 Conceptual Study for Port Facility

13.1 Study item

As shown in the following figure, the possible capacity and development schedule of coal-fired power plants are determined, for domestic coal-fired power plant cases via the coal mine development schedule, and for the import coal-fired power plant case by a procurement scenario concerning the demand-supply status in the world, and the schedule of port facility development that is the capacity of imports. In this chapter the conceptual study for the port facility is studied, which is important for imported coal-fired power plants developed in Bangladesh.



Source: PSMP Study Team

Fig. 13-1 Port facility and power plant planning

13.2 Outline of deep sea port master plan

The Ministry of Shipping of Bangladesh proceeded with the F/S in the development of the deep sea port (DSP) as a necessary development for the processed-export type industry. The contents are, first to select candidate sites which have the potential to be deep sea ports in the Bay of Bengal of which most of the area is shallow, and proceed with a site survey and technical and economic evaluation. After that to specialize on the Sonadia site (a sand island located north of Cox’s Bazar) as a final candidate site and proceed with the detailed plan (average freight 30 million ton per year, project cost 5 billion USD, 2055 completion).

In this study, five candidate sites for the deep sea port were investigated in consideration of appropriate sites for the fuel center.

13.3 Study for coal center concept

Almost all candidate sites of import coal-fired power stations on Chapter 12 are not located near deep seas or rivers of which international coal vessels can access. So that this Master Plan proposes a coal center system as a way to secure and transport import coal which Japan has quite experienced in. The following shows the coal center system and its application for this Master Plan.

13.3.1 Concept of site selection

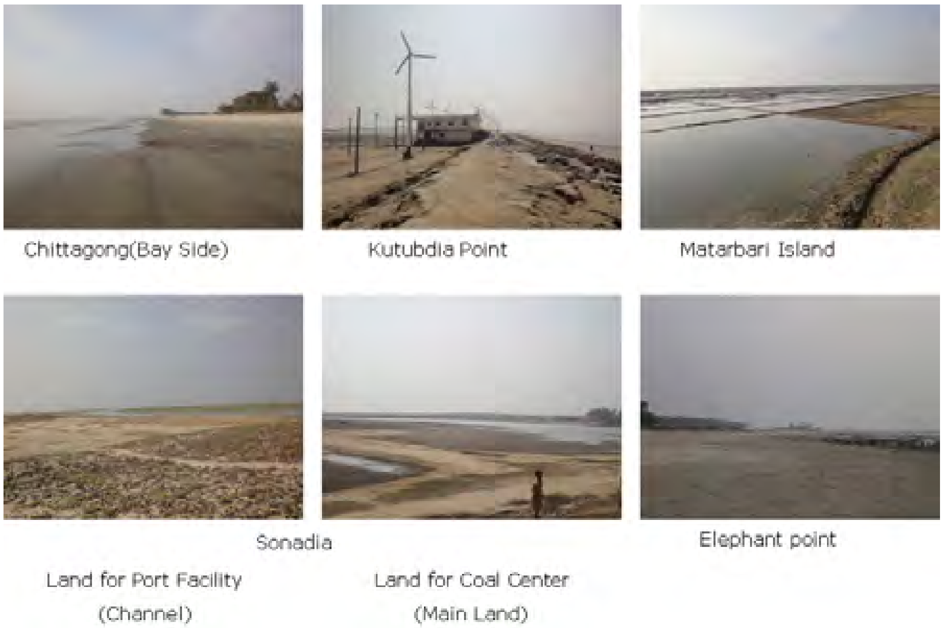
The condition for the candidate site of the coal center is as follows;

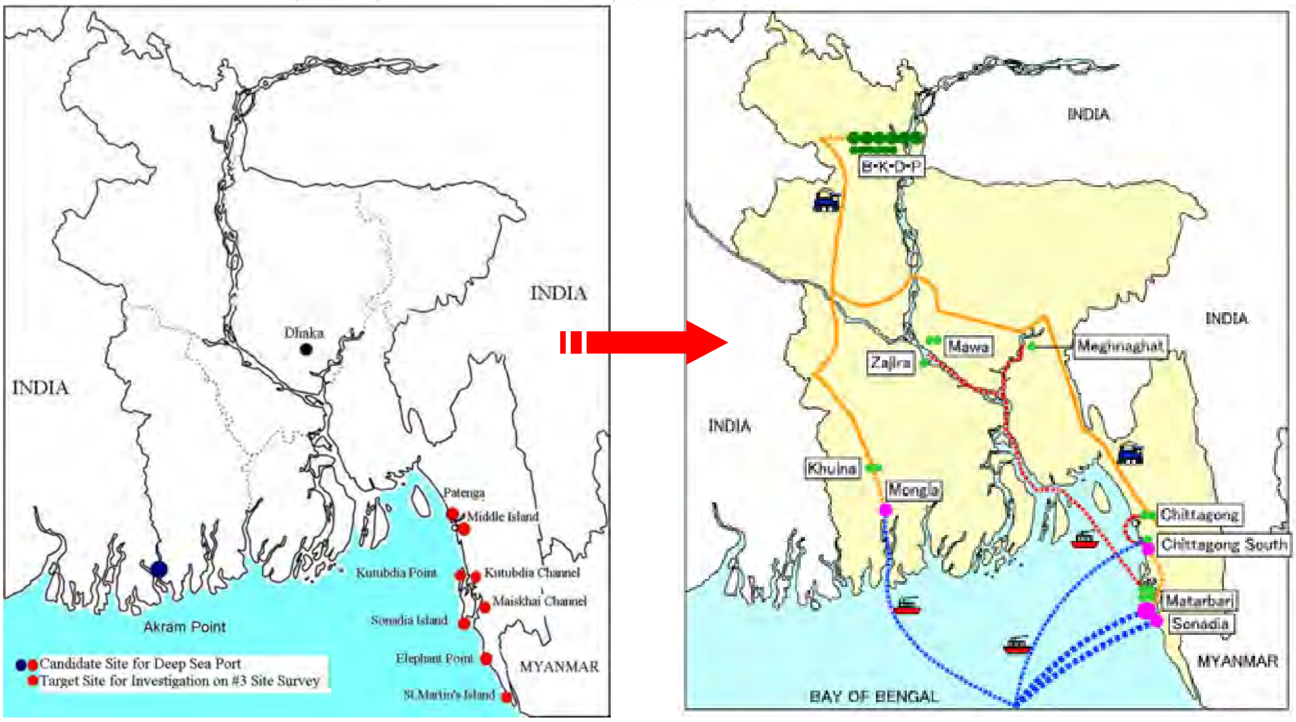
- Capability to approach for the international coal vessel
- Enough area for the coal stock yard

Further, it would be more rational and economic for the operation of the coal handling facility by setting the coal-fired power station adjacently. So that the candidate sites for the coal center would be selected prior to the candidate site for the power station.

13.3.2 Site survey

A site survey for the following 5 points was conducted.





Candidate site for deep sea port in the F/S　　Candidate site for port facility in this Master Plan

Source: PSMP Study Team

Fig. 13-2 Relationship between port facility and power plant planning

After site survey, the candidate sites for the coal center were selected from the power station sites under the condition that international vessels could approach, the results are Chittagong South and Matarbari. In addition, Sonadia has been selected as a site only for the coal center. Mongla is the point of relay towards Khulna. However, it has been determined as a coal center in this Master Plan.

The relation of each coal center and power station is as follows, considering the power development plan and the priority of each site.

Table 13-1 Relation between coal center and power station

Coal Center	Power Station (required Coal amount)
Mongla	Khulna (3.5 mil t/y)
Chittagong South	Chittagong (3.5 mil t/y) Chittagong South (1.75 mil t/y)
Matarbari	Meghnaghatt (3.5 mil t/y) Matarbari (7 mil t/y)
Sonadia	Mawa (3.5 milt/y) Zajira (1.75 mil t/y)

Source: PSMP Study Team

13.3.3 Formation of coal transportation

For the coal transportation, domestic vessels for the exclusive use of the coal have been adopted. The influence on the availability of the operation schedule the Bay of Bengal's weather conditions should be considered.

There are about 3 or 4 months of bad conditions for the ship operation by the Monsoon in the Bay of Bengal. So that the capacity of the coal stock yard in the power stations should be determined after considering whether or not it can secure enough coal during the term the vessel cannot operate.

13.3.4 Vessels for coal transportation

The depth of Chittagong port, which is currently under operation as the trading port, is only 8 to 9m, the Chittagong Port Authority determines the regulations for the restriction of the length of the ships as 186m. The coal vessel which could qualify this condition should be 28,000 ton class.

On the other hand, the coal center which would be constructed as the fuel center in the deep sea port can accept larger vessels, even a 50,000 ton class vessel can be accepted. For reference, Paradip Port, the east coast of India, 210 nautical miles south of Kolkata, developed the artificial deep sea port in 1962, which draft is 15 meter and accepts 75,000 ton class coal vessel.

Regarding domestic vessels, according to BIWTA (Bangladesh Inland Water Transport Authority), the levels of operation capability are determined in the Bay of Bengal according to weather conditions, and the largest size of the ship which can pass through the worst level area is 5,000 tons. Because the planning route for the domestic vessel in this Mater Plan includes this area, 5,000 ton class vessels have been selected as the domestic vessels.

The following table shows the vessels which would be used for coal transportation in Bangladesh.

Table 13-2 Coal vessels

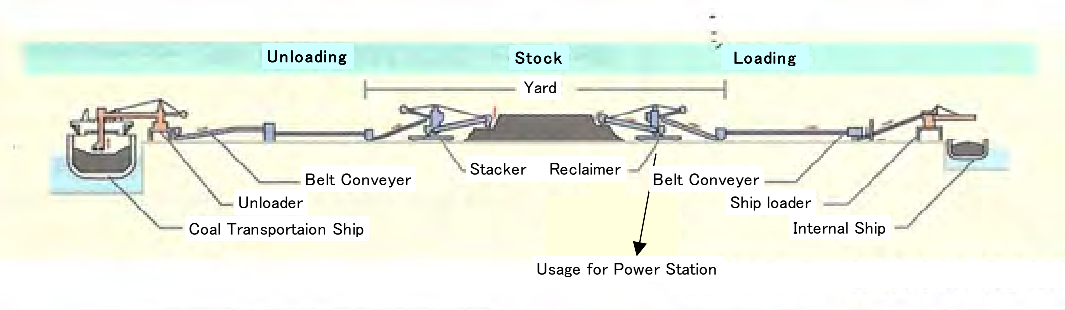
Example picture	Type	DWT	Length	Draft
	International vessel 1 (from Indonesia, Australia to Bangladesh)	50,000t Class	190m	12m
	International vessel 2 (from Indonesia, Australia to Bangladesh)	28,000t Class	170m	7m

Example picture	Type	DWT	Length	Draft
	Domestic vessel	5,000t Class	90m	5m
	Domestic vessel (Berge)	10,000t Class	80m	2m

Source: PSMP Study Team (photos from website)

13.3.5 Study for the capacity and the number of coal center

Regarding the capacity of the coal center, it would be rational to set 1 or 2 million tons as the maximum size of the coal stock yard, and 3 or 4 million tons as the maximum handling amount for a year concerning the current largest coal center (coal stock yard capacity: 2.5 million ton, coal handling amount: 6.25 million ton per year). The number of coal centers would be calculated from the total required amount of import coal, concerning the years up to 2030, 2 or 3 would be reasonable and realistic. In consideration that each coal center has a power station whose size is almost the same as the other power station which is the destination of the coal transportation, the 1 set of the coal center system has 6 to 8 million tons per year, and 24 million tons per year which has 3 sets of system would be the maximum amount for handling import coal.



Source: Idemitsu Kosan

Fig. 13-3 Role of coal center

13.3.6 Determination of the number of berth

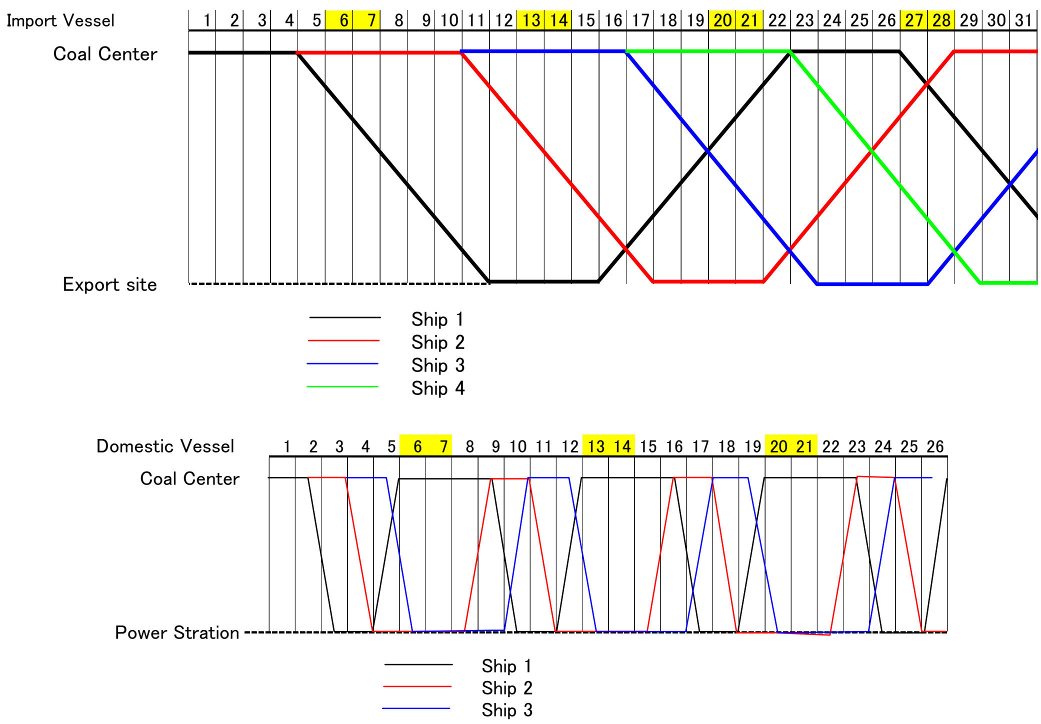
The number of required berths for each coal center and power station, the maximum handling amount for one berth, the operation schedules for international and domestic ships are calculated as follows;

Table 13-3 Required time for coal vessels

	International vessel	day	Domestic vessel	day
Work on berth	・Preparation, arrival	0.3	・Preparation, arrival	0.3
	・Preparation for loading, Custom	0.7	・Preparation for loading,	0.1
	・Loading	2.5	・Loading	1
	・Finishing, departure	0.5	・Finishing, departure	0.1
	Total	4	Total	1.5
Time for sailing	Indonesia <-> Bangladesh	7	Coal Center <-> Power Station	1

Source: PSMP Study Team

Based on it, the simulation result of ship operation is shown as follows, under the assumption that there is no work during the holidays.



Source: PSMP Study Team

Fig. 13-4 Operation simulation of coal vessels

13.3.7 Analysis of wave height data of the Bay of Bengal

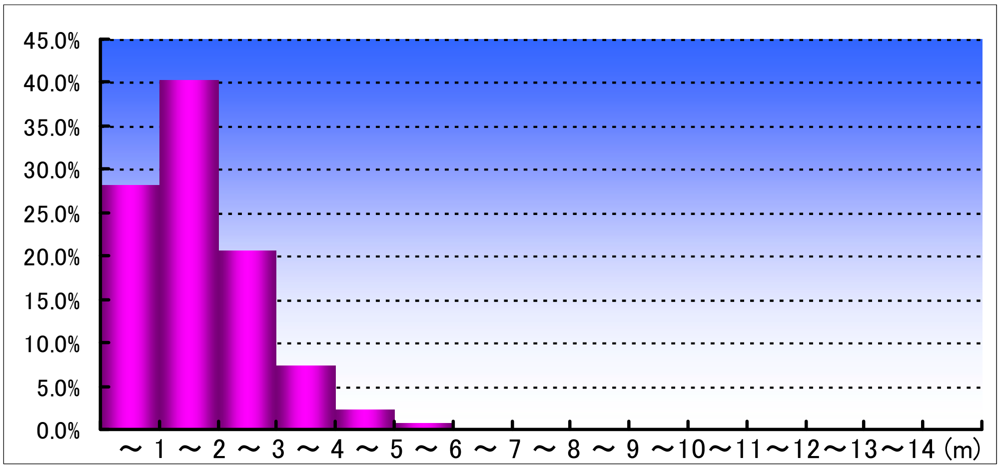
Theoretically, it is clear that,

Average work days of a year : 52 (weeks) * 5 (days) = 260 (days)

Number of ships of a year : International vessel 260 / 4 = 65

Domestic vessel 260 / 1.5 = 173

Actually the risk of bad weather, delays, or shutdown to worker strikes should be taken into consideration. Regarding bad weather risks, the following shows the summary of the wave height data at the Bay of Bengal.



Source: The Global Wave Statistics

Fig. 13-5 Wave height data of the Bay of Bengal

13.3.8 Annual number of ships for 1 berth

From the regulation for operation of a general shipping company as a reference, it has been determined that the condition for the enter/clear port is less than 3m of wave height. Therefore, the risk of weather is 10%.
And 3% is considered for other delay risks.
The worker strike risk is set as 2%, which translates into 7 days a year.
The result is shown as follows based on the above conditions,

Table 13-4 The number of ships for 1 berth per year

	International Vessel	Domestic Vessel
Theological Yearly Number of ships	Work day 52*5=260 260 / 4＝65	Work day 52*5=260 260 / 1.5＝173
Weather risk	10%	10%
Delay risk	3%	3%
Worker strike risk	2%	2%
Total risk	15%	15%
Yearly number of ships including risks	65×85%＝55	173×85%＝147

Source: PSMP Study Team

13.3.9 Annual amount of coal transportation for 1 berth

Regarding the loading of vessels, concerning that the number of DWT includes fuel and drinking water etc. and the loading loss is determined at 5%, therefore, the coal handling amount of 1 berth a year is shown as follows,

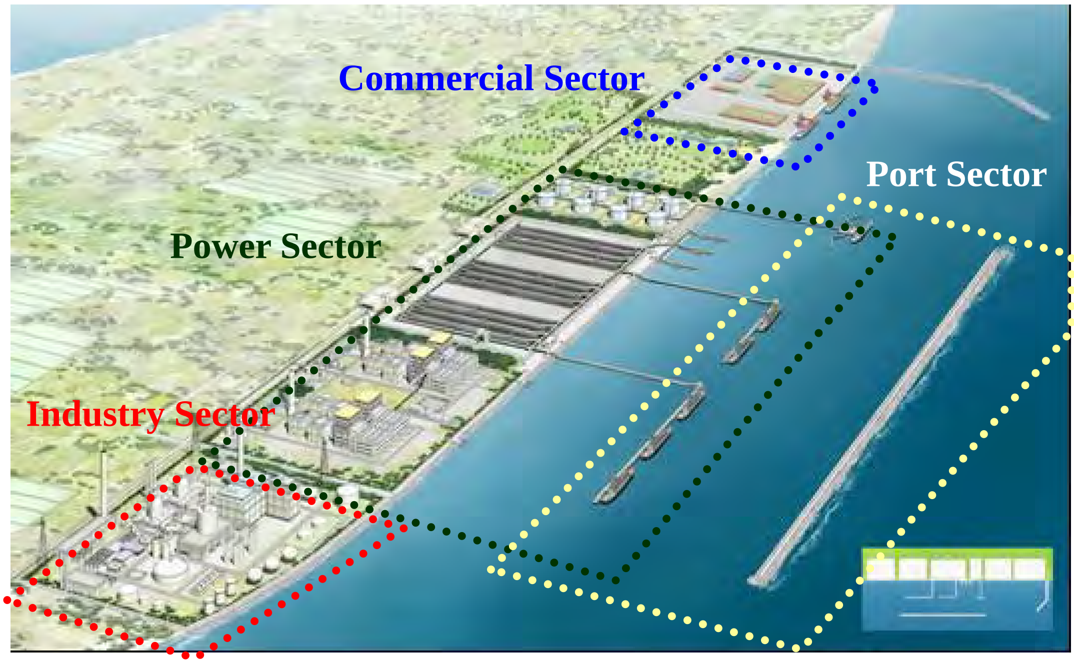
Table 13-5 Total coal amount per year for handling by 1 berth

	International Vessel		Domestic Vessel
	28,000t	50,000t	5,000t
Actual Loading	26,600 t (95% of DWT)	47,500 t (95% of DWT)	4,750 t (95% of DWT)
Yearly Amount	1,463,000 t	2,612,500 t	698,250 t

Source: PSMP Study Team

13.3.10 Necessity of collaborative development with multi sectors

It is obvious that the incremental power system adjustments are necessary in order to meet future demand increases, it is also necessary to develop the gas pipeline, deep sea port, inland water transportation, railways and so on as relating facilities with the power system. It needs a large amount of funds so that only the power sector is not able to proceed. Further, the realization of cost reductions and synergy are expected by proceeding with the collaboration with multi sectors. Furthermore, it is also possible to turn the area into an "industrial complex" in which not only an electric power supply but also heat supply could be shared and the transportation system could be developed by multi sectors. Based on the above, the following shows the concept of multi sector development.



Source: PSMP Study Team

Fig. 13-6 Image of deep sea port development at Matarbari

13.3.11 Schedule of coal center concept

In order to realize that coal center concept, the development of large-scale port facility is necessary, it means not only huge amount of fund but also long term development period should be needed. Considering these situation, the basic concept of schedule for secure import coal is as follows,

(1) Offshore unloading by using Mother-ship concept (until 2020)

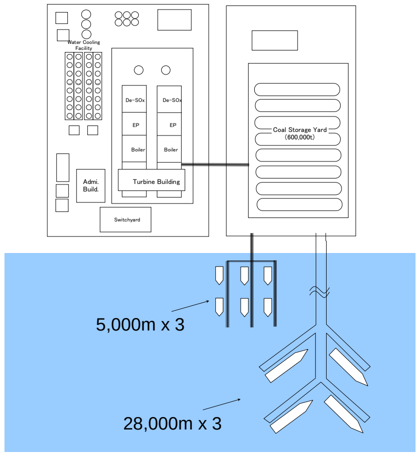
Considering necessary period for developing deep sea port, the coal center would be in service after 2020. So that until 2020, coal is transported by big coal vessel, and transshipped to a small vessel off the coast of power station (Mother ship system).

(2) Construction and operation of coal center (after 2020)

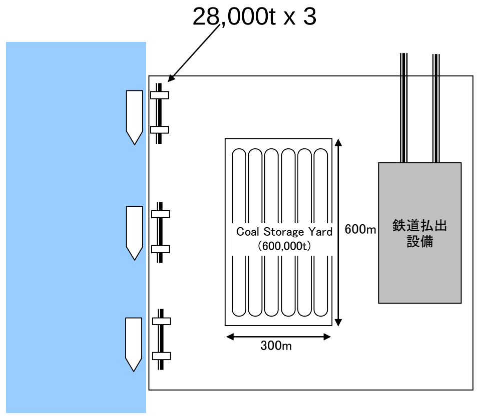
After 2020, the coal center would start construction and operation with the development of port facility. At the same time, the Mother ship system would be transferred to the coal center.

13.3.12 Conceptual layout plan of coal centers

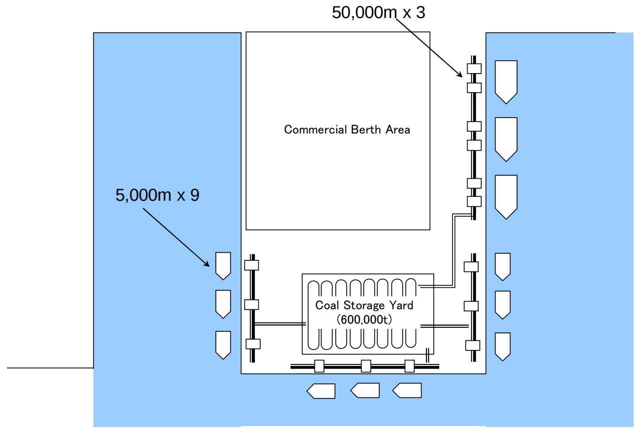
The following shows the conceptual layout plan of each coal center.



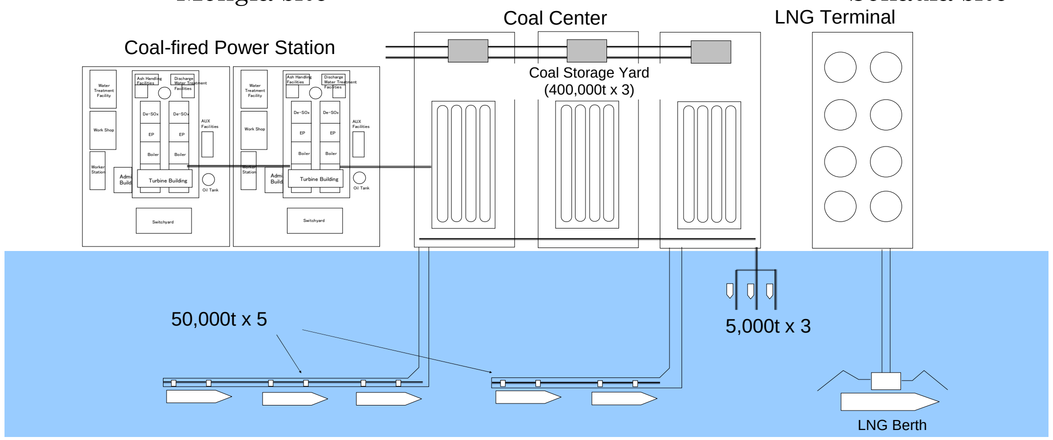
Chittagon-south site



Mongla site



Sonadia site



Matarbari site

Source: PSMP Study Team

Fig. 13-7 Conceptual layout plan of each coal center

Table 13-6 Specification of import coal-fired power plants and coal center

		Power Station							Coal Center (C/C)			Fuel Procurement			
		Specification	Per Capacity	Unit No.	Total Capacity	Port Facility portion for P/S			C/C +Port Facility for C/C						
			[MW]		[MW]	Type	Capacity	No of berth	Type	Capacity	No of berth	Chg S C/C	Matarbari C/C	Sonadia C/C	Mongla C/C
Import Coal P/S	Chittagong South P/S, C/C	P/S: USC (45%)	600	1	600	Import Berth	28,000	2	Import Berth	28,000	2	X			
		C/C: 5.25mil ton/year (3.5mil ton/year for ship)			0				Domestic Berth	5,000	6				
	Matarbari P/S, C/C	P/S: USC (45%)	600	4	2400	Import Berth	50,000	2	Import Berth	50,000	3		X		
		C/C: 8.25mil ton/year (1.75mil ton/year for ship)			0				Domestic Berth	5,000	3				
	Khulna P/S	P/S: USC (45%)	600	2	1200										X
					0										
	Chittagong P/S	P/S: USC (45%)	600	2	1200							X			
					0	Domestic Berth	5,000	5							
	Meghnaghat P/S	P/S: USC (45%)	600	2	600								X		
					0	Domestic Berth	5,000	5							
	Mawa P/S	P/S: USC (45%)	600	2	1200									X	
					0	Domestic Berth	5,000	5							
	Zajira P/S	P/S: USC (45%)	600	1	600									X	
					0	Domestic Berth	5,000	3							
	Mongla C/C				0				Import Berth	28,000	3				
		C/C: 3.5mil ton/year			0										
	Sonadia C/C				0				Import Berth	50,000	3				
		C/C: 5.25mil ton/year			0				Domestic Berth	5,000	9				
	[Total]			**14**	**7800**			**22**			**29**				

Source: PSMP Study Team

Chapter 14 The Conceptual Study on the Construction of Power Stations of Most Prioritized Projects

In this chapter, the concept of the study for power station construction according to Chapter 11's study flow is based on most prioritized projects in this study as models. It would be the base concept for the feasibility study of future power station planning. The objectives of this chapter are 2 types, the domestic coal-fired power station (B-K-D-P site) and the import coal-fired power station (Chittagong South and Meghnaghat).

14.1 Basic idea about conceptual study for most prioritized projects

14.1.1 Study condition

(1) Design code

The following international standard or Japanese standard which is the same or more than the material standard, design standard and test standard for the design of equipment and buildings.

- The American Society of Mechanical Engineer (ASME)
- International Electrotechnical Commission (IEC)
- Japanese Industrial Standard (JIS)

(2) Reliability

Because these power stations would be operated as the base load, reliable equipment and system should be adopted.

(3) Coal

Basically, domestic coal-fired power station would use the domestic coal of Bangladesh; import coal-fired power station would use imported coal which is imported from Bangladesh.

(4) Steam condition

Ultra super critical pressure condition which is state-of-the-art but much experience would be adopted. The steam condition is as follows;

- Main Steam Pressure 24.5 MPa
- Main Steam Temperature 600 degree C
- Designed Heat Efficiency 45% (LHV)

(5) Cost down

Tandem compound steam turbine, single series of boiler equipment would be adopted for cost cuts.

(6) Automatic control system

Coal-fired power station has more auxiliary machines compared with gas-fired ones so that the operation control is complicated. In order for Bangladesh, which does not have enough experience in operating coal-fired power stations to adopt easily, the integrated control system including automatic control system would be adopted.

(7) Climate condition

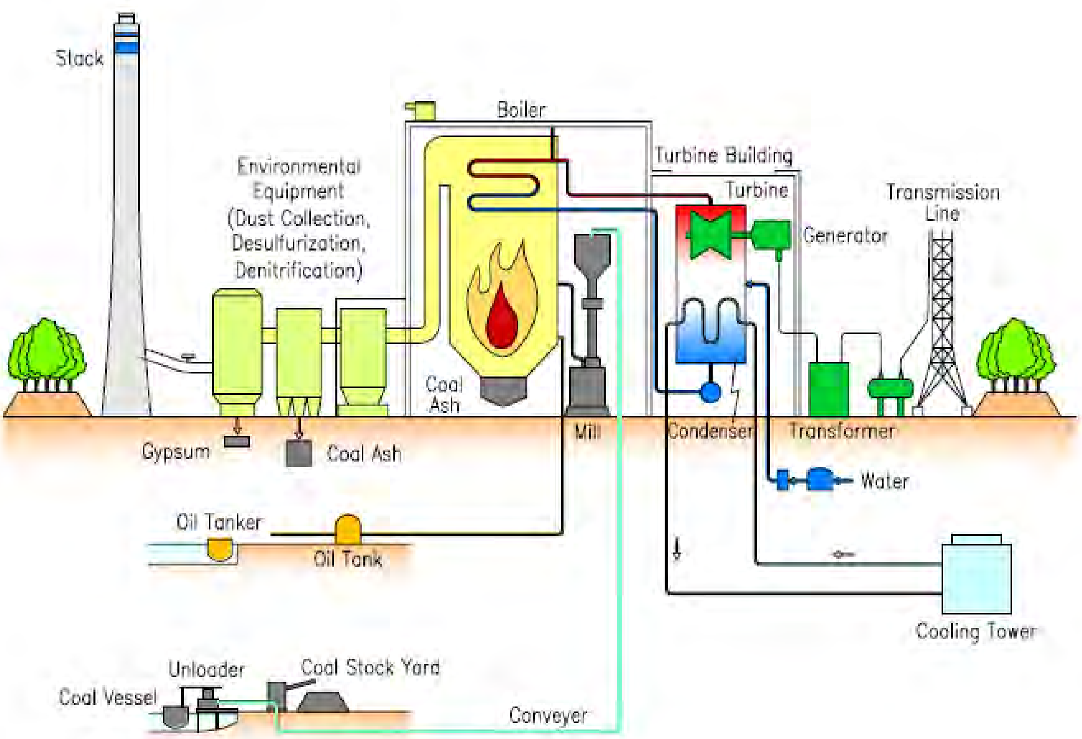
The climate condition for the conceptual design is determined as follows according to the site survey in consideration of the climate of Bangladesh;

- Ambient temperature 27 degree C Average
- Designed wind speed 30 m/s
- Humidity 90 % Max

14.2 Equipments of coal-fired power station

14.2.1 Equipment flow of thermal power station

A thermal power station is to change from thermal energy by firing fuel to electrical energy. Generally, a coal-fired power station is to make steam from high pressure and high temperature, and the steam swings the steam turbine, and to make and transmit electricity by the generator which is at the same shaft with the steam turbine, it consists of not only a boiler which makes steam by firing fuel, the turbine which spins by steam, generator which makes electricity by the steam turbine, the environmental facility which cleans up flue gas, the transformer and switchgear facility which transmits electricity to the grid, but also the coal stock and handling facility, coal ash treatment facility, water treatment facility which makes pure water for the power station. The following figure shows the equipment flow of the thermal power station.



Source: PSMP Study Team

Fig. 14-1 Equipment flow of thermal power station

14.2.2 Equipment specification of most prioritized project

The following table shows the equipment specification of most prioritized project. Each concept is explained from next section.

Table 14-1 Specification of coal-fired power station for most prioritized project

Item		Specification
General spec.	Capacity	600MW
	Thermal efficiency	45%(LHV)
	Steam condition	24.5MPa、600/600℃
Major Equipment	Boiler	Ultra Super Critical (USC) variable pressure once-through
	Turbine	Tandem compound (single shaft)
	Generator	H2 cooling type
	Environment facility	Electrostatic precipitator, Flue gas desulfurization

Item		Specification
	Ash treatment facility	(limestone gypsum wet method), 11.5.1 Flue gas denitrification (Selective catalytic reduction) Clinker system: wet treatment, Fly ash system: dry treatment
Coal consumption	Condition Annual consumption	Thermal efficiency 45%(LHV), Plant factor 85%, Heat value 7,100kcal/kg (domestic), 5,100kcal/kg (import) 1.4 mil t/y (domestic), 1.75 mil t/y (import)
Ash production	Condition Clinker production Fly ash production	Ash 15% 20,000 t/y (domestic), 30,000 t/y (import) 200,000 t/y (domestic), 230,000 t/y (import)
Water	Cooling water flow for Condenser (water cooling type) Water consumption	100～110,000t/h Pure water : 700～1,000 t/d Living water : 250 t/d
Flue gas desulfurization	Limestone consumption Gypsum production	18,000～20,000 t/y 34,000～38,000 t/y

Source: PSMP Study Team

14.3 Conceptual study for the equipments of coal-fired power stations

14.3.1 Determination of size of power station

By taking into account current situation of Bangladesh, the demand forecast and power development, which is explained in the previous section, the size of coal-fired power stations which have been adopted for most prioritized projects is 600MW per single unit and 2 plants per one site. Because it needs a big amount of capacity of the coal-fired power station, a 1000MW facility could be adopted for domestic coal on the condition that the entire infrastructure is made.

14.3.2 Boiler facilities

The boiler is a facility to make steam from water by firing fuel.
The item for consideration is as follows,

(1) Determination of steam condition

As was explained in Chap.11, generally the thermal power station is such that higher steam conditions correlate to higher efficiency. However, the cost becomes higher because of the material which can be used for high pressure and high temperature. So that the steam conditions should be determined by optimum cost condition.
The type of steam conditions of the thermal power station are divided at the critical point of water

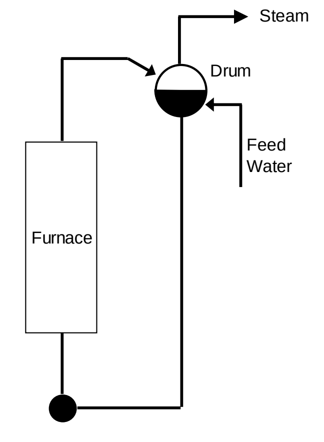
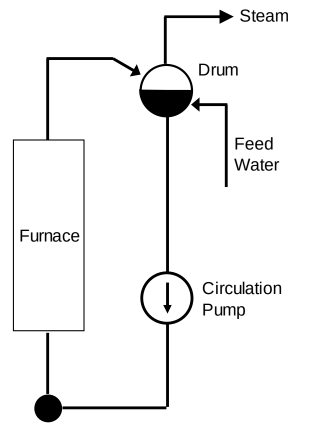
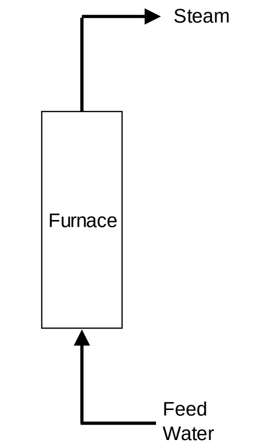
- Temperature 373.95 degree C
- Pressure 22.064 MPa

It is called Sub critical for under this point, and super critical for over this point, and it is called Ultra Super Critical for the point of very high pressure and temperature.
In this Master Plan, 600 decree C, 24.5MPa (USC) has been adopted for high efficiency and experience.
It is necessary to use a compound metal steel or stainless steel for the high pressure and temperature part. There is a reliability difference depending on the country where it is made and which standard is adopted. It requires high level technology for welding, thermal treatment, and the nondestructive inspection.

(2) Determination of boiler type

Because the amount of vaporization of the boiler for the power station is large, high pressure and high temperature steam is needed, “water pipe type boiler” is adopted. The water pipe type boiler is such that, fine tubes absorb heat energy. Then the water in the pipe changes to steam.
The boiler categorized as a circulation boiler and once-through boiler by its water supply. Generally, the once-through boiler is adopted for large scale boilers. Furthermore, only the

once-through boiler is adopted for super critical condition, so in this Master Plan, the once-through boiler is adopted.

		Circulation boiler		Once-thorough boiler
Model of water circulation		(Natural circulation)  	(Forced circulation)  	
Adoption		Small and medium size		Medium and large size
Pressure	sup critical	○		○
	Super critical	×		○

Source: PSMP Study Team

Fig. 14-2 Type of boiler for generation

(3) Determination of design coal

It is necessary to determine coal quality to determine the standard for the boiler design. Generally, in cases where only a certain type of coal is used, this coal would be the designed coal, and in case the number of types of coal is used, the design will be for some type of coal by making a range. Anyway, the design coal is determined after deciding which coal would be used.

The consideration point for the designing boiler after the determination of the design coal is that the shape and size of boiler should be designed so that the coal could be fired perfectly. Therefore, the design for low quality coal is larger than normal coal.

In this Master Plan, design coal cannot be determined, but the following concept would be adopted.

(a) Domestic coal

The domestic coal-fired power station should be designed basically only for domestic coal. The quality of coal is of little difference between Barapukuria and other developing mines shown in Table 4-7 to 4-9, but generally the coal in Bangladesh is of high quality (heat value 7,100 kcal/kg). It should be determined which design coal should be for main use.

(b) Import coal

As mentioned in Chapter 4, the candidate countries for import coal to Bangladesh are Indonesia, South Africa and Australia, the quality varies according to the site, generally, their coal is of low quality coal (heat value 5,100 kcal/kg). The design coal should be determined on the F/S stage after clarifying the site and quality of the coal. On the operation stage, it may be possible to blend with domestic coal, but the design is by import coal.

From above, the approximate size of the boiler, the import coal boiler is larger than the domestic coal boiler about 1.1.

(4) Other considering points

For the design of the boiler in this Master Plan, the following points also should be considered.

(a) Single series auxiliary facility to cost down

Recently, coal-fired power stations in Japan adopt a single series auxiliary facility for the FDF-IDF air and exhaust gas system. So that the house use ratio is about 3.5%. In this Master Plan, a single series is adopted.

(b) Perfect automatic control to reduce operator load

For Bangladesh, which has minimal experience of coal-fired power stations, when a USC plant is adopted, the mastering of operational skills would be a big problem. Therefore, the plant can perform an auto start and auto stop so that the operator load lessens.
Further, a data control system should be installed in order to share operational information with all of the workers in the power station.
The following are data control system examples that should be collected,

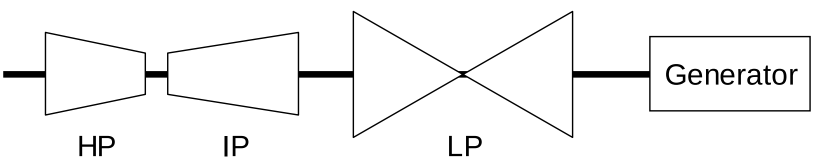
- All of plant PI data : every 1 minutes
- Log sheet data : every day
- Generation report data : every day
- Heat efficiency calculation data: every day
- Performance test result : every performance test
- Start stop loss calculation data : every start and stop
- Turbine vibration data when start : every start
- Message data : every occurance

(c) Other specific item

- Axial flow type should be adopted for FDF, IDF, PAF and BUF.
- The size of coal banker should be 10 hours.
- Vertical type roller mill or vertical type ball mill should be adopted.
- Feed water pump should power by steam turbine.
- Air heater should include sensor drive system.

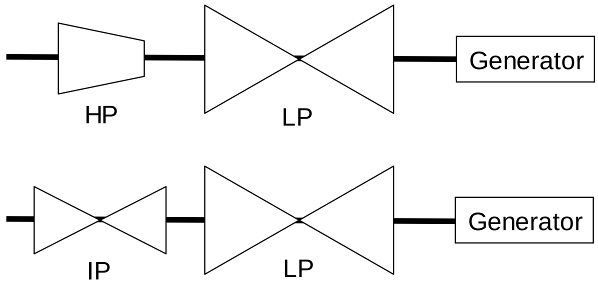
14.3.3 Turbine facility

Turbine changed from the high pressure high temperature steam to spinning energy (from heat energy to kinetic energy), and spin generator for generation.
Generally, the steam turbine in the thermal power station consists of a high pressure turbine, an intermediate pressure turbine and low pressure turbine according to steam pressure. A high pressure turbine receives steam from the boiler directly, an intermediate pressure turbine receives reheated steam, after that the low pressure turbine is on the receiving end of the intermediate turbine. The tandem compound refers to those turbines in one shaft, and the cross compound means separate.



Source: PSMP Study Team

Fig. 14-3 Tandem compound (single shaft) turbine



Source: PSMP Study Team

Fig. 14-4 Cross compound (double shaft) turbine

The cross compound was developed in order to shorten the length when a large amount of the facility was developed. The generator could also be made small. Currently, the technology of the big blades of the turbine has been developed, the big size tandem compound turbine has been developed and it contributes to cost cuts.

The item for consideration is as follows

(1) Determination of steam condition

The steam condition of the boiler is also for the turbine.

In this Master Plan, 24.5 MPa 600/600 degree c has been adopted.

(2) Determination of cooling system

There are two types of steam turbine condensers, air cooling and water cooling. Almost all Japanese thermal power stations adopt the water cooling type using sea water, overseas water cooling with a cooling tower or an air cooled condenser are also adopted. It should be chosen according to water securing methods.

In this Master Plan, for imported coal-fired power stations, because it is located riverside or seaside so that water cooling with seawater is one of the options, however, considering neighboring influence of warm water, the water cooling system with a cooling tower would be adopted.

For the domestic coal-fired power station, the how-to regarding securing water is a big issue. The following are some considerations.

(a) Type of water

First, there are two types of water required by a thermal power station, depending on the intended use.

- Cooling water

  When the condenser or bearing cooling system applies the water-cooling system, it needs cooling water. The amount of cooling water changes depending on the cooling system.

- Unit water

  It will be needed make-up water to compensate for the decrease in water used by the power generation facilities, such as boiler circulating water or bearing cooling water, and to maintain the quality of water. The required amount of water is 1,000–2,000 t/day per unit of 600 MW.

(b) Water securing method

Second, the PSMP Study Team studied the method to secure water in the candidate site as follows.

1) Securing water from deep wells

In Barapukuria, the neighboring area of this site, the water for the power station is secured from deep wells (14 wells in total). However, as a result of the survey and interview in the

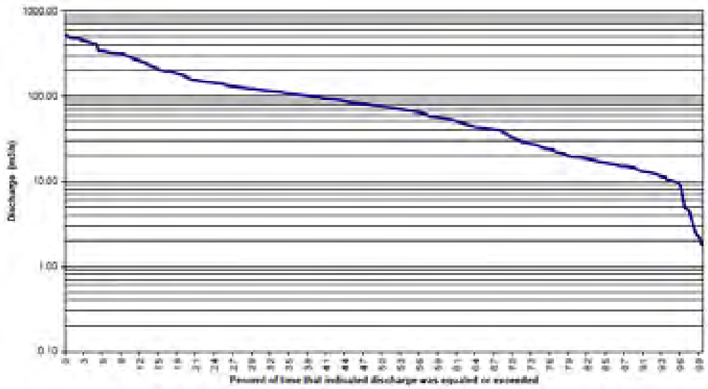
neighboring residential area conducted by the PSMP Study Team, it was found that there is a problem of land subsidence that appears to be caused by taking water from the deep wells.
Although the PSMP Study Team do not conduct a full-scale investigation (boring, etc.) of this site in the survey to explore the possibility of deep wells, it is highly probable that a similar problem will arise in this site, too, as the PSMP Study Team have already confirmed the influence in the neighborhood as stated above.

2) Securing water from rivers

The PSMP Study Team confirmed that there are two rivers (the Little Jamuna River and the Karotoa River) in the neighborhood of this site (a few kilometers away). In order to confirm the availability of water from these rivers, the PSMP Study Team collected flow data and created a duration curve as follows.

a) Little Jamuna River

The flow, level and speed of this river are recorded at the No.62 Gauging Station. Every month has only 2 data.
The following is the duration curve based on 1998 to 2006 flow data;

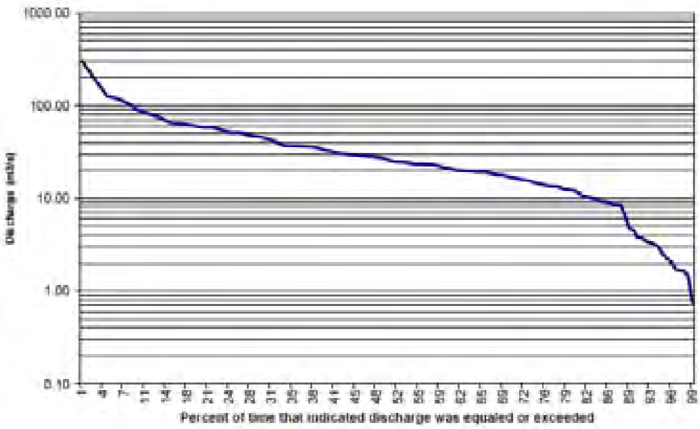


Source: PSMP Study Team

Fig. 14-5 Duration curve of Little Jamuna river

b) Karotoa River

The flow, level and speed of this river are recorded at No.133 Gauging Station. Also every month has only 2 data.
The following is the duration curve based on 1987 to 2006 flow data;



Source: PSMP Study Team

Fig. 14-6 Duration curve of Karotoa river

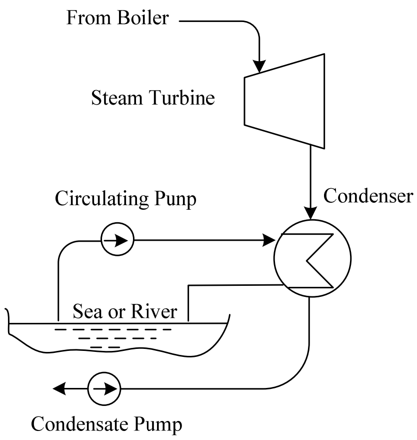
According to the guideline from BWDB, the maximum water intake from the river is 70% of the flow, so that the maximum water intake is 1.75m^3/s (1.75t/s) and 0.74m^3/s (0.74t/s).
Based on this result, it is clear that the amount for unit water can be secured from these rivers. However, the amount of cooling water cannot be secured annually. Based on this, the study for the cooling method is as follows.

(c) Study on the cooling method

The PSMP Study Team studied the cooling method of the power station as follows.
There are three options of the cooling method to be applied at the thermal plant currently projected in this survey: the transient cooling system, mechanical-draft cooling tower system, and mechanical-draft air-cooling tower system. The characteristics of each are as follows.

1) Transient cooling system

It is adopted in case abandoned cooling water could be secured. There is no need of a cooling tower and high cooling efficiency. In Japan, almost all thermal power stations adopt it by using sea water.



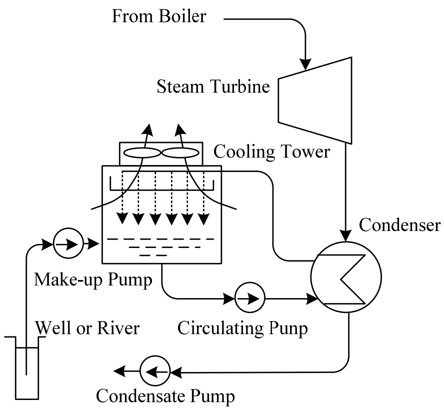
Source: PSMP Study Team

Source: TEPCO

Fig. 14-7 System and adoption example of transient cooling system

2) Mechanical draft cooling tower system

In case enough water cannot be secured, there are many cases adopted mechanical draft cooling tower system in the world. It needs equipment cost of cooling tower, cooling efficiency is high, and it is adopted in many cases in China and so on.
The necessary water supply for 600MW is about 1.5 t/s in total vaporization and make up.
At B-K-D-P site, the necessary amount of water for 600MWx2 is 3 m/s, however there are periods when it is impossible to intake enough water from the river, 10% for the Karatoa River (37 days), 4% for the Little Jamuna River (15 days). In order to stock water for these terms, 3x3600x24x37=9.6 million t of water stock is needed and it is not realistic. It is also difficult to use wells only during these seasons in consideration of the impact to neighboring residents.



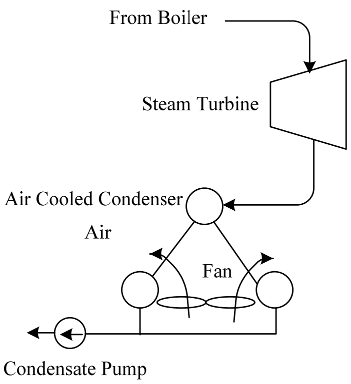
Source: PSMP Study Team

Source: PSMP Study Team

Fig. 14-8 System and adoption example of mechanical draft cooling tower system

3) Mechanical draft air cooling condenser system (ACC)

It has been adopted in case there is no cooling water. The required space and cost is high, house power consumption is high, cooling efficiency is low. However, the biggest merit is that there is no need to secure water. Large scale adoption examples for are the Mathinba Power Station (670MWx6) in South Africa and the Hancheng Power Station phase 3 (600MWx1). For this site, securing the required amount of space would not be a problem, and the merit of no water requirements is big compared with cost and efficiency.



Source: PSMP Study Team

Source: TEPCO

Fig. 14-9 System and adoption example of mechanical draft air cooling condenser (ACC)

The following is a summary of the above study.

Table 14-2 Comparison of cooling system

Item	Transient Cooling	Mechanical draft cooling tower	Mechanical draft air cooling condenser
Cooling Efficiency	High efficiency is expected by a large amount of water	Influence from climate	Enough efficiency cannot be expected in case high temperature
Facility Cost (600MW)	Construction of intake and exhaust water 15 mil USD	Cooling tower 10 mil USD	Air Cooled Condenser 50 mil USD
Running Cost (House Use	Only for Circulation Water Pump (small)	Circulation Water Pump + make up water pump	Big size cooling fan (big)

Item	Transient Cooling	Mechanical draft cooling tower	Mechanical draft air cooling condenser
Power)		+ cooling fan (Medium)	
Necessity to secure water	Need big amount of water (20 ～ 30 t/sec for 600MW)	Need make up water (1 ～ 2 t/sec for 600MW)	No need
Social considerations	Big influence for the neighbors by using big amount of water and warm exhaust water	In case of usage of well, influence about ground settlement	No influence regarding secure water

Source: PSMP Study Team

As the above study, regarding the selection of the cooling system, it is necessary to select an appropriate system for each site in consideration of how to secure water. The following is the selection in this Master Plan.

(d) Domestic coal-fired power station

According to the above study, first of all, at the B-K-D-P site, it is impossible to secure abandoned water, so the transient cooling system cannot be adopted. In the case of adopting a cooling tower system, the water intake from the river will not be enough for the whole of the year. So that, in this Master Plan, a mechanical draft air cooling condenser (ACC) system would be adopted. However if there is a possibility to secure water during the F/S, a cooling tower system should be adopted because its cooling efficiency is high. The following method for securing water could be expected;

- To supplement the insufficient part with deep well water. (a detailed study of environmental impact should be a requirement.)
- The power station is set near Jamuna River and the intake water is from Jamuna River. (Comparison of the fuel transportation cost should be needed)
- To use water from Phulbari O/C mine. (There is some experience in Europe, a detailed investigation should be a requirement.)

(e) Import coal-fired power station

Each site is located riverside, so it is better to adopt a transient cooling system. However, in consideration of the impact the warm water will pose to neighboring residents, the cooling tower system should be adopted.

(3) Determination of type

The types of turbines, tandem compounds or cross compounds, should be determined. The following is a comparison of these types, almost the difference of space.

Table 14-3 Type of turbine

	Tandem compound	Cross compound
Necessary area	Length long Width short	Length short Width long
Equipment	- 1 large capacity generator - large LP turbine	- generator capacity can be divided - not so large LP turbine

Source: PSMP Study Team

Recently a low cost large turbine has been developed, so the tandem compound is more economical if there are no transportation restrictions.

In this Master Plan, after an investigation of the transportation there is no problem, so a tandem compound has been adopted.

14.3.4 Generator

A generator consists of a stator, a rotor, a bearing, a cooling system and an exciter, the exciter provides electrical current to the rotor coil, to create a necessary magnetic field for the electro motive force.

The items for consideration are as follows;

(1) Cooling system

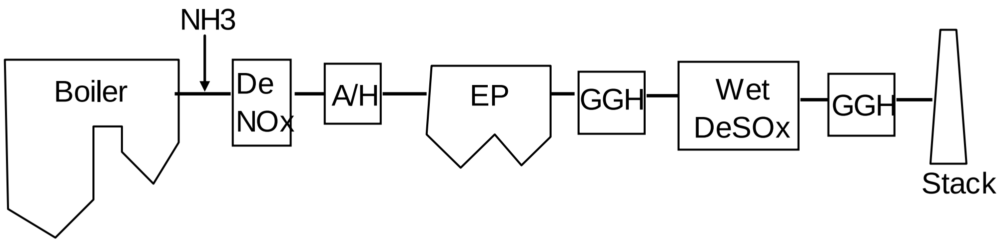
The turbine generator generates a tremendous amount of heat, so that a gas-cooling or liquid cooling system should be adopted. Currently, the almost large capacity generator adopts a H2 cooling system. The H2 is good for the cooling generator for many reasons like cooling efficiency and its lifespan. In this Master Plan, an H2 system should also be adopted.

(2) Excitation system

The DC supply is needed for the excitation system. In the past, the same shaft exciter was used. Currently, the AC generator and rectifier are popular. In this Master Plan, an AC generator and rectifier type should be adopted.

14.3.5 Environmental facility

Regarding NOx and SOx emissions, a system that eliminates stray dust will be employed. The compositional unit even in Japan is a general method. An example of how the equipment is arranged is shown below:



Source: PSMP Study Team

Fig. 14-10 An arrangement example of the environmental apparatus (Low-temp EP type)

(1) Determination of type of electrostatic precipitator

In order to primarily collect flue gas including “fly ashes”, an electrostatic precipitator will be installed. Although there are instances where a bag filter is employed at coal-fired power stations in one part of the country, in Japan, utilizing an electrostatic precipitator (EP) has become the standard. The types of EP are categorized into High, Low and Low-low temperatures depending on the temperature during operations. Specifically, the combustion ashes from designed coal are analyzed and after coming to an understanding of the electric resistance from ashes, it will be moved on to the designing stage. Further, given that the capacity and generation amounts (the contained amount of ash content) are the determining factors, design based on the type of coal is necessary. Hence, the coal type is decided on, and once the coal ash properties and its chemistry are understood, it will be moved on to the design specifics. In addition, a vacuous space in the EP’s exit is created in light of future coal property transformations and increases in the coal’s ash content as well as plans to affix dust collection electrodes and discharged electrodes to for the purpose of performance recovery when such performance begins to decrease. Furthermore, in order to prevent the re-entrainment of dust collection electrodes and discharged electrodes attached to ashes during “hammering”, a damper will be installed at the EP exit.

(2) Determination of type of desulfurization

The Desulfurization Facility is apparatus that eliminates flue gas including SOx particles, and for coal-fired power stations is considered to be the most widespread limestone-gypsum wet scrubbing method and via contact with limestone slurry, SOx particles are reacted with limestone resulting in a method that generates gypsum. Further, when seawater HCO3 is used as an absorbent, it is possible to come up with a simplified seawater scrubber-based desulfurization apparatus. Inside the "reaction tower", when emitted gas comes into contact with limestone slurry, it produces the following reaction, and gypsum (CaSO4・2H2O) is generated.

$$SO_2 + H_2O \rightarrow H_2SO_3$$
$$H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$$
$$H_2SO_4 + CaCO_3 + H_2O \rightarrow CaSO_4 \cdot 2H_2O + CO_2$$

When actually choosing a method in light of existing regulations, it is important to take into consideration the desulfurization efficiency and the costs. For this Master Plan, first with regards to domestic coal-fired power stations, the Desulfurization Facility will be planned with an eye towards cheap design and operational costs utilizing the "Blended Ash Method". From the perspective of the quality of the calcium sulfate, although the interfusion of impurities such as fly ash is to be expected, since it can be utilized as a "gypsum board", it is considered to be efficient.

(3) Determination of type of denitrification

The Desulfurization Facility is apparatus that eliminates flue gas including NOx particles, and for power plants is considered to be the most widespread Ammonia Catalytic Reduction Method available Furthermore, in concert with desulfurization apparatus, in order to reduce nitrogen oxide in the boiler, a "Low NOx Burner, two-staged combustion" is utilized. As with the Desulfurization Facility, in accordance with regulations a comparison of the desulfurization efficiency and costs are taken into consideration before adopting a method.

14.3.6 Utility equipment

(1) Determination of capacity of water treatment facility

Regarding the aforementioned inside of the unit's artificial ditch, given that fine, high grade water is required, especially for the water used to replenish the boiler's water supply etcetera, it is necessary to have water treatment apparatus inside the generator (water purifying apparatus). With regards to the design, after determining the required amount of water based on the design of the boiler and the environmental facilities, it is necessary to apply an appropriate amount of capacity.

(2) Coal stock & handling facility

At a stage of determination the capacity of coal stock facility in the power station, it should be determined how much needed according to the way of fuel transportation. For example, if the coal is provided continuously by truck or direct from coal mine, it is no need to secure large capacity of coal stock yard, but in case the transportation is vessels, 30 or 50 days of stock should be needed considering climate risk. According to risk, it should be determined.

In this Master Plan, for the import coal-fired power station the capacity of coal stock yard is determined as 45 days, to set 200,000 t capacity of coal stock yard is set for 600MW. For the domestic coal-fired power station it is determined as 15 days considering short span transportation from coal mine.

About coal handling facility, the item of consideration is different between domestic and import.

(a) Domestic coal-fired power station

In case of this site, because of its feature of being close to the coal mine that is the procurement source of fuel (several kilometers away), possible alternatives of fuel transportation mode are belt conveyors, trucks, and railways.

1) Belt conveyor

It is characterized by the low cost of construction and transportation on short haul. But if it is a long haul, maintenance cost is high and there is little performance record.

2) Truck

It is characterized by easy loading/unloading and easy adjustment of the amount of load by increasing or decreasing the number of trucks, but to make an efficient transportation stable, you need the road maintenance (pavement), which costs a lot (you should construct exclusive lanes for mass transportation). Also, for mass transportation, you need many trucks; hence, the purchasing cost of vehicles and the labor cost for drivers will increase. In addition, there is a big risk of traffic accidents.

3) Rail

It has an advantage over other transportation modes because it can transport a large amount of load at one time; however, you need various costs, including cost for rail development, cost for constructing loading/unloading facilities, cost for purchasing freight cars, etc. It helps to reduce operational cost for a long haul but can be rather expensive for a short haul.

The PSMP Study Team summarized the above studies in the following table (details of the amount, etc., are under investigation).

Table 14-4 Comparison of fuel transportation modes

Item	Belt Conveyor	Truck	Rail
Construction and equipment cost	Approx. 5,000 USD /m	Road Truck : Approx. @100,000USD	Rail : Approx.2 mil USD/km Car : Locomotive 4 mil USD Freight Car 200,000 USD
Running Cost	(Power for Conveyor・Maintenance cost)	(Fuel cost, Maintenance cost)	(Train Operation cost, Maintenance cost)
Operation	(Fixed route)	(Flexible (amount control, route change))	(Transportation on the rail)
Maintenance	(cleaning of conveyor joint point)	(Car maintenance, Road maintenance)	(Car maintenance, Rail maintenance)

Source: PSMP Study Team

As for the cost, while the cost for a belt conveyor is proportional to the distance, truck and railway require a large amount of initial investment such as purchase of vehicles that are not proportional to the distance; therefore, the belt conveyor will be advantageous if it is a short haul. But on the negative side, the weak point of the belt conveyor is that it can transport only on a fixed route; however, flexibility counts for little if it is used for a fixed route such as between a coal mine and a power station.

In addition, it is proposed that railway should be developed to transport domestic coal from coal mine to import coal-fired power station such as Khulna, Meghnaghat by mixing domestic coal which is cheap and good quality with import coal, to make stable firing and to hedge the risk of the import coal chain.

(b) Import coal-fired power station

In the case of import coal-fired power station, the conveyance of the coal will be connected to the sea port as specified in Chapter 13 where it states that Chittagong South will serve as the coal center for coal supplies to Chittagong. On the other hand, Meghnaghat will only be responsible for incoming domestic vessels from Matarbari. Import vessel entry will be prohibited.

For the base of Chittagong South's import vessels, given that area along the coast is too shallow, a T-shaped off-island location about 1km away with a 10m depth and a 28,000t capacity will be utilized. However, the domestic vessel berth will be constructed connecting to the dry land. The following indicates the necessary base numbers for the two locations.

Table 14-5 Necessary berth number of Chittagong South and Meghnaghat

	Chittagong South	Meghnaghat
Import Vessels	4 (5)	0
Domestic Vessels	6	5

Source: PSMP Study Team

With regards to coal transport (from ship to land) and storage, import coal-fired power station are different than their domestic counterpart in that they are not dealing with only one set type of coal. Further, depending on the type of coal, given that a coal mixture may be necessary, specifications overseeing coal transport and storage to ensure proper "coal mixing" will be required. Specifically, at the storage site, a system must be set up whereby the coal is properly divided into piles by type and then in order to create a coal type that is close to the boiler's design specifications, have the necessary amount of coal taken from each pile and then placed in a "delivery line" from where it will be sent to the "blending apparatus". For "reclaims" and "stock reclaims", the number of piles will be installed.

Further, since coal transport and storage for incoming foreign vessels will be a 24hour operation, a system capable of overall operational handling and supervision will be built to be installed in the "Coal Transport Control Room." Several TV cameras connected "changing-screen monitors" will be installed in the control room to allow for surveillance of the berth and coal storage activities. The same will be applied to outgoing transfer work of other firepower.

(3) Determination of type of ash treatment facility

How ash exhaust from the boiler is collected and disposed are the determinants of the type of apparatus and capacity amount (how much is capable of being stored).

With regards to the 600MW plant equipment planned for this master plan, per each generator, approximately 200,000 tons per year of coal ash is generated. Categorically speaking, 15% of this is clinker ash (ash that accumulates at the bottom of the boiler) and 85% is fly ash (ash from flue gas and ventilation pipes that is primarily collected by the EP). The clinker ash is collected utilizing water (a wet cleaning method) from the bottom part of the boiler while fly ash is collected via a dry method. Further, next to the generator, a spot has been secured for the disposal of ash which under normal circumstances would be buried in the ground. However, in terms of construction materials, given that coal ash has many utilitarian purposes such as serving as mixture material for concreter, a thick alternative to cement, fertilizer for soil enhancement, landfill reclamation and marine reclamation etcetera, at the ash disposal site, it is put aside and categorized as a substance that in an emergency can serve many beneficial purposes.

14.3.7 Other common facility

(1) Main building

For the main power generator building, in order to install the steam turbine, it is supported by a very strong, highly reliable foundation and in order to lessen damage from machine vibrations, a design employing a sufficient amount of rigidity and intensity is applied to the uneven settlement.

(2) Stack

From the perspective of environmental safety, the height of the chimney was determined to be 140m in consideration of exhaust input/output speed and concentration diffusion.

(3) Attached buildings

The administration office, separate from the machinery operators, has been designed for full-time workers. On the first floor, there is a chemical analysis laboratory, a cafeteria, a resting area, air-conditioning equipment room, storage. On the second floor, there is an office, meeting room, head office, dressing room, and a material room. Other buildings include the repair factory, parts storage building, Coal Transport Control Building, Environmental Apparatus Control Building, Hazardous Materials Storage Building, the Water Treatment House, and the Security building (guard house).

14.3.8 Facilities for co-existing areas

In order to promote harmonious co-existence between power station and their local surroundings, it is of vital importance that a relationship of trust be established with surrounding residents. Hence, the power station should adopt a position of openness to the public and actively contribute to the area's lifestyles. In this master plan, there are plans to construct a park, a cricket field, and a pool in the nearby surroundings for local inhabitants. Further, the promotion of planting greenery in the power station's surrounding areas will also be encouraged.

14.4 Study of equipment transportation

During the construction stage of the power station, the main equipment such as the boiler, turbine, and generator are partly assembled in the factory prior to being transported to the site, so there are large equipment that needs to be transported via special means. If the power station site is located seaside, it is possible to use a barge ship. However in case that the site is inland, land transportation is needed. So it is necessary to deeply consider the logistics of land transportation. After designing, what kind of equipment, how it is packaged, actual route verification, optimum route selection, and bridge or road repairs if necessary.

On this Master Plan, the B-K-D-P site has the most restrictions concerning the transportation of equipment, so the study for transportation is conducted as follows;

14.4.1 Specification of transportation

The major equipment for the 600MW class coal-fired power station is as follows;

Table 14-6 Specification of equipments

Equipment	Specification	Remarks
(Major equipment)		
Generator	600MW class	Including stator, rotor
Transformer		Impossible to separate
Turbine	Single shaft (HP,IP,LP)	Possible to separate
Boiler		Assembly at site
Cooling system	Air Cooled Condenser	Possible to separate
Anxiety equipment		Possible to separate

Source: PSMP Study Team

For the transportation, in case of ship, choose freight vessel, in case of usage of river, rush vessel or barge vessel would be used. At the road transportation, it is generally to use the railway or large trailer. Therefore, not to make damage is important especially for main equipments.

And it is necessary not to exceed construction limit, the generator and transformer are the maximum pack.

Following is transportation specification.

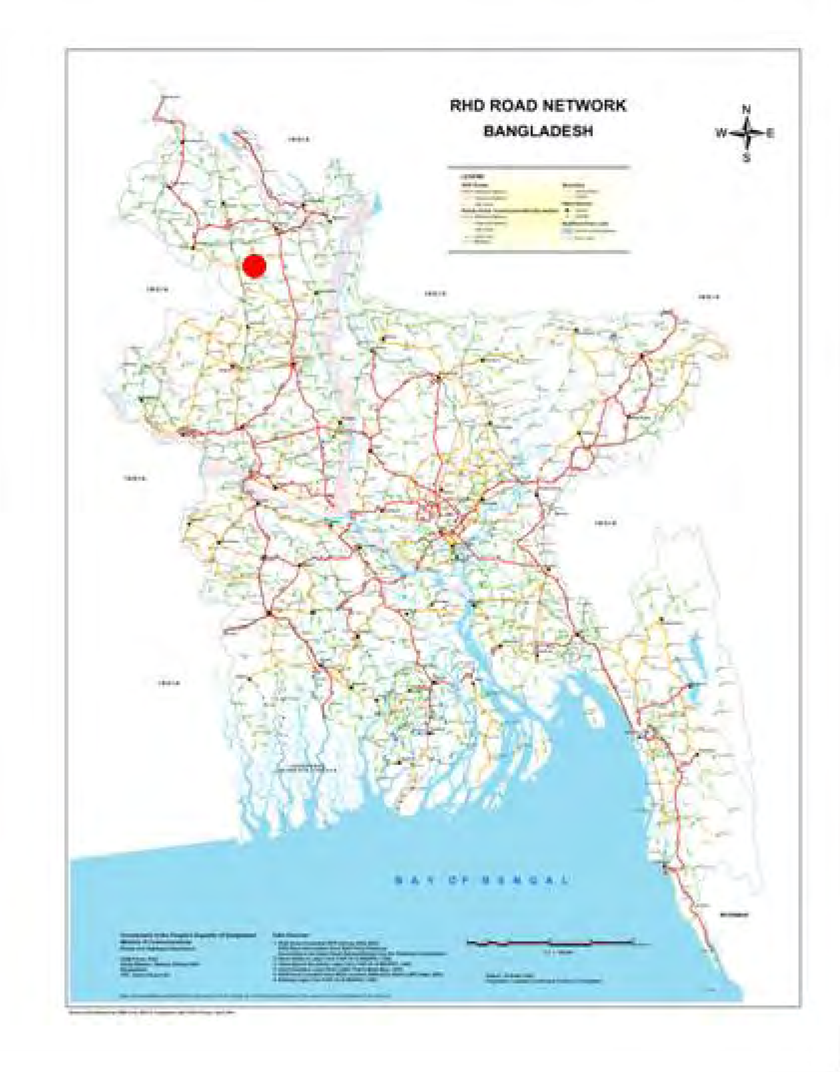
Table 14-7 Specification for transportation

Equipment	Size	Weight
Generator	15m×7m×5m	400t(stator)
Transformer	14m×13m×10m	320t

Source: PSMP Study Team

14.4.2 B-K-D-P site

B-K-D-P site is located N-25° 23.491' E89° 07.003', about 15km distance from Barapukuria coal mine, and 7km east side from Nababganj Upazila in Dinajpur.



Source: PSMP Study Team

Fig. 14-11 B-K-D-P site map

14.4.3 Selection of transportation route

It is assumed that the equipment and materials for the new power station will be off-loaded at either Chittagong seaport or Mongla seaport from where these may be carried by waterways and/or roads/railways etc. From any of the seaports, the cargoes containing the power station equipment and materials will be loaded on the barges for transportation through waterways to the nearby river port from where the cargoes will be loaded on the multi-axle trailer to carry them to the B-K-D-P site through roads. Another option is to unload the equipment and materials from the barges to the trailer at the seaport and then transported to the B-K-D-P site through roads. Hence, the following three routes have been proposed to carry the equipment and materials from the seaport to B-K-D-P site:

Route-1: River route from Mongla port to Balashi Ghat and thereafter overland route from Balashi Ghat to B-K-D-P site;

Route-2: River Route from Chittagong Port to Balashi Ghat and thereafter overland route from Balashi Ghat to B-K-D-P site;

Route-3: Overland route from Mongla Port to B-K-D-P site.

14.4.4 Study for the transportation from Mongla port to B-K-D-P site

(1) Geographical position of Mongla port

Mongla Port is situated on the East Bank of Pussur River near the confluence of Pussur River and Mongla Nulla at Channel distance of 71 Nautical Miles from the Fairway Buoy situated (Lat. 21026.9` N. long. 890 34.4 E) in the Bay of Bengal.

Mongla Port is controlled by the Mongla Port Authority, the second largest port in Bangladesh, 350 ships arrive at the port every year, the amount of cargo treatment is 3.4 million tons per year as follows;

Table 14-8 Trend of cargo treatment amount of Mongla Port

(1,000 t)

FY	Import	Export	Total
1995	2,322	725	3,047
1996	2,443	396	2,839
1997	2,174	520	2,694
1998	2,340	508	2,848
1999	3,054	382	3,436

Source: Mongla Port Authorlty

Source: Mongla Port Authority

Fig. 14-12 Pussur River with Mongla Port

(2) Mooring and anchoring facility of Mongla port

There are 5 mooring facilities at Mongla port for normal cargo and container, and also 7 at the river mooring berth and 14 at the anchorage berth. The maximum capacity of the cargo treatment is currently 40 t, so a 500 or 800t crane barge is needed.

Source: PSMP Study Team

Fig. 14-13 Mooring facility of Mongla Port

(3) Mongla port and approach channel from the Bay of Bengal

The Mongla Port Authority (MPA) maintains a draught above 7 meter near the jetties by dredging for ship berthing. No-heavy lift cargo can be easily unloaded on the jetties (5 nos.). Outer anchorages have draughts of 9 meters and above. There should be no problem for ships to offload the heavy lift cargo on to the barges. The port area being 131 km away from the Bay of Bengal and is safe in respect of storms and tidal bores.

The approach Channel with draught of 28meter is very wide (7000m) and has sufficient draughts (9m to 28m) for bigger ships to ply to the port.

(4) Tide

The tides are important for navigation as determines the possibility of crossing the shallow outer bar at the entrance. The tides are semi diurnal with prominent diurnal effect. The approx. tidal range is between 1.2 m. to 3.5 m. all over the channel.

(5) Navigational facilities

Maximum length of ship that can enter Mongla Port is 225m. Pilotage is compulsory. Anchorage condition is good.

(6) Unloading and loading at Mongla port

For the proposed B-K-D-P Coal Fired Power station, the heavy lift equipment with maximum single package may be assumed to weigh up to 400tons has to be transported by barges or road from the seaport to the B-K-D-P candidate site at Nababganj, Dinajpur

(7) Transportation

Barge (L38.5mxW20.0mxD2.13m capacity 600tons)	:	1 No.
Tugboats (Twin screw, 500hp)	:	2 Nos.

Tugboats (Twin Screw) each of 500hp capable to operate during high river velocities up to 3.5m per second will have to be arranged. This may hired locally.

All heavy cargoes will arrive at Mongla port by ship from abroad. The existing jetty at Mongla port can not handle such heavy cargoes. The carrying ship will have to unload with its own crane all the heavy equipment packages at outer anchorage on to special barge detailed by the carrying contractor. For the heaviest single lift cargo of 400tons, the barge deck has to be reinforced and leveled by steel sheeting adapting to the size of the equipment packages of stator of generator. After placing in position on the special barge, the package should be covered and wrapped adequately for protection and special care should be taken during transportation. Specially trained and experienced crew and staff including security force should be deployed for the purpose.

14.4.5 Study about river transportation from Mongla port to Balashi Ghat

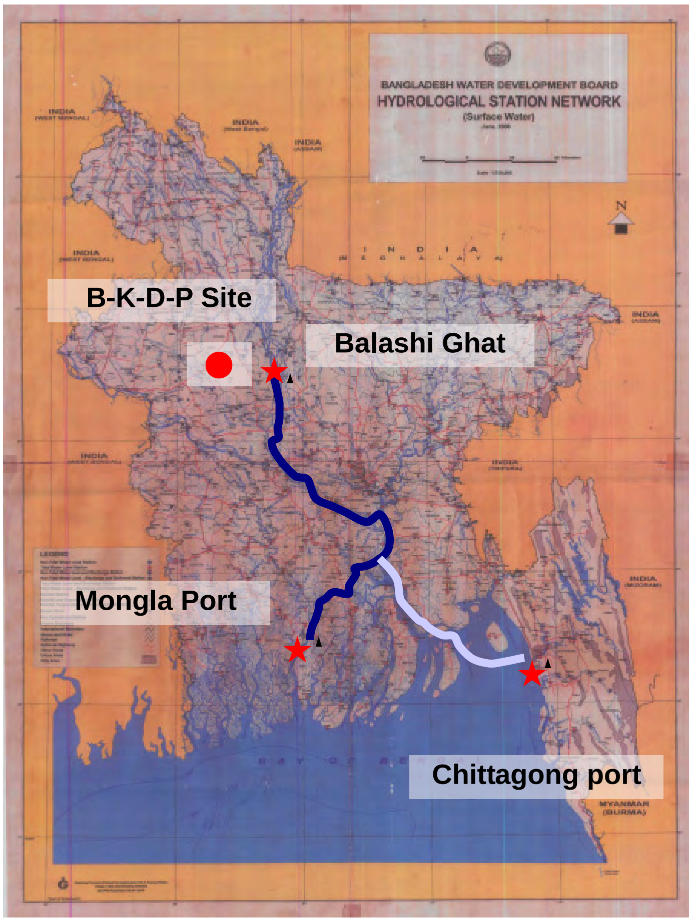
Possible river route from Mongla port to Balashi Ghat has been studied. The river route from Mongla Port to Balashi Ghat is about 468km long.

(1) Transportation route

The route has passed through the rivers Pussur, Mongla, Kumarkhali, Ghashiakhali, Panguchi, Kacha, Gabkhan, Gajal, Nalchiti, Barisal, Arialkhan, Azimpur, Dharmogonj, Meghna, Padma/Ganges and Jamuna. Satellite image showing River route from Mongla Port to Balashi Ghat is given as follows;

(2) Condition of river

Following table shows the condition of Jamuna river from Mongla Port to Balashi Ghat.



Source: PSMP Study Team

Fig. 14-14 Route map of river transportation

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Table 14-9 Channel condition from Mongla Port to Balashi Ghat

No.	Section		Distance from Mongla Port(km)	Width (m)	Depth (m) at mid point	Remarks
	From	To				
1.	Mongla	Morelgonj	38	200-700	4.6-10.2	
2.	Morelgonj	Kawkhali Ferighat	77	700-2500	9.5-22.1	
3.	Kawkhali	Barisal CSD Ghat	114	120-800	6.2-24.4	
4.	Barisal	Hizla	142	300-1700	5.3-25	
5.	Hizla	Chandpur	193	600-10000	4.8-40.5	
6.	Chandpur	Mawa	241	300-3900	4.8-27.1	
7.	Mawa	Daulatdia	295	400-5300	11.5-53.9	
8.	Daulatdia	Chowhali	332	2000-7000	6.2-39.3	
9.	Chowhali	Sirajganj	365	500-6000	4.8-32.2	
10	Sirajganj	Balashi Ghat	468	500-6000	4.8-32.2	

Source: PSMP Study Team

(3) The channel Mongla to Hizla (142km)

This section having widths of 120meter to 2500m and draughts of 4.6m to 25m is suitable for all season transportation of cargoes by barges.

(4) Hizla to Daulatdia (153km)

This section is very wide and deep with a number of islands. Its navigation line having draughts of 4.8m to 53.9m is also suitable for all season transportation of cargoes by barges.

(5) Daulatdia to Balashi Ghat (173km)

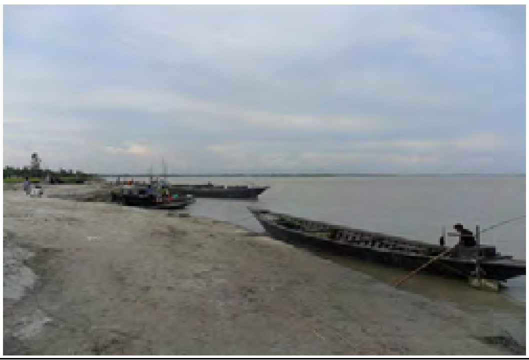
This section is also very wide and deep with a number of islands. Its navigation line is very narrow and un-navigable during winter. But it becomes navigable during monsoon period particularly between July and September (draught 4.8m to 39.1m). Transportation of cargoes by barges is possible only during this period. A dredger of adequate size and pilot service from BIWTA will have to be arranged for this section with every trip. Channel dredging will be required to extend the navigability beyond monsoon period i.e. up to June-November, if desired. In this section, Jamuna Multipurpose Brride (JMB) known as “Bangabandhu Shetu” is located near Serajgonj. Although the height of this bridge above flood level is about 30m, special care must be taken to avoid any accidents during carrying the heavy cargoes.

Source: PSMP Study Team

Fig. 14-15 Below Bangabandu Shetu

(6) Balashi Ghat

Balashi Ghat is situated on the west bank of the Jamuna River in the district of Gaibandha. It is located at N 25018.908’, E-89036.938’. This is used as river port from where the ferries, launches, boats and oil tankers etc are plying to other river ports e.g. Sirajganj, Daulatdia etc. There is one pontoon for loading and unloading of ferries, launches, boats etc. The draught at Balashi Ghat in the winter is about 4.5m. Jetty may be installed at this Ghat to unload heavy cargoes of B-K-D-P Power station to transport from this Ghat to B-K-D-P site by road.

	
Oil Tanker & Launch waiting	Boat waiting at Balashi Ghat
	
Ferry Mooring	Downstream view
	
Upstream view	Opposite side view

Source: PSMP Study Team

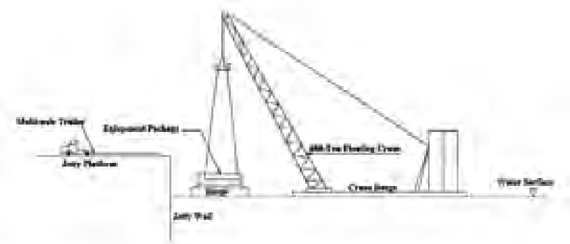
Fig. 14-16 Photo of Balashi Ghat

14.4.6 Unloading methodology at Balashi Ghat

There is no Jetty at present at Balashi Ghat except one pontoon. A jetty has to be built by the EPC Contractor. During the Survey a possible site for Jetty was found at the bank of the River Jamuna. The carrying ship will unload with its own crane all the heavy equipment packages on to special barge. The heavy equipment above 40tons would be loaded on 600-ton barge and would be towed by tugboats to Balashi Ghat. Pilot service is essential for safe cruising. Tugboats will tow the barge to Balashi Ghat Jetty. Cargoes offloaded from the barge by 600-ton self propelled barge mounted floating crane on the trailer placed on the jetty.

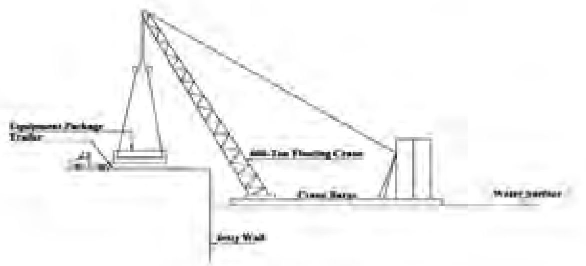
Steps to be followed at Balashi Ghat for the single lift cargoes above 40tons:

(1) On arrival of special barge with cargo a high capacity barge mounted floating crane will be placed along the barge carrying the cargo.
(2) The floating crane will lift cargo from barge to the required height
(3) The empty barge will be moved away by the tug
(4) The floating crane will proceed with the equipment towards unloading point of the jetty.
(5) The crane will lower the cargo on the trailer placed on the jetty platform specially prepared by others
(6) The cargo will be wrapped after placed on the trailer and the wire will be removed.
(7) Trailer (driven by Prime mover) will carry the cargoes to the site following the overland route.
(8) The equipment will be off-loaded from the trailer by suitable crane.



Source: PSMP Study Team

Fig. 14-17 Unloading from barge



Source: PSMP Study Team

Fig. 14-18 Loading to trailer

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