Chapter 17 Improvement of Demand/supply Operation of Electric Power and Frequency Quality

17.1 Fundamentals of Electricity Demand/supply Operation Process

"Demand/supply Operation" is to coordinate various kinds of power sources with its demand in order to realize the most economical dispatch under the conditions of maintaining the power system reliability or quality, such as system frequency and voltage.

To conduct an appropriate demand/supply operation, the work starts with plan and development of adequate power plants and transmission facilities based on the correct demand forecast for a long range of 10 to 20 years. And then, it is seamlessly brushed up with detailed information of demand forecast or planned/unplanned outages by year-ahead, month-ahead, week-ahead, day-ahead and the day plan.

The following is brief explanations of the demand/supply operation planning in Japan.

17.1.1 Demand/supply operation planning

(1) Yearly plan

In this phase, combination of various kinds of power sources such as hydro, thermal and nuclear power plants is optimized so that the economical dispatching is realized to the demand forecasted throughout the year. Development plans of power plants, periodical maintenance plans of thermal and nuclear power plants, fuel operation plans of oil or gas and water operation plans of reservoir are taken into consideration.

(2) Monthly plan

In this phase, fuel operation plans and maintenance plans of generation facilities are expected to become firm, and yearly plan is revised with these detailed plans.

(3) Weekly plan

Weekly start-and-stop plans for the thermal power plants and generating plans of hydro power plants (reservoir, pondage and pumped-storage type) are formulated because the accuracy of demand forecast will be improved and maintenance plans of generation facilities are expected to be finalized, in this phase.

(4) Day-ahead plan

Daily start-and-stop schedule of thermal power units, generating plans of hydro power units, economical load dispatching plans are formulated and final demand/supply operation plans are fixed because accuracy of demand forecast is highly improved.

17.1.2 Real-time operation

(1) Economical load dispatching control (EDC)

EDC is to operate the output of generators every ten-odd minute in order to realize an economically optimal allocation based on the past achievements.

In case of a power system connected with large amount and various kinds of generating units, and in the case where the system load is widely changing, EDC is largely dependent on the automatic calculation and online instruction by computers, and instructions by phone of manual operations by shift engineers are performed only when unforeseeable events occur, such as enormous change in weather, temperature, or sudden shut off of generators.

(2) Load frequency control (LFC)

LFC is to control generating output on a cycle of the range from several minutes to several tens of minutes in order to keep the system frequency constant.

LFC is almost completely dependent on the automatic and centralized control by computer system in national (central) dispatching center. It is an essential condition to realize the power frequency quality in developed countries (0.2-0.3Hz or less).

(3) Free governor mode operation (FGMO)

For more frequent load fluctuations ranging from several tens of seconds to several minutes, the free governor mode operation by generators is effective to absorb them.

FGMO is a kind of distributed control system, which can be performed by each units, independently. And it is also essential item for power quality.

(4) Self-regulating characteristics of load

For more fine fluctuations of several tens of seconds or less, it is impossible to control them artificially because of the delay or dead band of control system, such as LFC. Fortunately, these fine fluctuations can be absorbed by the inherent frequency-load characteristics or inertia of generators.

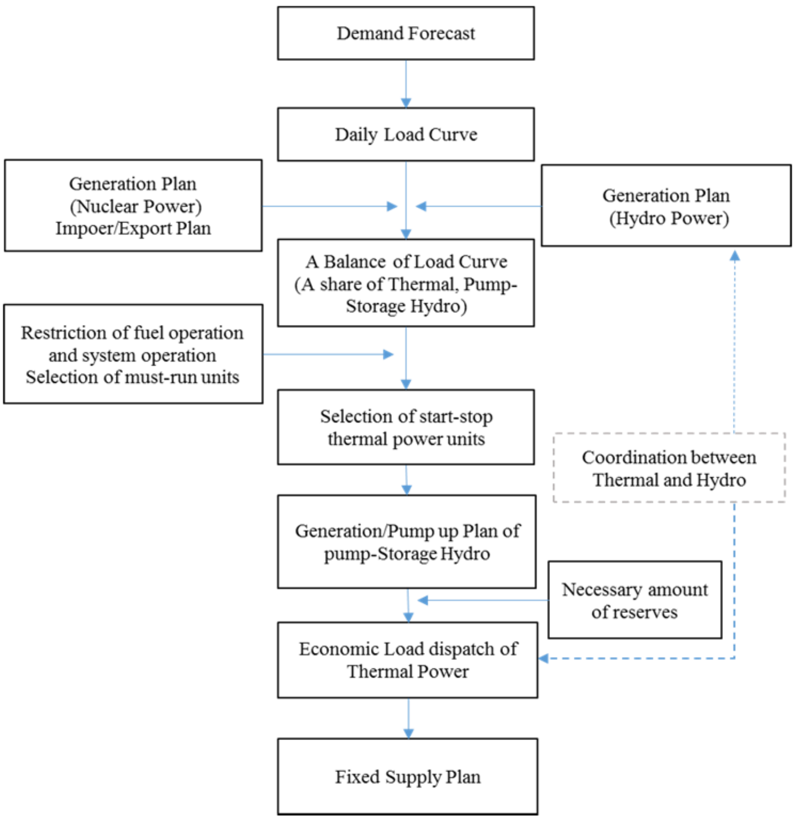


Figure 17-1 Flow Diagram of Day-ahead Demand/supply Planning Process

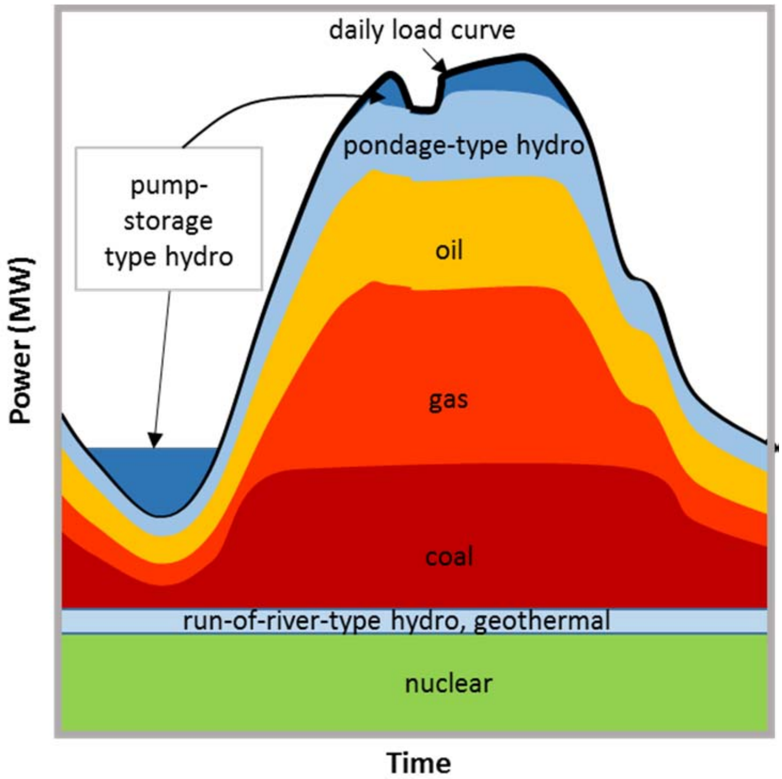


Figure 17-2 Example of Typical Daily Load Curve and Allocation of Power Sources in Japan

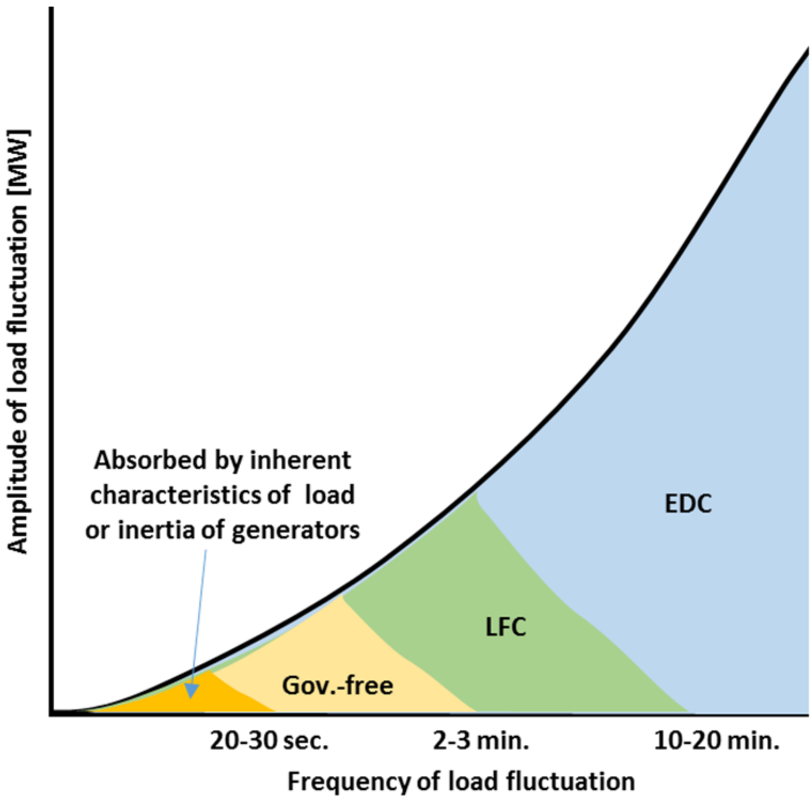


Figure 17-3 Conceptual Diagram of Role Sharing of Each Control Method

17.2 Present Status and Necessity of Improving Power Frequency Quality in Bangladesh

17.2.1 Electricity demand-supply operation in Bangladesh

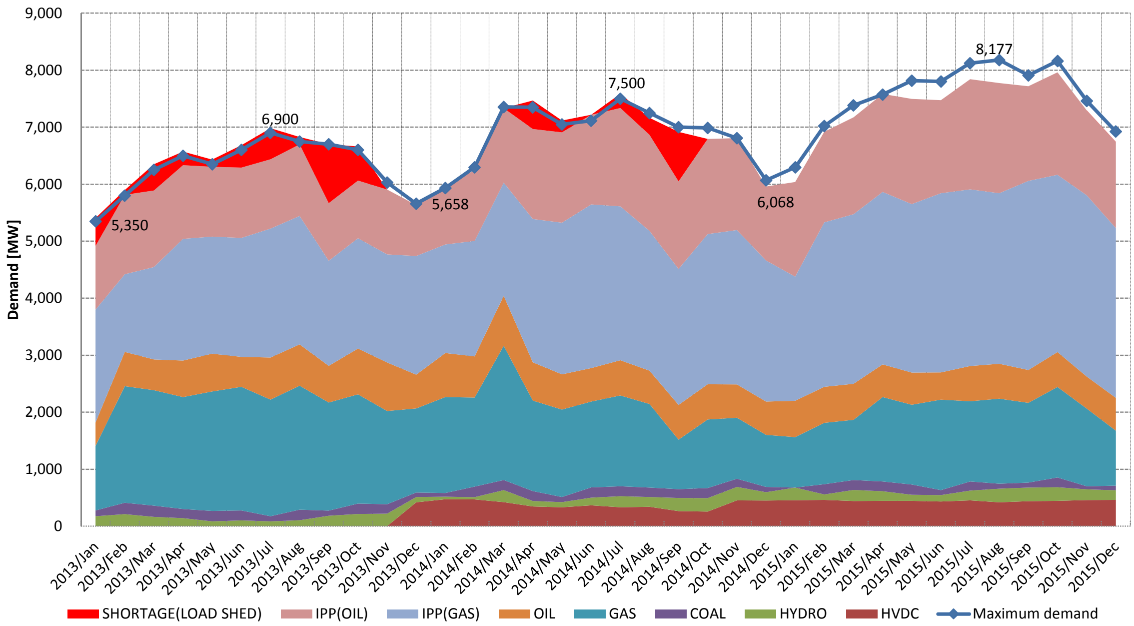
(1) Long-term planning

As shown in
Figure 17-4 Figure 17-4, load-shedding operations used to be conducted throughout the year in the past. However, it has gradually been limited to the peak load period and, in 2015, it is reduced to several days per year. (The graph in Figure
Figure 17-4 shows supply-demand balance of the day of maximum peak load for every month. Therefore, if the load-shedding operations were performed in the other days, they are not illustrated in this graph.)

As the results of interviews with key persons, it is found that following conditions were merely good at supply-demand balancing operations, and they are short-lived situations:

- Commencement of operation of newly installed generators
- Commencement of electricity import from India via HVDC interconnection
- Falling short of forecast demand

Therefore, load-shedding scheme is still one of the major solutions for deficiency of power source.



Source: Created based on daily reports in NLDC

Figure 17-4 Monthly Trend of Peak Load Power Sources in Bangladesh

(2) Short-term planning

The results of the site investigations give us a glimpse of how serious the situation of short-term supply/demand balance planning is. In the process of settling the short-term plan, NLDC, primarily, should have authority to gather necessary information, to integrate them for settling plans and to instruct according to the plans. As a matter of fact, BPDB or generating companies settle the generation plan, and NLDC has no authority to coordinate plans.

Variety of the Term of Planning

- A day plan and a day-ahead plan is formulated in NLDC. Weekly, monthly, yearly or longer term plans are not dealt with.

Integration of the Generation Plans (Maintenance Outage Plans)

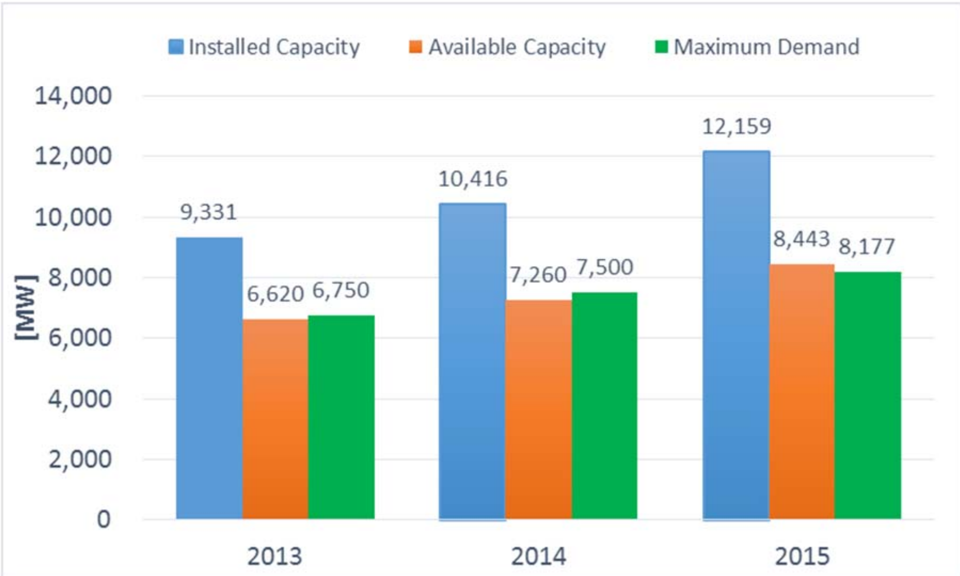
- Generation plans are not provided to NLDC until a previous day of actual operation.
- Coordination of the maintenance outage plans is performed by BPDB, and NLDC can't take part in the decision making process of the plan.

Plans of Demand-supply balancing and Unit Commitment

- The day-ahead plan is formulated at the timing of two peak hours in daytime and nighttime.
- The day plan is formulated on the hourly basis from 16:00 to 15:00 of next day.

(3) The actual conditions of existing generation plants

According to the Daily Report of Bangladeshi NLDC, the installed capacity of generators is gradually increased corresponding to the demand rise, Figure 17-5 shows the situation of supply- demand balance in the day of maximum peak demand from 2013 to 2015.



Source: Created based on daily reports in NLDC

Figure 17-5 Situation of Supply/Demand Balance in the Day of Maximum Peak Demand (from 2013 to 2015)

The installed capacity rate has been adequately secured at more than 130% every year. In reality, however, the available capacity is chronically insufficient due to decreases in the output and thermal efficiency and failures of power generators mainly due to the insufficient periodic maintenance, which results in a decrease in around 30% of installed capacity. Till 2014, in particular, load shedding had been performed due to the shortage of power sources.
In 2015, load shedding could be prevented because the available capacity barely exceeded the maximum demand.
However, the rate of capacity decrease is remaining unchanged and the risk of load shedding is still high. Therefore, a drastic measures for securing power sources are urgently required to taken.

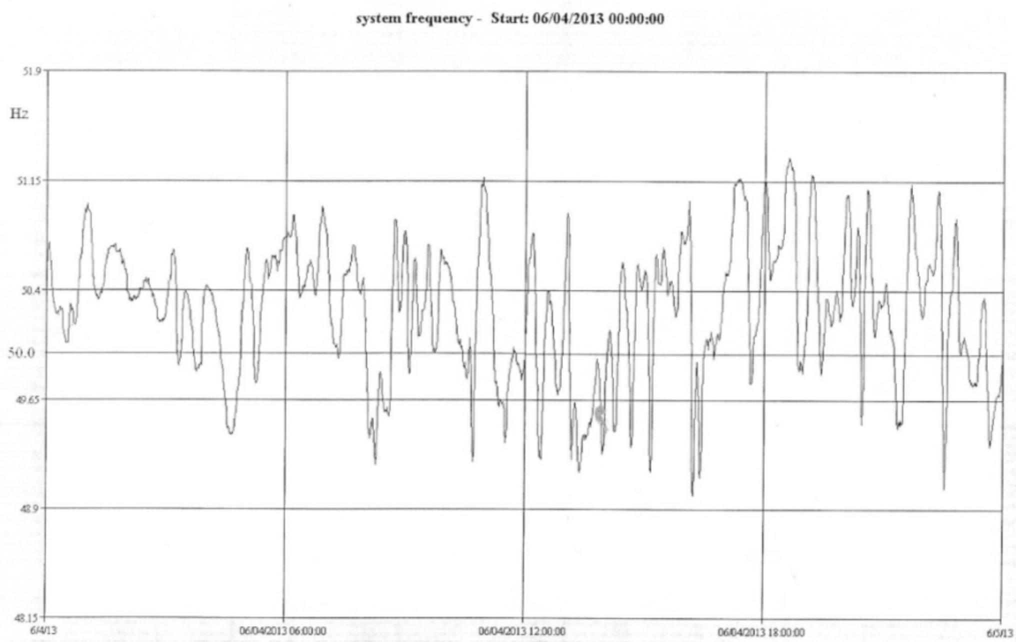
(4) Necessary actions for improving demand/supply balance

While steady development of power sources and repair of the existing power sources based on an appropriate demand forecast is hoped in the middle to long terms, in the short term, eliminating the causes that obstruct efficient demand-supply operations, such as a gap between a demand forecast and actual demand, a gap between generating plans and actual operation, an increase in loss of power transmission and electricity stealing, is important.

17.2.2 The Actual Conditions of Power Frequency Quality

(1) The actual conditions of power frequency control

At present, adjustment of the output of the generator is instructed by phone (online instructions from SCADA are not issued). As shown in the Figure 17-6, system frequency deviation from 50 Hz is often exceeding ±1.0 Hz even in the normal operating condition (Grid Code stipulates that the system frequency shall be controlled within 50Hz±1.0Hz under the normal condition.)



Source: Provided by NLDC

Figure 17-6 Actual Situation of Frequency Adjustments in Bangladesh

PGCB kindly provided us the following opinions in relation to actual situations:

- An installation of the nuclear power station is, now, planned in 2024, but it will be difficult to keep generating operation stable on the condition of existing quality of frequency. An enhancement of frequency quality is eagerly desired.
- Before the unbundling of an electricity industry in 1996, a fluctuation of the frequency was smaller than the present situation because about 50% of generators could offer reserves for frequency control, including generators in Kaptai hydro power station. However, since the unbundling, the number of generators which can offer the reserves has gradually decreased.
- PGCB estimates the following 2 causes of degradation of the frequency quality.
  1. There is almost no remaining power which can be offered for frequency control due to a significant deficiency of power source. That is, all generators have no other choice except to keep their outputs at a maximum of available capacity.
  2. The electricity industry was unbundled without rules and authorities for demand-supply

control.

BPDB and Siddhirganj power station also gave us following comments for problems at present:

- It may be possible to operate in AGC (Automatic Generation Control) mode with the necessary modifications and testing conducted by manufacturer (GE), yet the generators have not set to respond to the LFC (Load-Frequency Control) signal from NLDC system, now.
- They are considering that a burden of FGMO should be shared among generators as many as possible, in order to reduce the power fluctuation of each generator.
- They have willingness to cooperate to the frequency control, if a system is developed that can make compensation for an opportunity loss of power selling.
- They have a strong desire to share a detailed information about the situation of a power system among the stakeholders, because this operation should be performed under the fair and transparent terms.

(2) Necessity of improving power frequency quality

To adjust the frequency, it is necessary to supply part of generator output as adjustment power, and the power generation operator that supplies the adjustment power needs to shoulder a specific loss of the opportunity to generate power and a fall in power generation efficiency. The resource to make up for the loss comes from electricity charges or tax, which means that the citizen eventually has to bear the burden. The economic effect brought by the technological power and improvement of frequency quality in a given era and the burden of the people are in a trade-off relationship.
Quantitative evaluation is extremely difficult in reality, and the target frequency deviation values of Japan, the U.S., and European countries vary as shown in the table below.

Table 17-1 Target Frequency Deviation Values of Japan, North America, and Europe

Region	Target frequency deviation value	Criteria
Bangladesh	50±1.0 Hz max.	Instantaneous
Hokkaido	50±0.3 Hz max.	Instantaneous
Eastern region (Tohoku & Tokyo Electric Power Co.)	50±0.2 Hz max.	Instantaneous
Mid-western region (Chubu Electric Power Co. & westward)	60±0.2 Hz max.	Instantaneous
North America (NERC)	East: 0.018 Hz max. West: 0.0228 Hz max. Texas (ERCOT): 0.020 Hz max. Quebec: 0.0212 Hz max.	Annual standard deviation (average in 1 minute)
Europe (UCTE)	50±0.04 Hz max., 90% min. 50±0.06 Hz max., 99% min.	Hour stay rate

Consumers, especially, general households use electric appliances and IT products that have an inverter circuit and distributed power source systems such as for solar and wind power generation are connected to an inverter in many cases. For this reason, the influences of frequency fluctuation on electric equipment are smaller than before. It is therefore becoming more difficult to dig out needs of suppressing frequency from general consumers than before.
On the other hand, however, industries are said to suffer from the adverse influences stemming from frequency fluctuation as shown in the table below, and potential needs for frequency fluctuation suppression are considered to remain high.
From the viewpoint of suppressing frequency fluctuation, it will be very effective to coordinate synchronization with other countries (coordination through AC transmission lines). In this case, however, there is a risk that a decrease in power quality or power outage in one country spreads the

other countries. Realizing such coordination is therefore considered very difficult. However, potential needs of suppressing frequency fluctuation to the equivalent to that of developed nations are considered high in the future.

Table 17-2 Examples of Adverse Influences of Power Frequency Fluctuation on Industries

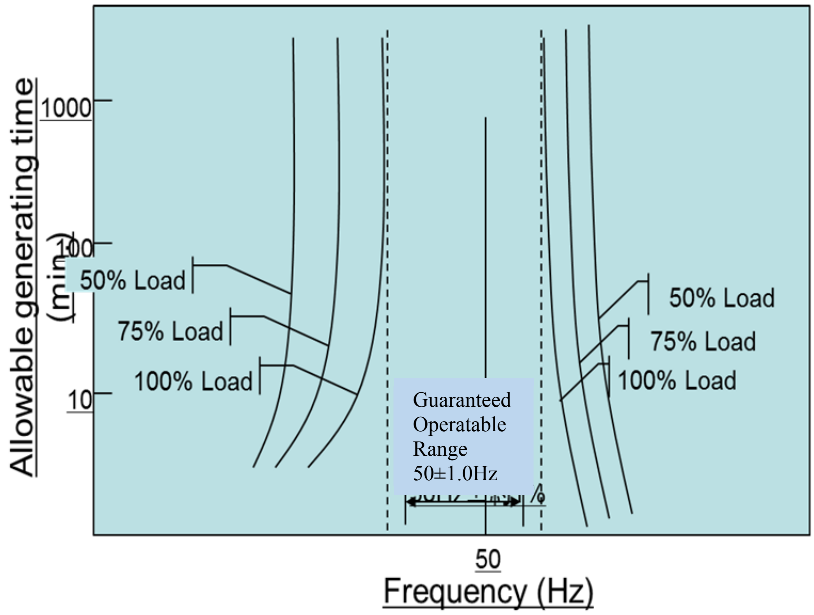
Industry	Influences of frequency fluctuation
Chemical fiber	Yarn may break or the thickness may become uneven because the speed of winding varies.
Paper manufacturing	Paper may break or the thickness may become uneven because the speed of winding varies.
Oil	Controlling pressure for decomposition and desulfurization may be affected and impurities cannot be removed.
Steel & aluminum	Rolling process may be affected, making the thickness of the product uneven.
Automobile	Welding strength and quality of appearance may be affected because the energization time of the body panel varies.

Thermal power generators and synchronous power generators have the following restrictions. These generators are designed not to operate continuously, from the viewpoints of generation of repetitive stress and member fatigue due especially to resonation of turbine moving blade and shaft vibration, unless the frequency fluctuation is kept to within a specific value (within ±1% in Japan). Therefore, the needs of suppressing frequency fluctuation are potentially high from the viewpoint of protecting machines and equipment. The effect of reducing failures of generators by suppressing frequency fluctuation can also be expected.

Table 17-3 Example of Operational Restrictions of Synchronous Generators

Turbine	Resonation of moving blade, shaft vibration
Generator	Over excitation, overload
Boiler, auxiliary device	Drop in capability of feed water pump, etc.

Figure 17-7 illustrates a conceptual diagram of a characteristic curve that indicates how long a generator is allowed to operate by the restrictions concerning resonation and shaft vibration of the turbine moving blade at a frequency (which is proportional to the number of revolutions of the turbine).
This generator can continuously run in the vicinity of the reference frequency (50 Hz) but the duration it can operate is rapidly shortened in the region outside the allowable limit. In addition, the lighter the load of the generator, the wider, though slightly, the frequency region where the generator can operate.
In general, the allowable range in the higher frequency region is narrower than in the lower frequency range because a problem of centrifugal force is added to the problem of resonation of the turbine moving blade.



Source: Created based on documents made public

Figure 17-7 Conceptual Diagram of Frequency vs Continuous Operable Time Characteristics of Synchronous Generator

Based on the information described above, it can be said that an existing status of the frequency quality is inadequate from the viewpoint of protection management of generators.
Particularly, in order to keep stable operation of a nuclear power generator planned to connect to a power system in around 2024, it will be eagerly desired to enhance the quality level of a frequency fluctuation to the global standard as shown in the Table 17-1.

According to ”Electric Grid Reliability and Interface with Nuclear Power Plants”, issued by IAEA, following frequency quality shall be required in the case of connecting the nuclear power plants:

- A generating unit is able to operate continuously at full output for the normal range of variation of grid frequency -- +/-1.0% (49.5Hz～50.5Hz).
- A generating unit is able to operate for a limited time, on a few occasions per year, perhaps at reduced output, for a range of frequency outside the normal range -- +4%, -5% (48.0Hz～r 52.0Hz).

In order to fulfill these requirements, frequency fluctuation must be improved to a half or less within the next decades, so, it is urgent problem for Bangladesh.

17.3 Scope of This Investigation

The scope of this project is as follows:

(1) Proposal for preparation of a legal framework, revision of rules and work procedures

- We will propose and support for preparation or amendment of various rules with reference to the rules in Japan (or Europe/America, if necessary) and TEPCO.
- We will check process of supply-demand balance planning and frequency control, and propose several improving points.

(2) Draft of plan for frequency quality improvement

- Estimation of frequency sensitivity in response to sudden change of power supply or demand, and evaluation of frequency quality improvement by introducing generators equipped with frequency control function.
- Development of future plan for securement of spinning reserve, such as FGMO and LFC considering generation development plan and roadmap for frequency quality improvement.

(3) Improvement plan of EMS/SCADA system in NLDC

- Confirming needs for introducing new function or adding data to the EMS/SCADA system, in order to realize an online output instruction order to power stations.

17.4 Investigation of the Regulatory Framework for Electricity Business

17.4.1 Regulatory framework for power system planning/operation

(1) The case of Japan

Majority of the electric power companies is profit-making corporation with a joint-stock (limited liability) company system. Therefore, their business managements are subject to / under protection of provisions of the general laws, such as civil laws, commercial laws or criminal laws.

In addition, they are regulated by a special law - the Electricity Business Act in order to control their sound development, to protect the consumers' interests, to secure the public safety and to preserve the environment.

As shown in Figure 17-8, the legal or regulatory structure in relation to the power system operation, in particular, the demand/supply operation or frequency control, consists of 3 stages.

Regulation by a Nation
- Electricity Business Act
  - Operational regulations concerning the law
  - Ordinance regarding the foundation of Organization of Cross-regional Coordination of Transmission Operations (OCCTO)

Regulation by OCCTO
- Rules of Services
  - Guidelines on Demand Forecast
- Detailed Rules of Network Operations

Self-management Rules of Transmission and Distribution Sector in General Electricity Utilities
- Rules of Power System Operation
- Rules of Information Publication

Figure 17-8 Regulatory Framework for Electricity Supply Industry in Japan

The Organization of Cross-regional Coordination of Transmission Operations

The Organization of Cross-regional Coordination of Transmission Operations (hereinafter shortened to OCCTO) is founded in April, 2015, in order to manage the development works of nation-wide bulk power network or to enhancing the function of nation-wide power exchange under the normal and emergency conditions. All electricity supply companies shall become a member of OCCTO, and are regulated neutrally and fairly under the rules, mentioned in Figure 17-8. (Hereinafter "OCCTO Grid Code".)

Followings are the main tasks:

- To enhance the nation-wide transmission facilities such as interconnection lines, including frequency converting stations, and the nation-wide power exchange though these inter-ties, by coordinating the demand/supply balancing plans and the network development plans.
- To perform a nation-wide backups for regional operation of demand/supply balancing and frequency control under the normal conditions, conducted by each operator of general electricity utilities.
- To take an initiative to coordinate nation-wide power supply under the emergency conditions such as disasters.
- To conduct the reception works of generators access to the network in neutral and transparent manner by publicizing power system information.

General Electricity Utility

General Electricity Utility means a major electric power company supplying the electricity power to meet the needs of general electricity demand in Japan. As shown in Figure 17-9, there are 10 regional service areas and, in each area, there is one company. (In total, 10 companies in Japan.)

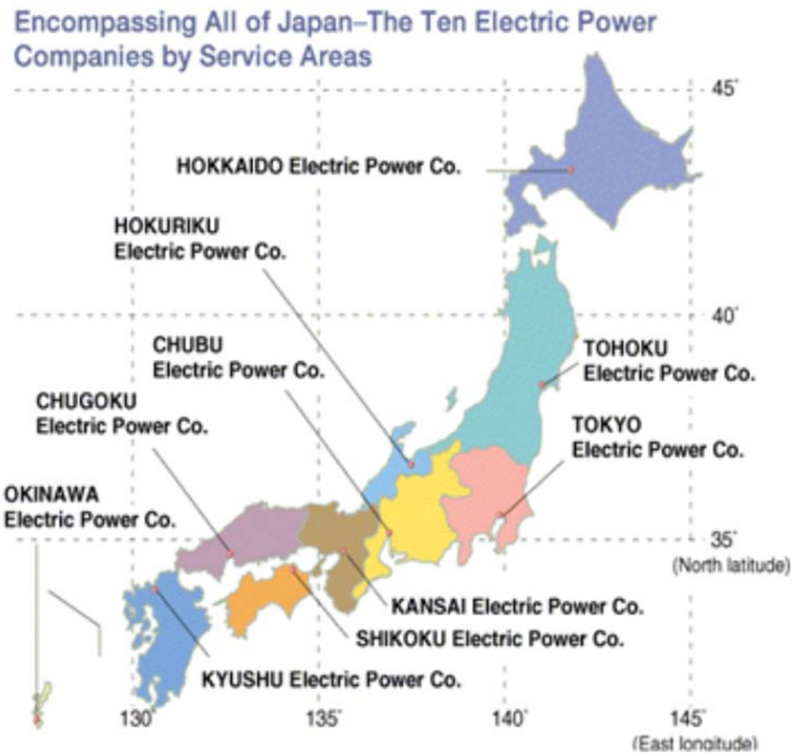


Figure 17-9 Ten General Electricity Utilities and their Service Area

Since the foundation of the companies in 1952 based on the current Electricity Business Act, they have been vertically integrated monopolies in each area. Then, partial liberalization of electricity retail market started in 2000. After that, as described in Figure 17-10, whole liberalization of electricity retail market will start in April, 2016 and general electricity utilities will be unbundled into 3 sectors – power generation sector, transmission and distribution sector and retailing sector by 2020.

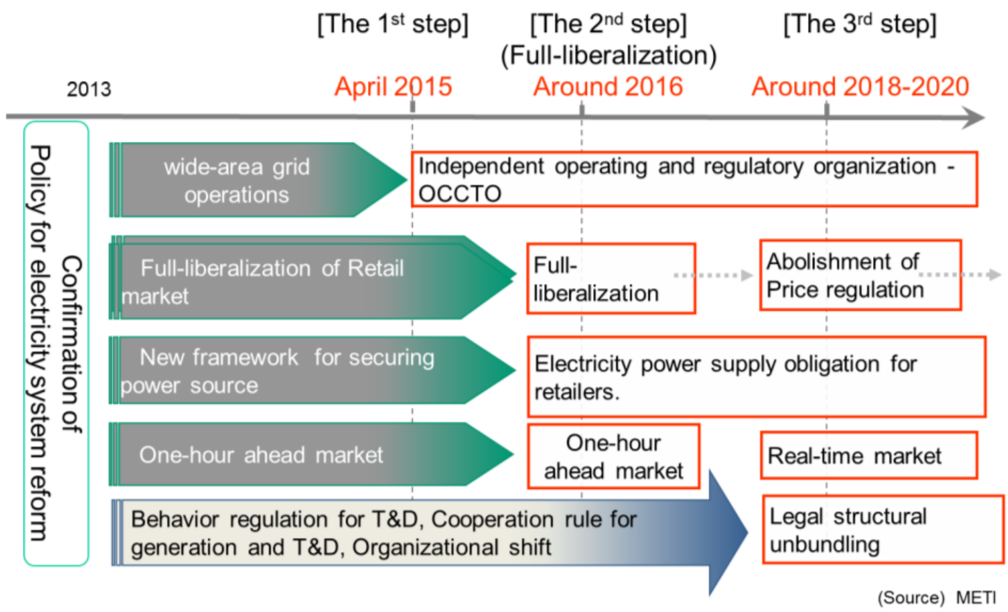


Figure 17-10 Schedule of Deregulation and Unbundling in Japanese Electricity Industry

The network operation sector will still monopolize and own the network facilities, and, like TSOs in Europe, will continuously implement the construction and O&M works.
For this reasons, the network operation sector of each area is regulated by the OCTTO Grid Code and local detailed rules, bearing each areas' circumstances fully in mind, are drawn up and opened to the public as a "self-management rules".

(2) The case of Bangladesh

As shown in Figure 17-11, legal framework in relation to supply/demand balancing and frequency control of electricity industry in Bangladesh consists of 3 stages, like in Japan.

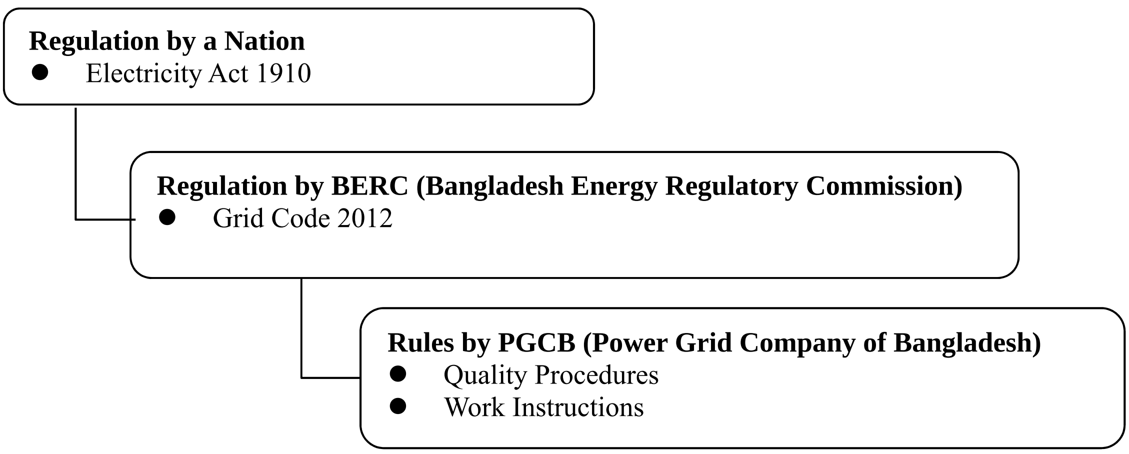


Figure 17-11 Regulatory Framework for Electricity Supply Industry in Bangladesh

17.4.2 Regulation by the Electricity Acts

Followings are the things required in legal restraints, in general:

- ✧ To secure the continuous power supply to all consumers with adequate quality
- ✧ To give authority to some entities to impose penal provisions on offenders

The Electricity Business Act in Japan has various regulatory terms on electricity supply companies (in particular, the public utilities) with the aim of sound expansion of the industry and protection of consumers.

Above all, followings are important items in relation to stable demand/supply operation and frequency control:

- ✧ Obligation to supply
- ✧ Obligation of preparing and obtaining official approval to general supply provisions and their amendments
- ✧ Obligation of endeavor to maintain voltage/frequency value
- ✧ Obligation of preparing and notifying a supply plan and its amendment
- ✧ Restriction on use of electricity
- ✧ Penal provisions

Table 17-4 describes the results of rough comparative study between provisions of Japan and Bangladesh.

For detailed comparative investigation and some proposals are drafted in Table Table 17-5.

Table 17-4 Rough Comparison of the Electricity Act between Japan and Bangladesh

Provisions	General Remarks	Electricity Business Act (Japan)			Electricity Act 1910 (Bangladesh)		
		Article	Obliges;	Penalty	Article	Obliges;	Penalty
Obligation to supply	Key rules in order to force the utilities to maintain and guarantee the following power quality: ✧ No interruptions. ✧ Proper voltage/frequency value.	18	Electricity Utilities	Imprisonment, fine, or both			
Obligation to prepare “General Supply Provisions”		19, 19-2 20, 21	Electricity Utilities	Imprisonment, fine, or both	22	Licensee	
Obligation of endeavor to maintain voltage/ frequency value		26	Electricity Utilities	Fine	(Grid Code)		
Obligation to prepare a “Supply Plan”	Key rules in order to force the utilities to promote development of power plants and to procure adequate power sources	29	Electricity Utilities	Fine			
Restrictions on Use of Electricity	Key rules in order to prevent wide area interruption as a last resort	27	Consumers	Fine	(Grid Code)		
Other related penal provisions		115 Obstructions to Business	Offenders	Imprisonment, fine	29 [30 [39 Dishonest abstraction, etc. of energy	Offenders	Imprisonment, fine
		116 Unlicensed Business	Offenders	Imprisonment, fine, or both	39A Installation of artificial means, etc.	Offenders	Imprisonment, fine
					32 [40 Maliciously wasting energy or injuring works	Offenders	Imprisonment, fine
					36 [41 Unauthorized supply of energy by non-licensees	Offenders	Imprisonment, fine
					38 [43 Illegal transmission or use of energy	Offenders	Imprisonment, fine

Table 17-5 Comparison between the Terms of Electricity Business Act in Japan and Electricity Act 1910 in Bangladesh

Provisions	General Remarks	Electricity Business Act (Japan)	Electricity Act 1910 (Bangladesh)	Considerations/Proposals
Obligation to supply **Obligation of preparing and obtaining official approval to general supply provisions and their amendments**	In order to maintain adequate power quality, it can be simply said that; ✧ There is no interruptions. ✧ Voltage/frequency value is stably constant. Purpose of these three provisions are to guarantee the above mentioned power quality.	● An Electricity Utility shall not refuse to supply electricity without justifiable grounds. ● A General Electricity Utility shall formulate general supply provisions to set rates and other supply conditions and obtain official approval of them and publicize them. ● These articles carry penalty (imprisonment, fine, or both)	Followings are the main points of provisions of "**Obligation on licensee to supply energy"**(Article 22)[49] ● Where energy is supplied by a licensee, every person within the area of supply shall, in principle, be entitled to a supply on the same terms as those on which any other person in the same area is entitled in similar circumstances to a corresponding supply. ● Provided that no person shall be entitled to continue to receive from a licensee a supply of energy unless he has agreed with the licensee to pay to him such minimum annual sum as will; ➢ give him a reasonable return on the capital expenditure ➢ cover other standing charges incurred by him ● There seems to be no penal provisions	Provisions of "obligation of supply" and "obligation of endeavor to maintain the voltage/frequency value" are one of the most fundamental terms to force an Electricity Utility to promote development of power plants or voltage control equipment and to secure adequate active/reactive power sources and reserves from a long/medium-term viewpoint. This provision in Bangladesh corresponds to "general supply provision" in Japan. Moreover, it carries no penal provisions, so, this provision seems to be a kind of exemption clause for utilities. Therefore, the provisions of "Obligation of supply" carried by penalty should be added to the Act in order to protect consumer's interests by the administrative control.
Obligation of endeavor to maintain voltage/frequency value		● An Electricity Utility shall endeavor to maintain the voltage value or frequency value of electricity at the levels, as below. ✧ Voltage : Nominal Voltage / Acceptable Range 100V / 101V±6V 200V / 202V±20V ✧ Frequency: specified value (50Hz,60Hz) ● Official order for improvements of values, with penalty (fine) ● Obligation to measure/record/preserve[50] values, with penalty (fine)	● Provisions in relation to voltage/frequency quality are stipulated not in Electricity Act 1910, but in Grid Code and relevant rules.（refer to Table 17-13） ● There seems to be no penal provisions.	
Obligation of preparing and notifying a supply plan or its amendment	Provision of "Supply Plan", together with the "obligation of supply", is another one of the most important terms to force an Electricity Utility to promote development of power plants and to secure adequate power sources and reserves from a long/medium-term viewpoint.	● An Electricity Utility shall prepare a plan on the supply of electricity[51] and the installation and operation of Electric Facilities[52]（hereinafter referred to as a "Supply Plan"）and notify the competent minister of a plan or its amendments (via OCCTO), with a penalty (fine). ● Official recommendation or order for improvements of plan, with penalty (fine).	There seems to be no provisions concerning a security of long-term adequacy of power source in Electricity Act 1910, nor is in Grid Code. There seems to be no penal provisions.	In Bangladesh, There may be no need to regulate the electricity utilities for the purpose of long/medium-term adequacy of power source, because it may be secured by policy makers and nation-level initiative. The important thing is that an appropriate decision-making process is eagerly required and legislated, in which all relevant entities can participate, such as national government, regulatory authorities, electricity utilities, power system operators, etc., in order to realize the stable power supply by legally binding regulatory control.
Restrictions on Use of Electricity	There is a risk of affecting the supply-demand balance and wide area interruption caused by the excessive consumption of electricity by a certain users.	● The competent minister may restrict the use of electricity by limiting the power usage or peak load or specifying the purpose of use or the date and time when power usage should be stopped, if no adjustment is made to the supply and demand of electricity, a shortage of electricity supply will adversely affect the national economy and standard of	Provisions in relation to load shedding are stipulated not in Electricity Act 1910, but in Grid Code and relevant rules.	This provision is applied only to the emergency condition that all countermeasures to secure the power source to meet the demand by power system operators have been exhausted. Under the condition of chronically significant deficiency of power sources in Bangladesh, this provision may be severe term for

[49] **Obligation on licensee to supply energy**
22. Where energy is supplied by a licensee, every person within the area of supply shall, except in so far as is otherwise provided by the terms and conditions of the license, be entitled, on application, to a supply on the same terms as those on which any other person in the same area is entitled in similar circumstances to a corresponding supply:
Provided that no person shall be entitled to demand, or to continue to receive, from a licensee a supply of energy for any premises having a separate supply unless he has agreed with the licensee to pay to him such minimum annual sum as will give him a reasonable return on the capital expenditure, and will cover other standing charges incurred by him in order to meet the possible maximum demand for those premises, the sum payable to be determined in case of difference or dispute by arbitration.

[50] Following items in relation to frequency shall be recorded and preserved for 3 years.
- Specified value
- Daily maximum and minimum values, Monthly accumulated deviation
- A type and number of the meter
- Name of the person who is in charge of metering

[51] Major notification items in relation to "supply of electricity":
- Yearly maximum power and energy (from 1 to 10 years ahead)
- Monthly maximum power and energy (1 year ahead)

[52] Major notification items in relation to the "installation and operation of the Electric Facilities"
- Newly construction or enhancement plans of generating stations, generation costs (which will commence to operate or construct within 10 years, and have rated capacity of 350MW or more)
- Newly construction or enhancement plans of substations or transmission facilities (which will commence to operate within 10 years)
- Generating plan (1 year ahead)
- Fuel operation plan of the thermal power plants (1 year ahead)
- Electricity marketing plans (from 1 to 10 years ahead), Documents of marketing plans (1 year ahead)
- Power system maps and power flow diagrams (1, 5 and 10 years ahead)
- others

	Therefore, in an unavoidable case, restrictions of usage even to the sound consumers are strongly required by the administrative control.	living or public interest. ● This article carries penalty (fine).		system operators because they have no choice except to conduct a load shedding even under the normal condition, according to the Grid Code or rules for work process. However, in order to prevent an unforeseeable outage, fair and transparent processes and rules of load shedding or rolling outage under the administrative control may be eagerly required.
Penal provisions		In addition to the penal provisions carried by provisions of obligation and administrative order each, there are other specific penal provisions in the Electricity Business Act. Followings are examples of penalty in relation to demand supply operation or frequency control: ● **Obstructions to Business** ✓ Obstructions to the generation, transformation, transmission or distribution of electricity; ➢ by damaging the Electric Facilities or causing interference with the functioning of Electric Facilities. ➢ by operating the Electric Facilities without due cause. ✓ These articles carry penalty (imprisonment, fine) ● **Unlicensed Business** ✓ Electricity supply under unlicensed condition. ✓ This article carries penalty (imprisonment, fine, or both)	Followings are examples of penalty in relation to demand supply operation or frequency control: ● Penalty for dishonest abstraction, etc. of energy[53] ● Penalty for installation of artificial means, etc.[54] ● Penalty for maliciously wasting energy or injuring works[55] ● Penalty for unauthorized supply of energy by non-licensees[56] ● Penalty for illegal transmission or use of energy[57]	

[53] **29[30[39.** (1) Whoever dishonestly abstracts, consumes or uses energy shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to three years and shall also be liable to a fine of ten thousand taka.

[54] **39A.** Whoever installs or uses any device, contrivance or artificial means for dishonest abstraction, consumption or use of energy of a licensee, whether he derives any benefit therefrom or not, 31[shall be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to fine which may extend to twenty thousand taka] and if it is proved that any device, contrivance or artificial means for such abstraction, consumption or use exists or has existed on a premises, it shall be presumed, unless the contrary is proved, that such person has committed an offence under this section.

[55] **32[40. (1)** Whoever maliciously causes energy to be wasted or diverted, or, with intent to cut off the supply of energy, cuts or injures, or attempts to cut or injure, any electric supply-line or works shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to five years and shall also be liable to a fine of ten thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such second or subsequent conviction be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to fine which may extend to twenty thousand taka.]

[56] **36[41. (1)** Whoever, in contravention of the provisions of section 28, engages in the business of supplying energy shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to five years and shall also be liable to fine which may extend to fifteen thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such-second or subsequent conviction, be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a daily fine of one thousand taka.]

[57] **38[43. (1)** Whoever, in contravention of the provisions of section 30, transmits or uses energy without giving the notice required thereby, shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to three years and shall also be liable to a fine of ten thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such second or subsequent conviction, be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a daily fine of one thousand taka.]

17.4.3 Regulation by independent regulatory organization

In this section, the comparative study between two Grid Codes established by the regulatory commission of both countries, BERC and OCCTO.

As shown in Figure 17-8 and Figure 17-11, there are detailed rules or work process manuals based on the Grid Code in both countries. However, these rules will be referred only when necessary, because major scope of this section is overviewing a general framework of both Grid Codes.

In this section, we performed comparative study of following provisions in relation to the supply-demand operation and frequency control:

- Long-term supply-demand operation plan
  - A) Supply plan
- Short-term supply-demand operation plan
  - A) Demand forecasting
  - B) Planned Outage Coordination of Generator/Network
  - C) Plans for Demand-supply Balance and Generation Schedule
  - D) Real-time System Operation and Frequency Quality Control
  - E) Information Publication of Power System

Table 17-6 describes an outline of items in both Grid Codes.

Table 17-6 Outline of Grid Codes in Both Countries concerning Supply-demand Operation and Frequency Control

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)
Supply Plans (Power Plants and Network Development Plan)		● Responsibility of OCCTO to collect, coordinate and study the Supply Plans from the nation-wide viewpoint.	
Demand Forecasting	**Variety of Forecasting**	● Type, contents and deadline of submit	● Type, contents and deadline of submit
	Responsibility of Forecasting	● General Electricity Utilities: Area-wide forecast ● OCCTO: Nation-wide forecast	● The Distribution Utilities: each demand and load shedding estimation. ● The Licensee: Integrated demand estimation.
	Post Facto Inspection	● Responsibility of OCCTO to perform post facto inspection of demand estimation by General Electricity Utilities.	
Planned outage coordination of generator / network	**Integration for the Draft Plans**	● Responsibility of OCCTO to integrate ”original plans” submitted by utilities into yearly and monthly “draft plan” of Generator/Transmission Outage.	● Responsibility of the Licensee to integrate into a draft Outage program based on a transmission outage planned by itself and the plans of generator/distribution utility.
	Coordination between Users and Finalization of the Plans	● Responsibility of OCCTO to re-coordinate the “draft plan” in response to the requirement from members and formulate and share the “final plan”.	● Responsibility of the Licensee to interact with all Users as necessary to review and optimize the draft plan.
	Remarkable Points to note	● Preparation of a list of operation steps prior to an actual operation. ● Operation shall be implemented based on the instructions by dispatching office. ● Work process in case of suspension, reconsidering or extension of outage.	● Restriction of removal from service without specific release from the NLDC. ● Responsibility of NLDC and Users concerned to inform the other party suspension of works together with revised estimation of restoration time.
Plans for Demand - supply Balance and Generation Schedule	**Preparation of the plan and Monitoring the balance**	● Responsibility of each Electricity Utility, Supplier and OCCTO to submit, coordinate, prepare and monitor the supply-demand plans and generation plans.	● Responsibility of the NLDC, Licensee, generators to submit, coordinate, prepare the load/generation balance schedules and generation schedules.
	Operating Reserves	● Responsibility of General Electricity Utilities to strive to secure reserves which can promptly raise their output against the deficiency of power source.	
	Spinning Reserves	● There is no description in OCTTO Grid Code.	

		Instead, the self-management rule in TEPCO has provision of CLDO's responsibility to strive to secure adequate spinning reserves.	
	Margin for lowering	● Responsibility of CLDO to secure margin for lowering the power source when frequency rises during less demand season.	
	Measures when supply demand balance get worse	● Instruction by OCCTO when supply-demand balance grows worse gradually ● Instruction by OCCTO when supply-demand balance reaches to emergency condition ● Sanctions on members who refuse to obey the instructions	● The processes of normal load control and emergency load control are stipulated in the "Load Control (Load Shedding) (WI-PSO-02)"
Real-time System Operation and Frequency Quality Control	**Frequency Control**	● There is no description of frequency target value in OCTTO Grid Code. Instead, Self-management rules of General Electricity Utilities have the values as 50Hz +/- 0.2-0.3Hz or 60Hz +/- 0.2-0.3Hz. ● Detailed operation processes under normal condition and abnormal condition are stipulated in each self-management rules in General Electricity Utilities.	● Normal state : 49.0Hz-51.0Hz ● Emergency state: Generating unit is capable of operating at full rated power output within the range of frequency: 47.5Hz-52.0Hz, voltage: +/-10% rated value and power factor: 0.8 lagging to 0.95 leading. ● Detailed operation processes of frequency control are stipulated in the "Frequency & Voltage Control (WI-PSO-01)" and "Load Control (Load Shedding) (WI-PSO-02)"
	Power Quality Analysis	● Responsibility of OCCTO and work processes to put together a report on the results of analysis for power quality in relation to frequency, voltage and interruptions based on the data provided from General Electricity Utilities.	
Information Publication		● There are provisions to publicize to several items of network information on the Web site of OCCTO and each General Electricity Utilities.	

In the following several sections, we conduct a detailed comparative study between the Grid Codes of both countries, and proposals for necessary improvement are drafted from Table 17-7 to Table 17-13.

(1) Long-term supply-demand operation plan

(a) Supply plan (power plants and network development plan)

In order to maintain supply-demand balance for an extended period, demand should be estimated properly and steady development of power plants and enhancement of network based on the estimation is crucial.
Development or enhancement of electric facilities needs appropriate duration more than several years or tens of several years for planning, engineering, procuring and construction.

Bangladesh has very high potential of economic progress and rapid growth in power demand. Therefore, it is essential thing to secure power sources in a long-sustained way.

In Japan, Electricity Utilities are obliged to prepare the "Supply Plan", as described in previous sections, and OCCTO shall collect and analyze the plans to monitor the long-term circumstances of the nation-side balance. As the results of study, OCCTO can require the utilities to revise the plans.

(2) Short-term supply-demand operation plan

(a) Demand forecasting

Demand Forecasting is one of important process to prepare the supply-demand operation plan from a long-term viewpoint of steady development of power source, and from a short term viewpoint of stable operation with an adequate power source and reserves.

In Japan, official demand forecast is implemented by following 3 entities:

- OCCTO — Nation-wide forecast
- TDS of the General Electricity Utilities — Area-wide forecast
- Electricity retailing companies — Each company's own forecast

The area-wide forecast is the most important values because the TDS in General Electricity Utilities is legally responsible for maintaining the supply-demand balance in their own service area. For this reason, OCCTO Grid Code has several provisions regarding common method of area-wide demand estimation. OCCTO Grid Code also has terms of study, revision and post facto evaluation process of these estimation in comparison with the nation-wide demand estimated by itself.

In case of Bangladeshi Grid Code, there are some simple provisions of Licensee's obligation. According to the Grid Code, demand forecasting from 2-year ahead to day ahead estimation shall be implemented by Licensee. Unfortunately, Participation of NLDC in the process of estimation seems not to be clear.

(b) Planned outage coordination of generator/network

As of preparation for the supply-demand operation plan, it is essential process to implement fair and transparent coordination between generation outage plans or network outage plans which affect the generating operation (their necessity, season, duration, and so on) from the following points of view:

- Interests of network owners or operators: To maintain the healthiness of network facilities by certain implementation of periodical maintenance, on the premise of securing adequate power source (including reserves).
- Interests of generators: In addition to get approval of the necessary maintenance outage plans, to coordinate with network outages and adjust the outage time and duration in order not to affect the generation plans.

(c) Plans for demand-supply balance and generation schedule

Short term demand-supply balance plans and generation plans shall be reviewed at every occasion of preparing yearly, monthly, weekly, day-ahead, the day plan incorporated with revised demand forecast, generation plans and outage plans.
In the Grid Code, it is important to stipulate the provisions to monitor and regulate from the viewpoint of adequacy of power source including reserves to meet the forecasted demand.

OCCTO Grid Code has not only several above-mentioned provisions, but also terms giving OCCTO authority to instruct electricity utilities to exchange power to solve partial power shortage.

In Bangladesh, the provisions of preparing process are appropriately stipulated in Grid Code and Quality Procedures / Work Instructions (PGCB). However, there seems to be no provisions of securing reserves and measures for power source deficiency.

(d) Real-time system operation and frequency quality control

In Japan, OCCTO Grid Code stipulates several provisions of fundamental framework and self-management rules of each TDS in General Electricity Utilities stipulates rules of specific values and detailed processes because there are some special necessities of each service area.

In Bangladesh, Grid Code has almost the same framework as Japan, and it sufficiently stipulates necessary items, these processes and responsible entities.

Unfortunately, there are some provisions seem to be not as efficacious as they are expected to be, based on the results of investigations at site.

(e) Information Publication of Power System

Publication of power system information has a risk of threatening the system security. However, under the liberalized and unbundled structure, it is necessary actions to disclose information to users of network.
In Japan, as shown in Table 17-13, wide-ranging of power system information is publicized for fair and transparent business process. In Bangladesh, there seems to be no rule in BERC Grid Code.

When visiting the power stations in Bangladesh, there are some comments such as:
“At present, there are only one-sided instructions from NLDC regarding increase/decrease of output.”
“We would like to know information of overall supply-demand balance to cooperate with NLDC”

Contents of system information in Japan is still said to be insufficient, but information publication is important actions for users, in particular, generators to make estimation of profitability, fair and transparent transactions of energy, reserves and ancillary services at the electricity market.

17.4.4 Summary

In general, amendment of relevant Acts is urgently required regarding several kinds of obligation rule, their penal provisions, etc., in order to maintain and improve the power quality by administrative control.

Grid Code and work process rules in Bangladesh, on the other hand, seems to be still rougher than those in Japan, but have mostly necessary and minimum provisions which clearly mention the must-have terms and their responsibilities.

But, unfortunately, these provisions seem to be not as efficacious as they were expected to be because they are not correspond to the actual conditions found out in some field surveys. For these reasons, it is indispensable to tighten the regulation by means of social sanctions such as post facto investigations or deprivation of licenses against offenders. It is also eagerly desirable to get necessary legal steps to accuse offenders of civil or criminal responsibility.

The Grid Code should be amended so that the NLDC has fitting authorities and independence for their important responsibility for maintaining and improving the power quality. PGCB, BPDB and BERC should devote themselves to providing backup support.

Interviews with staff in NLDC reveals the following issues, which can be fully appreciated:

- BPDB deals with all processes from generation planning through implementing plans to O&M, NLDC cannot take part in these processes.
- There is no obligation/responsibility and penal rule to the generators to provide reserves for FGMO / LFC.
- Grid Code 2012 has already come into operation, but is still no effectiveness.
- Establishment of the ancillary services in relation to the frequency control is eagerly desirable in Code 2012.

Table 17-7 Grid Code concerning the Demand Forecast / Demand Estimation

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
Supply Plans (Power Plants and Network Development Plan)		● OCCTO shall request all members their 10 year-ahead plans of power plants and network development in order to integrate, coordinate and study them from the nation-wide viewpoint, and then, submit to the competent minister and publicize them. ● OCCTO shall investigate whether the plans are adaptable to the "Detailed Rules of Network Operations (OCCTO)"and "Guidelines on Demand Forecast (OCCTO)". If necessary, according to the results of this study, OCCTO coordinates them or requests members a revision of them. For the coordination, following points are taken into consideration: ✧ Trends of actual demand ✧ Past records of demand estimation in the plans ✧ Guidelines and description requirements set by a nation separately ✧ The level of reserves ✧ Any factor that significantly affects the supply-demand balance ✧ Others ● OCCTO shall investigate the following points, based on the "Detailed Rules of Network Operations" or business experiences: ✧ Appropriateness of the plans ✧ Adequacy of power source to meet the estimated demand.	There seems to be no provisions concerning this category.	In Bangladesh, where is expected to be under the high potential of economic growth and remarkable demand rise, development of large-scale power plants and enhancement of the network need to be forwarded in cooperation with national policy, including the issue Whether the NLDC or PGCB should shoulder the consistent responsibility throughout the plans to actual operation. Therefore, it is not the matter of being stipulated in Grid Code, but being clarified within the policy-making process in relation to overall electricity industry.
Demand Forecasting	**Variety of Forecasting**	● For long term: From 3 to 10 year-ahead Max. kW and kWh each year ● For short term: Refer to Table 17-9.	● The year ahead: Monthly peak/off peak period demand ● The month ahead: Daily peak/off peak period demand ● The day ahead: Hourly demand	
	Entity and Process of Forecasting	**Area-wide demand estimation** ● General Electricity Utilities shall forecast the electricity demand based on the "Guidelines on Demand Forecast"[58], economy forecast, the latest trend of demand, past records of actual demand, specific matters, and so on. **Nation-wide demand estimation** ● OCCTO shall prepare a "Reasonable Level of Nation-wide Electricity Demand" in order to perform an appropriate estimation. As the preparation, the results of studies, regression analysis among population, economic indicator and actual demand will be taken into account. ● OCCTO shall study appropriateness of area-wide demand forecast compared with the "Level", adaptivity to the "Detailed Rules of Network Operation" and "Guideline on Demand Forecast", and then, if necessary, require revision of the estimation to General Electricity Utilities. ● OCCTO shall publicize the demand forecast of nation-wide and area-wide by the end of January, each year.	● The **Licensee**[59] shall make demand estimation for every division described above, based on the demand estimation[60] and load-shedding estimation by **Distribution Utilities**. According to the "Procedure for Power System Operation & Control (QP-PSO-1)" ● DMLDC makes daily demand planning on the basis of the following: ➢ Season & weather condition ➢ Previous days tears demand conditions ➢ Working day or holiday ➢ Existence of any emergency/priority situation, etc.	According to the Grid Code 2012 in Bangladesh, Licensee and NLDC shall separately estimate the demand from 2-year ahead to the day ahead, and the day respectively. For seamless planning, it is important to make enormous efforts to cooperation with each other, though both entities are members of Operating Committee. Survey team heard in the field survey that there is a reorganization plan of NLDC into Independent System Operator (ISO). Bangladesh should take an opportunity to centralization of responsibility and authority in the new organization.
	Post Facto Inspection	● General Electricity Utilities shall submit the following information to OCTTO. ✧ Actual demand for 10 years (Max. kW and kWh) ✧ Influence of temperature on the actual demand. ✧ The results of self comparative study between estimated and actual demand[61] ● OCCTO shall study the following points based on the business experiences: ✧ Difference between estimated and actual area-wide demand, causes and trend. ✧ Appropriateness of concept and process of self studies performed by General Electricity Utilities.		In general, it is difficult to accurately estimate electricity demand because it is influenced by various factors such as temperature, humidity, social activities, or others. So, establishment of continuous improvement cycle, so called PDCA cycle, is an effective measures. In this cycle, participation of a disinterested party such as BERC may be essential requirement.
Planned outage coordination	**Integration for the Draft Plans**	OCCTO shall prepare the "draft plan" of Generator/Transmission Outage by integrating the "original plans" submitted by TDS in General Electricity Utilities. **Varieties of the plan** (For preparation schedule, refer to Table 17-8)	All **Generators** and all **Distribution Utilities** shall provide their proposed Outage programs according to the following manner: ● 2 year ahead, and year ahead (July to June)	

[58] OCCTO prepares "Guideline on Demand Forecast" so that the estimation works well and smooth. This guideline includes following contents:
- Fundamentals for demand forecasting (Duration, Responsible entities, etc.)
- Correcting method based on the temperature, an intercalary year, and so on.
- Estimation method of area-wide demand (short term, long term)
- Estimation method of each electricity supplier. (short term, long term)

[59] In Grid Code 2012, "Licensee" is defined as "The holder of the Transmission License for the bulk transmission of electricity between Generators and Distributors"

[60] **Distribution Utilities** shall provide to the **Licensee** their estimation of each inter-connection point on a 2 year ahead, year ahead, month ahead, week ahead and day ahead.

[61] In comparative studying, factors which can influence on the electricity demand, such as temperature, population, economic trend and others, should be taken into account.

of generator / network		✧ Yearly plan (1 & 2 years ahead) ✧ Monthly plan (1 & 2 months ahead) **Plans to be coordinated** ● Outage plans for following network facilities and Generators connected to them. ✧ Inter-area lines ✧ Transmission lines, Bus-bars operated at the highest and the second highest voltage in each area, and transformers connected to them. ✧ Network facilities whose outages can affect the ATC of the inter-area lines. ● Outage plans for remaining facilities are prepared and coordinated within the general electricity utilities and members who have interests. **Items to be considered when coordinate scheduled outages** ✧ Public and personnel safety ✧ Electric facilities' preservation ✧ Power system security, reliability ✧ Adequacy of reserves ✧ Degree of influence on major electricity consumers' operation plans ✧ Avoidance of unplanned restraint of generating operation ✧ Rationality of outage schedule ✧ Others	● Generators' program: to Licensee and NLDC by 31st March each year ● Distribution Utilities' program: to Licensee by 31st March each year The **Licensee** shall a draft Outage program based on a yearly transmission Outage program produced by itself and the information received from **Generators** and **Distribution Utilities**, taking into account of demand estimation. The Licensee, the NLDC and the Generators shall establish Operating Committees, and establish the procedures relating to the operational inter faces between parties. They shall include Outage coordination, generation scheduling, and so on.	
	Coordination between Users and Finalization of the Plans	● Any member who comes under the followings can ask for re-coordination of the draft plans: ✧ Members whose utilization plan of inter-area lines may be affected. ✧ Members whose generating plan may be affected. ➢ OCCTO shall re-coordinate the "draft plan" and formulate and share the "final plan".	The Licensee shall interact with all Users as necessary to review and optimize the draft plan, and then release the finally agreed transmission outage plan to all Users by 31st May each year. The Licensee shall review plan monthly, and Users' requests for additional outages will be considered and accommodated to the extent possible.	
	Process of Outages	● TDS in General Electricity Utilities and on-site engineers shall cooperate with each other to prepare a list of operation steps prior to an actual operation in order to prevent an unexpected accident and interruption. ● An actual operation shall be implemented based on the instruction from shift engineers of load dispatching office. ● Both parties shall confirm the starting and finishing time of outages. ● In case of suspension, reconsidering or extension of outage, both parties shall confirm all the facts and reasons for these changes.	Notwithstanding provision in any approved Outage plan, no cross boundary circuits or Generating Unit of a Generator shall be removed from service without specific release from the NLDC. Once an Outage has commenced, if any delay in restoration is apprehended, the NLDC or Users concerned shall inform the other party promptly together with revised estimation of restoration time.	This provision seems not to be as efficacious as it is expected to be because it is not correspond to the actual conditions – the survey team heard that many generators are not operated conforming to the instructions issued by NLDC. For these reasons, It is indispensable to tighten the regulation by NLDC.
Plans for Demand - supply Balance and Generation Schedule	**Preparation of the plan and Monitoring the balance**	● Each Electricity Utility and Supplier shall submit the supply-demand plan (Table 17-9), generation plan (Table 17-10) or its amendment to TDS in General Electricity Utility. ● Each General Electricity Utility shall integrate the supply-demand plan in its service area, and submit it to OCCTO. ● OCCTO shall supervise the following items: ✧ Supply (including reserves) and demand balance of each Utility ✧ Supply (including reserves) and demand balance of each area ✧ Supply (including reserves) and demand balance of the whole of Japan	**Load/generation Balance Schedule** ● The NLDC and the Licensee shall coordinate and prepare load/generation balance schedules and generation schedules, and shall provide them to the Licensee and Generators according to the schedules shown in Table 17-12. **Generation Schedules** ➢ All Generators shall provide the MW/MVAR declared availability capacity (0:00-24:00 hours) of all Generating Units, to the NLDC during each hour of the day commencing 36 hours ahead and provisionally, for the day immediately after (plant availability notification) by 12:00 hours. ➢ Hydro Power Stations shall take into account their respective reservoir levels and any other restrictions and shall report the same to the NLDC. ✧ The NLDC shall produce a day ahead hourly generation schedule after consolidation of the data provided by Generators. It shall consist of Availability, Scheduled generation, Allocated spinning reserve and Generating Unit Standby requirements	This provision also seems not to be as efficacious as it is expected to be. For these reasons, It is necessary to give an authority to NLDC (PGCB) and BERC to take the initiative in procurement of reserves.
	Operating Reserves	● TDS in General Electricity Utilities shall strive to secure reserves which can promptly raise their output against the deficiency of power source caused by troubles of electric facilities, estimation errors of demand or total generation output. ● Reasonable level of operating reserves is under consideration. ● According to the self-management rules of TDS in TEPCO: ➢ CLDO shall strive to secure operating reserves more than 5% of maximum demand forecast of the day with taking following items into account: ✧ Error of maximum demand forecast caused by error of temperature ✧ Trouble of generator ✧ Congestion of generation caused by trouble of network ➢ Operating reserves shall be secured by the following measures: ✧ Hydro and thermal power in partial load ✧ Hydro power in stand-by mode ✧ Emergency Gas Turbine Generators		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.

	Spinning Reserves	● According to the self-management rules of TDS in TEPCO: ➢ CLDO shall strive to secure spinning reserves more than 3% of maximum demand forecast of the day against sudden change of load or shut off generators ➢ Spinning reserves shall be secured by the following measures: ✧ FGMO of generators ✧ Emergency power injection from HVDC or FC. ✧ Switching off the pump up operation of the pump-storage hydro power		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.
	Margin for lowering	● CLDO shall secure margin for lowering the power source when frequency rises during less demand season. ● Reasonable level of the margin is under consideration.		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.
	Measures when supply demand balance get worse	**Instruction by OCCTO when supply-demand balance grows worse gradually** ● OCCTO can instruct members to exchange surplus power or to lease network facilities. **Instruction by OCCTO when supply-demand balance reaches to emergency condition** ● Heavy load case: suspension of planned outage, start of stand-by generators, output increase of in-service generators, restriction of electricity use based on the contracts ● Light load case: export to the area where has adequate lowering margin **Sanctions on members who refuse to obey the instructions** ➢ Notification to the competent minister	**According to the "Load Control (Load Shedding) (WI-PSO-02)"** ● The whole country is divided into 9 distribution zones --DESA, Chittagong, Comilla, Sylhet, Mymensing, Khulna, Barisal, Rajhsahi, Rangpur ● Load control will be imposed in proportionate to the demand of the respective zones as per load control chart. **Normal Load Control** ➢ Load dispatching control room will send the massage of load allocation (together with amount, duration and cause) to the respective zone over carrier telephone. ➢ The despatcher closely monitor whether the load control is implemented properly or not with the help of telemetering/SCADA system. ➢ If any zone do not carry out the given load control plan properly, the despatcher will implement forced load control by switching off 33kV feeders, after give alert to the zone. **Emergency Load Control** ➢ The direct actions of switching off 33kV feeders by despatcher will be prioritized. Refer to "**Operation in a frequency drop**", described below.	In Bangladesh, load Shedding is performed not only in the emergency operation, but in the normal operation, frequently. In Japan, OCCTO Grid Code and Self-management rules of TDS stipulates that load shedding is performed only when the power source deficiency condition has gone beyond operator's control. Principle that the load shedding scheme is the last resort should be specified in the Grid Code, so that electricity utilities urged to make efforts to procure sufficient reserves.
Real-time System Operation and Frequency Quality Control	**Frequency Control**	● There is no description of frequency target value in OCTTO Grid Code. Instead, Self-management rules of General Electricity Utilities have the values as 50Hz +/- 0.2-0.3Hz or 60Hz +/- 0.2-0.3Hz. ● Reasonable level of LFC or FGMO capacity is under consideration. ● In case of significant frequency deviation due to sudden trip of electric facilities or change of demand, following measures shall be taken, in addition to LFC and FGMO: ✧ Emergency trip or rapid output control of generation/pump up ✧ Emergency power exchange through the inter-area lines ✧ Load control or shedding as a last resort ✧ Disconnection of inter-area lines to prevent nation-wide blackout.	**Responsibility** ● NLDC shall monitor actual load and generation balance and regulate generation and demand to maintain frequency. ● Generators shall follow the dispatch instructions issued by NLDC. ● All Generating Units shall have the governor available and in service and must be capable of automatic increase of decrease in output within the normal declared frequency and within their respective capability limit. **Acceptable frequency range** ● Normal state : 49.0Hz-51.0Hz ● Emergency state: Generating unit is capable of operating at full rated power output within the range of Frequency: 47.5Hz-52.0Hz, Voltage: +/-10% rated value, Power factor: 0.8 lagging to 0.95 leading	Effectiveness of this provision in Grid Code 2012 is crucial for future improvement of power quality.
	Frequency Control (Detailed)	**According to the self-management rules in TEPCO** **Control under the normal condition** ● CLDO shall adjust the supply-demand balance in each service area by means of output control instruction to the generators in response to the change of demand. ● CLDO shall secure the reserves for LFC amount to 1-2% of total demand. ● Acceptable range: 50.0±0.2Hz Acceptable time-lag : ±15 sec. ● All generators shall obey the instructions issued from CLDO, and inform any change of circumstances they cannot obey the instructions without delay. ● All generating units which can serve the output control or LFC operation shall be operated under FGMO, in general. **Control under the abnormal condition** In case of significant frequency deviation due to sudden trip of electric facilities or change of demand, following measures shall be taken: ● CLDO shall issue an instruction of manual trip or output change to the most effective generating unit to restore the frequency quality, such as the unit which is rapidly adjustable or has wide margins. ● CLDO can issue the load control/shedding instructions only when control by the generating units cannot meet the required amount for restoration from	**Generation Despatch** ● All Generators shall comply with a dispatch instruction issued by NLDC. ● In absence of any dispatch instructions by the NLDC, Generators shall generate according to the day ahead generation schedule. ● Despatch instruction feedback from Generators shall be issued by telephone or computer to computer communication. ● The generator shall promptly inform the NLDC in the event of any unforeseen difficulties in carrying out an instruction. ● Generators shall inform the NLDC of any change of AVR and/or governor control mode of service with reasons. ● Generators shall not de-synchronize Generating Units without instruction from the NLDC except on the grounds of safety to plant or personnel. ● Generators shall report any abnormal voltage and frequency related operation of Generating Units promptly to the NLDC. **According to the results of site investigation works, "Frequency & Voltage Control (WI-PSO-01)" and "Load Control (Load Shedding) (WI-PSO-02)"** **Operation in a frequency drop (Supply < Demand)** ● In the situation of load shedding, each generator output is operated at available capacity and not in FGMO (in load-limit mode instead). ● Demand-supply balancing control is performed by load shedding. To be concrete,	It is indispensable to tighten the regulation by means of social sanctions such as post facto investigations or deprivation of licenses against offenders or uncooperative entities. It is also eagerly desirable to get necessary legal steps to accuse offenders of civil or criminal responsibility. In Bangladesh, load Shedding is performed not only in the emergency operation, but in the normal operation, frequently. In Japan, OCCTO Grid Code and Self-management rules of TDS stipulates that load shedding is performed only when the power source deficiency condition has gone beyond operator's control.

		under-frequency condition. ● CLDO shall disconnect the inter-area lines to prevent the cascading blackout. **Abnormal under frequency condition** ➢ CLDO shall endeavor to rapidly restore the frequency to 48.5Hz or above, by generation or load control. **Abnormal over frequency condition** ➢ CLDO shall endeavor to rapidly restore the frequency to 50.5Hz or below, by generation or load control.	NLDC allocates a cap of available power to each of the 9 ALDC (Area Load Dispatching Center). And then the ALDC shuts off the 33kV distribution lines so that the power demand in the ALDC = allocated available power. ● In the case of a sudden decrease of frequency due to the unplanned outage of a generator, inadequate load shedding, and so on, automatic switching control by SCADA system is performed. (Controllable capacity is 547 ccts of distribution lines; maximum demand of 6,837MW in whole power system) ● In the case of further frequency decrease, despite the SCADA control, load shedding by UFR (Under Frequency Relay) is performed in the range of 48.90Hz to 49.50Hz. UFR can shed a maximum of 2,000MW loads. **Operation in a frequency rise (Supply > Demand)** ● Operated in following manner and order: ① Re-charging of shed distribution lines ② Instruction for power output decrease	Principle that the load shedding scheme is the last resort should be specified in the Grid Code, so that electricity utilities urged to make efforts to procure sufficient reserves.
	Power Quality Analysis	● OCCTO shall put together a report on the results of analysis for power quality in relation to frequency, voltage and interruptions based on the data provided from General Electricity Utilities. ● All General Electricity Utilities shall submit, every year, the actual data of a duration time ratio per year that the frequency deviation was controlled within 0.1Hz, 0.2Hz, 0.3Hz and more than 0.3Hz, to OCCTO.		Framework of continuous monitoring, analysis and evaluation of frequency quality should be stipulated in Grid Code 2012.

Table 17-8 Submission of Outage Plans to General Utilities (Japan)

	Annual plan (1 & 2 years ahead)	Monthly plan (1 & 2 month ahead)	Revision Unplanned Outage
Original	The end of October, each year	1st, each month	Any time (without delay)
Draft	The end of December, each year	10th, each month	
Final	Mid-February, each year	The middle of each month	

Table 17-9 Submission of Supply-demand Plans by Each Utility (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	The end of October every year	The 1st day of every month	Every Tuesday	Every noon	Any time
Forecasted demand	Max./Min. power (kW) by weekday/holiday of each month	Max./Min. power (kW) by weekday/holiday of each week	Max./Min. power (kW) and time every day	Energy (kWh) every 30 min.	Energy (kWh) every 30 min.
Supply for demand	Total planned value of supply power (procured/unprocured)				

Table 17-10 Submission of Generation Schedule by Eeach Supplier (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	The end of October every year	The 1st day of every month	Every Tuesday	Every noon	Any time
Schedule by power stations	Max./Min. power (kW) by weekday/holiday of each month	Max./Min. power (kW) by weekday/holiday of each week	Max./Min. power (kW) and time every day	Energy (kWh) every 30 min.	Energy (kWh) every 30 min.

Table 17-11 Integration of Supply-demand Plans (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	25th March every year	25th every month	Every Thursday	17:30 every day	Any time
Demand of service area	Maximum demand of each month	Maximum demand of each week	Maximum demand every day	Max./Min. power (kW) and time of the next day	Max./Min. power (kW) and time of the day
Supply for demand	Total value of supply power				

Table 17-12 Generation Scheduling by Licensee (Bangladesh)

	Annual plan (year ahead)	Quarterly plan (quarter ahead, remaining quarter of current year)	Monthly plan (following 2 months)	Weekly plan (week ahead)	Day ahead schedule
Deadline	Not less than 90 days before the beginning of each calendar year	Not less than 60 days before the beginning of each quarter	Not less than 14 days before the beginning of each month	Not less than 48 hours before the beginning of each week	Not less than 7 hours before the beginning of each day
Items	Monthly basis	Weekly basis	Daily basis	Hourly basis	Hourly basis

Table 17-13 Details of Information Publication Rules in OCCTO Grid Code

On the Web site of OCCTO	On the Web site of General Electricity Utility
(a) Information for system interconnection ・ Simplified diagram of transmission system drawn on a map showing restriction in system interconnection of generation facilities (154kV or over) ・ Plans for the construction of network system	(a) Information for system interconnection ・ Simplified diagram of transmission system drawn on a map showing restriction in system interconnection of generation facilities (154kV or over) ・ Plans for the construction of network system
(b) Nationwide demand forecasting ・Nationwide demand power Maximum demand power in each month of 1 and 2 years ahead Maximum demand power in the following month Maximum/minimum demand power and forecasted time in the following day ・Nationwide supply power Maximum supply power in each month of 1 and 2 year ahead Maximum supply power in the following month Maximum supply power in the following day	(b) Area-wide demand forecasting ・Area-wide demand power Maximum demand power and forecasting time in the following month Maximum demand power and forecasted time in the following day ・Area-wide power supply Maximum supply power in the following day Maximum supply power in the day
(c) Actual demand power ・Total amount of nationwide; present demand power actual demand curve of the day and previous day ・Total amount of nationwide and area-wide; actual maximum demand power of the day generation time of the day	(c) Actual demand power ・Total amount of area-wide; present demand power actual demand curve of the day and previous day actual maximum demand power of the day generation time of the day
(d) Output limitation of RES ・Area where output limitation occurred ・Date and time when output limitation occurred ・Total amount of output limitation ・Causes	(d) Output limitation of RES ・Date and time when output limitation occurred ・Total amount of output limitation ・Causes
(e) OCCTO Grid Code ・Rules of Services ・Detailed Rules of Network Operations ・Guidelines on Demand Forecast	(e) Rules of TDS ・Rules of information publication ・Rules of system development ・Rules of interconnection ・Rules of power system operation

17.5 Proposal for Frequency Quality Improvement Roadmap

17.5.1 Future electricity demand and power source in Bangladesh

A relationship between future electricity demand and power source in Bangladesh is shown in Figure 17-12.

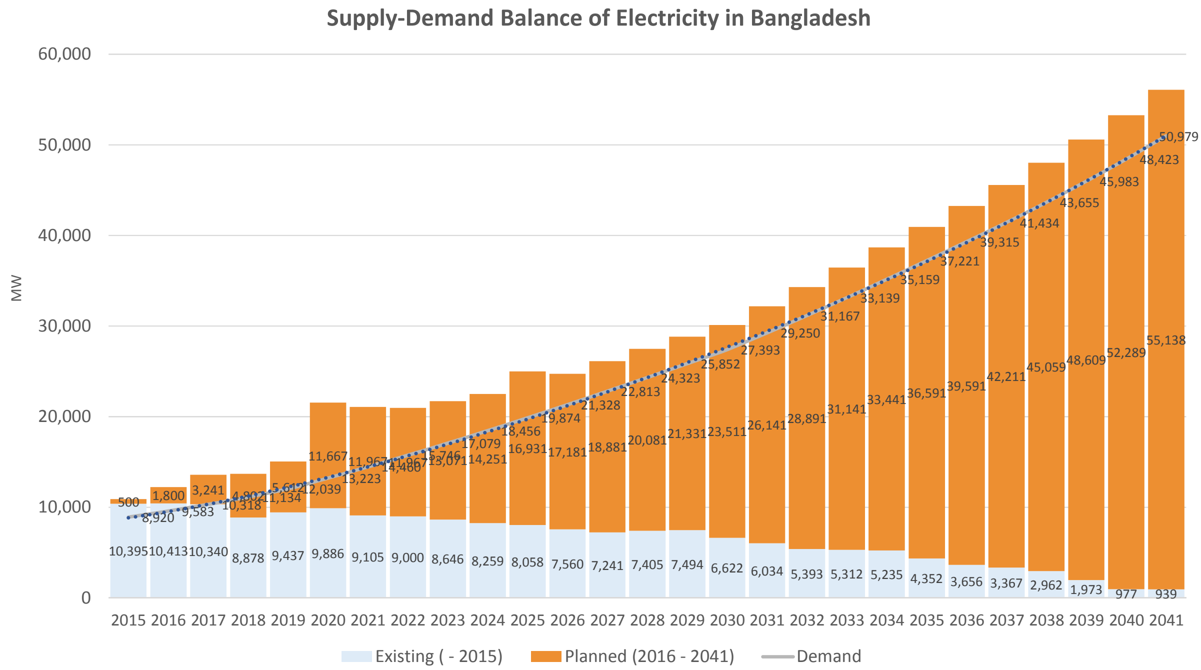


Figure 17-12 Prospect of Demand and Supply Balance to 2041 (PSMP2015)

Future demand is assumed that it will increase at a rate of about 5 to 10% per year. Supply for increase of demand is planned to be secured by the increase in imports due to the new construction and expansion of coal-fired and gas-fired, nuclear power, international tie-line of high-voltage direct current (HVDC).

In the range of this Master Plan existing generators (pale blue colored) are expected to continue as part of supply. However these cannot be expected as a stable supply and primary reserve because machine trouble or output reduction due to aging and lack of maintenance has frequently occurred.

Fortunately, these existing units are gradually abolished or replaced by new units. Moreover, along with the strong economic development, generators which are planned to be newly constructed and expanded after 2015 (orange colored) are expected to occupy an overwhelming share. Therefore, following matters should be taken into account:

- To establish the system of the periodical maintenance, so that these generators can stably output up to the rated capacity throughout their life.
- To consider the free-governor mode operation (FGMO) and load frequency control (LFC) at the design stage, so that the frequency control function is appropriately provided from the commencement of operation.

17.5.2 Reserves for power frequency control

(1) Trial calculation of availability for reserves

(a) Availability from newly constructed generation units (commissioned after 2015)

Figure 17-13 shows a detail of planned power source after 2014, which is classified by types, fuels and power producers in the case of gas-fired type. Power source in the future highly depends on the coal-fired and gas-fired (Producers have not undecided, yet). Power import from neighboring countries and nuclear power planned in 2024 and 2025 also occupy more than a few amount of power source.
In addition, there is a development plan of hydroelectric power in Meghalaya, India after 2030 (pumped-storage hydro power is highly recommended), which is, as one of ideas, directly interconnected to the power system in Bangladesh through AC transmission line. Although its proportion is small, the flexibility of demand-supply control is expected to be increased.

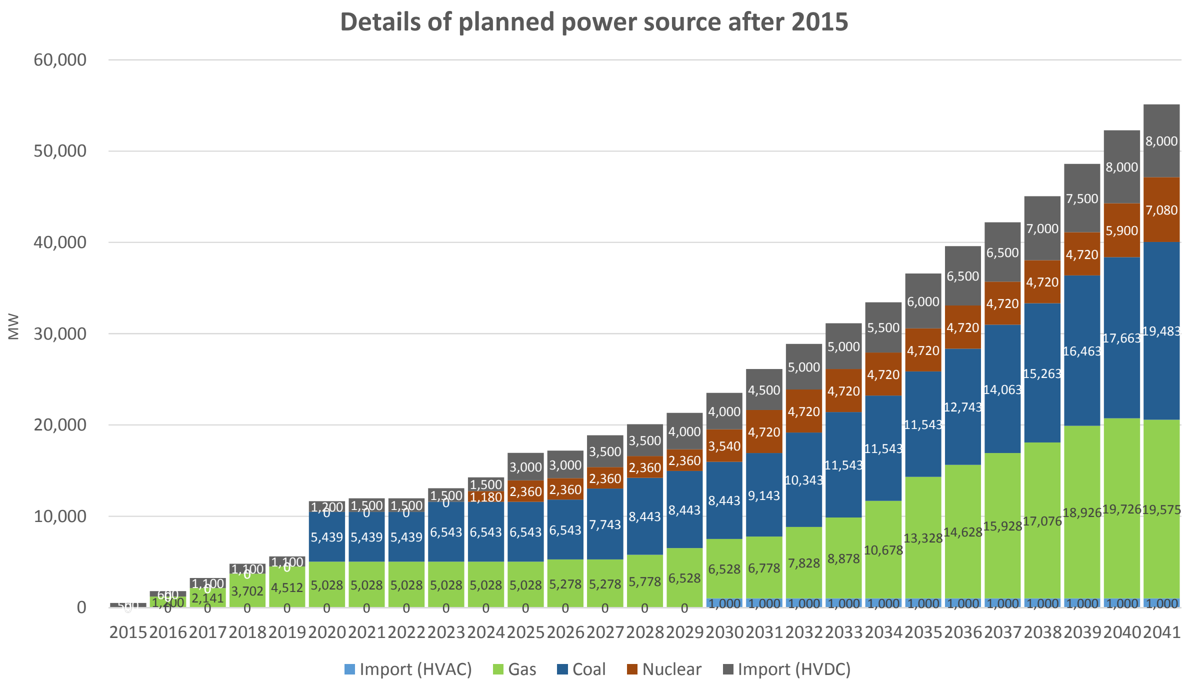


Figure 17-13 Detail of Planned Power Source after 2015

All of newly constructed power sources should ideally provide reserves. In fact, there are the following problems and risks:

HVDC international tie-line — From a technical point of view, it is possible to equip the LFC function at normal and emergency conditions such as Hokkaido-Honshu HVDC Link in Japan. Actually, the international agreements and the establishment of fair and transparent rules are strictly required because this function affects the power frequency quality of another country.

Nuclear power generation — From a technical point of view, while FGMO and LFC (AGC: Automatic Generation Control) can be applied to nuclear power plants, a political decision-making process may be strictly required to go through. In Japan, in order to give priority to the stable operation of the plant, power system operators are restricted to issue instructions of FGMO and LFC, to say nothing of output change.

Coal-fired generation — In Japan, generation cost of coal-fired is low because of low fuel cost (variable cost). Therefore, from the point of view of the most economic dispatch and the merit order, it is expected as well as nuclear power as a base load capacity (24 hours full operation). In order to recover the equipment cost of regulation function (fixed cost) and ancillary service cost (variable cost), such as FGMO and LFC, the development of framework for cost recovery (including the market mechanism).

According to the interviews with PGCB, BPDB and NLDC, they have a plan to impose an obligation to provide reserves on 50% of coal-fired generators, while HVDC tie-lines and nuclear power plants are not expected to provide reserves. Besides, all providable generators are required to provide 10% - 15% of rated capacity as the reserves, each. Therefore, we performed the trial calculation on the condition that each of available newly constructed hydro, oil-fired, gas-fired and a half of coal-fired generators should provide a 10% - 15% power of rated capacity as the reserves (in units of 1%). [62]

(b) An efforts of existing generation units (commissioned before 2014)

In November 2015, the first discussion meeting between power producers and BPDB was held in Ministry of Power Energy and Mineral Resources (MOPEMR), concerning the expansion of contribution for frequency control of existing generator. In order to rapidly improve the power quality, the following content has been discussed and agreed:

- In order to secure at least 300MW of primary reserve, there is an urgent need to carry out the FGMO at least by 8-10 power plant, and to secure 300MW of primary reserves.
- Thus, the generation units listed in Table 17-14 are agreed to carry out FGMO around January 2016.

As described in section 17.5.1 , although we have some concerns about the existing generating units as the qualified providers of primary reserves, above all, the power plants in Table.16-14 can be expected to provide the primary reserve.
However, it is difficult to expect the long-term primary reserve, because the exisiting generating units are gradually abolished or replaced by new units. Therefore they are not incorporated into the primary reserve.

Table 17-14 The List of Existing Units Which are Expected to Perform FGMO from January 2016

SL. No	Name & Capacity	Owner
1	Sikalbaha 1x150 MW	BPDB
2	Sylhet 1x150 MW	BPDB
3	Baghabari 100 MW	BPDB
4	Baghabari 71 MW	BPDB
5	Kaptai 4&5	BPDB
6	Shahajibazar 8&9 (2x35 MW)	BPDB
7	Siddhirganj 2x120 MW	EGCB
8	RPCL (Steam 75 MW)	RPCL
9	Sirajganj 225 MW (150+75 MW)	NWPGCL
10	Khulna 1x150 MW	NWPGCL
11	Summit Bibiyana-2 (1x222 MW)	Summit Power
12	Summit Meghnaghat (2x110 GT+1x110 ST MW)	Summit Power

[62] The upper and lower limits of LFC control is generally set as follows in TEPCO. Therefore to determine whether it is possible to require supplying 10% to 15% of rated output, it is necessary to undergo a careful process.

- Thermal power generator : The upper/lower limits are ±5% of output instruction (base output)
- Hydro power generator : The difference between current output and the upper/lower limits of machine output
- Nuclear power generator : No settings.

Incidentally, we were separately provided the list of existing units which currently obey the output adjustment instructions from NLDC by phone, as shown in Table 17-15.
Although they are mostly overlapped with the lineup of Table 17-14, yellow-colored units are out of FGMO test operation. They are urgently required to implement maintenance to be able to contribute as the number of reserve expansion.

Table 17-15 The List of Existing Units Which Obey Instructions of Output Adjustment from NLDC

SL. No	Name & Capacity	Owner
1	Sikalbaha 1x150 MW	BPDB
2	Sylhet 1x150 MW	BPDB
3	Baghabari 100 MW	BPDB
4	Baghabari 71 MW	BPDB
5	Kaptai 4&5	BPDB
6	Shahajibazar 8&9 (2x35 MW)	BPDB
7	Siddhirganj 2x120 MW	EGCB
8	Haripur Power Ltd. (1x235+125)	HPL
9	Sirajganj 225 MW (150+75 MW)	NWPGCL
10	Khulna 1x150 MW	NWPGCL
11	Summit Bibiyana-2 (1x222 MW)	Summit Power
12	Meghnaghat Power Ltd (2x150+150 MW)	MPL

(c) Estimation of the planned outages (Maintenance outages) and unplanned outages

The ratio of planned outages (maintenance outages) and unplanned outages of generators is one of the most uncertain but important elements to conduct a trial calculation.
Unfortunately, information on this point could not obtained in the investigation in Bangladesh, so we assumed the outage rates as 0% to 20% (by 5% increments).

(d) Risk of delay in developing the LFC by SCADA/EMS in NLDC

Moreover, as details are described in section 17.6 , we should take a risk of delay in developing the LFC by SCADA/EMS in NLDC into consideration. Thus, preparation of the available primary reserve list provided by only FGMO is required.

Fortunately, there seems to be no risk to realize FGMO by the newly constructed generators commissioned after 2015, for the following reasons:

- All generators are generally equipped with governors for the purpose of maintaining constant rotor speed.
- FGMO can be easily realized by setting up the permanent speed variation and limiter of the governor.

From the TEPCO's experiences, the primary reserves (FGMO + LFC) have been secured from 3% to 5% of the maximum demand. And spinning reserves (FGMO) have been secured around 2% of the maximum demand. Thus, the ration of FGMO among the primary reserves amounts to one-thirds to two-thirds.

In case of Bangladesh, the primary reserve is planned to secure, at least, 10% of the maximum demand, so contribution of FGMO can be estimated about 3% to 7% of the maximum demand.

(e) The results of calculations

Table 17-16 shows the available primary reserves, when both of FGMO and LFC are carried out.
Table 17-17 shows the available primary reserves, when only FGMO are carried out.

Hereinafter, study will be performed based on the Table 17-17, for severer side estimation.

Table 17-16 Available Primary Reserve List

Rate of operation	Rate of reserve	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
100%	10%	0	120	214	370	451	775	775	775	830	830	830	855	915	1000	1075	1175	1235	1400	1565	1745	2010	2200	2396	2571	2816	2956	3032
	11%	0	132	235	407	496	852	852	852	913	913	913	940	1006	1100	1182	1292	1358	1540	1721	1919	2211	2420	2636	2828	3097	3251	3335
	12%	0	144	257	444	541	930	930	930	996	996	996	1026	1098	1200	1290	1410	1482	1680	1878	2094	2412	2640	2875	3085	3379	3547	3638
	13%	0	156	278	481	587	1007	1007	1007	1079	1079	1079	1111	1189	1300	1397	1527	1605	1820	2034	2268	2613	2860	3115	3342	3660	3842	3941
	14%	0	168	300	518	632	1085	1085	1085	1162	1162	1162	1197	1281	1400	1505	1645	1729	1960	2191	2443	2814	3080	3354	3599	3942	4138	4244
	15%	0	180	321	555	677	1162	1162	1162	1245	1245	1245	1282	1372	1500	1612	1762	1852	2100	2347	2617	3015	3300	3594	3856	4224	4434	4548
95%	10%	0	114	203	352	429	736	736	736	788	788	788	812	869	950	1021	1116	1173	1330	1487	1658	1909	2090	2276	2442	2675	2808	2880
	11%	0	125	224	387	471	810	810	810	867	867	867	893	956	1045	1123	1228	1290	1463	1635	1823	2100	2299	2504	2686	2942	3089	3168
	12%	0	137	244	422	514	883	883	883	946	946	946	975	1043	1140	1225	1339	1408	1596	1784	1989	2291	2508	2731	2931	3210	3370	3456
	13%	0	148	264	457	557	957	957	957	1025	1025	1025	1056	1130	1235	1328	1451	1525	1729	1933	2155	2482	2717	2959	3175	3477	3650	3744
	14%	0	160	285	492	600	1030	1030	1030	1104	1104	1104	1137	1217	1330	1430	1563	1642	1862	2081	2321	2673	2926	3187	3419	3745	3931	4032
	15%	0	171	305	527	643	1104	1104	1104	1183	1183	1183	1218	1304	1425	1532	1674	1760	1995	2230	2487	2864	3135	3414	3663	4012	4212	4320
90%	10%	0	108	193	333	406	697	697	697	747	747	747	769	823	900	967	1057	1111	1260	1408	1570	1809	1980	2156	2314	2534	2660	2729
	11%	0	119	212	366	447	767	767	767	822	822	822	846	906	990	1064	1163	1223	1386	1549	1727	1990	2178	2372	2545	2788	2926	3001
	12%	0	130	231	400	487	837	837	837	896	896	896	923	988	1080	1161	1269	1334	1512	1690	1885	2171	2376	2588	2776	3041	3192	3274
	13%	0	140	250	433	528	906	906	906	971	971	971	1000	1070	1170	1258	1375	1445	1638	1831	2042	2352	2574	2803	3008	3294	3458	3547
	14%	0	151	270	466	568	976	976	976	1046	1046	1046	1077	1153	1260	1354	1480	1556	1764	1972	2199	2532	2772	3019	3239	3548	3724	3820
	15%	0	162	289	500	609	1046	1046	1046	1120	1120	1120	1154	1235	1350	1451	1586	1667	1890	2113	2356	2713	2970	3234	3470	3801	3990	4093
85%	10%	0	102	182	315	383	659	659	659	705	705	705	727	778	850	914	999	1050	1190	1330	1483	1708	1870	2037	2185	2393	2512	2577
	11%	0	112	200	346	422	724	724	724	776	776	776	799	855	935	1005	1099	1155	1309	1463	1631	1879	2057	2240	2404	2633	2764	2835
	12%	0	122	218	378	460	790	790	790	847	847	847	872	933	1020	1096	1198	1260	1428	1596	1780	2050	2244	2444	2622	2872	3015	3092
	13%	0	133	237	409	499	856	856	856	917	917	917	945	1011	1105	1188	1298	1365	1547	1729	1928	2221	2431	2647	2841	3111	3266	3350
	14%	0	143	255	440	537	922	922	922	988	988	988	1017	1089	1190	1279	1398	1470	1666	1862	2076	2392	2618	2851	3059	3351	3517	3608
	15%	0	153	273	472	575	988	988	988	1058	1058	1058	1090	1167	1275	1371	1498	1575	1785	1995	2225	2563	2805	3055	3278	3590	3769	3865
80%	10%	0	96	171	296	361	620	620	620	664	664	664	684	732	800	860	940	988	1120	1252	1396	1608	1760	1917	2057	2253	2365	2425
	11%	0	106	188	326	397	682	682	682	730	730	730	752	805	880	946	1034	1087	1232	1377	1536	1769	1936	2108	2262	2478	2601	2668
	12%	0	115	205	355	433	744	744	744	797	797	797	821	878	960	1032	1128	1186	1344	1502	1675	1930	2112	2300	2468	2703	2837	2910
	13%	0	125	223	385	469	806	806	806	863	863	863	889	952	1040	1118	1222	1284	1456	1628	1815	2090	2288	2492	2674	2928	3074	3153
	14%	0	134	240	415	505	868	868	868	930	930	930	958	1025	1120	1204	1316	1383	1568	1753	1954	2251	2464	2683	2879	3154	3310	3395
	15%	0	144	257	444	541	930	930	930	996	996	996	1026	1098	1200	1290	1410	1482	1680	1878	2094	2412	2640	2875	3085	3379	3547	3638

Table 17-17 List of the Primary Reserve by FGMO Only

Rate of operation	Rate of reserve	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
100%	3%	0	36	64	111	135	232	232	232	249	249	249	256	274	300	322	352	370	420	469	523	603	660	719	771	845	887	910
	4%	0	48	86	148	180	310	310	310	332	332	332	342	366	400	430	470	494	560	626	698	804	880	958	1028	1126	1182	1213
	5%	0	60	107	185	226	387	387	387	415	415	415	427	457	500	537	587	617	700	782	872	1005	1100	1198	1285	1408	1478	1516
	6%	0	72	128	222	271	465	465	465	498	498	498	513	549	600	645	705	741	840	939	1047	1206	1320	1438	1542	1689	1773	1819
	7%	0	84	150	259	316	542	542	542	581	581	581	598	640	700	752	822	864	980	1095	1221	1407	1540	1677	1799	1971	2069	2122
95%	3%	0	34	61	105	129	221	221	221	237	237	237	244	261	285	306	335	352	399	446	497	573	627	683	733	802	842	864
	4%	0	46	81	141	171	294	294	294	315	315	315	325	348	380	408	446	469	532	595	663	764	836	910	977	1070	1123	1152
	5%	0	57	102	176	214	368	368	368	394	394	394	406	435	475	511	558	587	665	743	829	955	1045	1138	1221	1337	1404	1440
	6%	0	68	122	211	257	442	442	442	473	473	473	487	522	570	613	670	704	798	892	995	1146	1254	1366	1465	1605	1685	1728
	7%	0	80	142	246	300	515	515	515	552	552	552	569	608	665	715	781	821	931	1041	1160	1337	1463	1593	1710	1872	1966	2016
90%	3%	0	32	58	100	122	209	209	209	224	224	224	231	247	270	290	317	333	378	423	471	543	594	647	694	760	798	819
	4%	0	43	77	133	162	279	279	279	299	299	299	308	329	360	387	423	445	504	563	628	724	792	863	925	1014	1064	1091
	5%	0	54	96	167	203	349	349	349	373	373	373	385	412	450	484	529	556	630	704	785	904	990	1078	1157	1267	1330	1364
	6%	0	65	116	200	244	418	418	418	448	448	448	462	494	540	580	634	667	756	845	942	1085	1188	1294	1388	1520	1596	1637
	7%	0	76	135	233	284	488	488	488	523	523	523	539	576	630	677	740	778	882	986	1099	1266	1386	1509	1620	1774	1862	1910
85%	3%	0	31	55	94	115	198	198	198	212	212	212	218	233	255	274	300	315	357	399	445	513	561	611	656	718	754	773
	4%	0	41	73	126	153	263	263	263	282	282	282	291	311	340	365	399	420	476	532	593	683	748	815	874	957	1005	1031
	5%	0	51	91	157	192	329	329	329	353	353	353	363	389	425	457	499	525	595	665	742	854	935	1018	1093	1197	1256	1288
	6%	0	61	109	189	230	395	395	395	423	423	423	436	467	510	548	599	630	714	798	890	1025	1122	1222	1311	1436	1507	1546
	7%	0	71	127	220	268	461	461	461	494	494	494	509	544	595	640	699	735	833	931	1038	1196	1309	1426	1530	1675	1759	1804
80%	3%	0	29	51	89	108	186	186	186	199	199	199	205	220	240	258	282	296	336	376	419	482	528	575	617	676	709	728
	4%	0	38	68	118	144	248	248	248	266	266	266	274	293	320	344	376	395	448	501	558	643	704	767	823	901	946	970
	5%	0	48	86	148	180	310	310	310	332	332	332	342	366	400	430	470	494	560	626	698	804	880	958	1028	1126	1182	1213
	6%	0	58	103	178	217	372	372	372	398	398	398	410	439	480	516	564	593	672	751	838	965	1056	1150	1234	1352	1419	1455
	7%	0	67	120	207	253	434	434	434	465	465	465	479	512	560	602	658	692	784	876	977	1126	1232	1342	1440	1577	1655	1698

(2) Trial calculation of the required amount of reserves

Fundamental concept of assumption of possible fault

In order to make a trial calculation, assumption of possible fault is an important factor to calculate required amount of reserves. i.e.

N-0 → Frequency control under no contingency situation
N-1 → The largest loss of power supply due to single apparatus contingency, such as sudden trip of one maximum capacity generating unit or sudden trip of one transmission line which results in loss of multiple generating units.
N-2 → The largest loss of power supply due to double simultaneous apparatus contingency.

Probability of simultaneous multi apparatuses faults is smaller than that of single fault, while the impact on the frequency fluctuation is larger. In the case study of demand-supply operation planning, N-1 tends to be applied as the severest contingency from the viewpoint of global trend, including TEPCO. Therefore, we also considered the N-0 and N-1 contingency in this study.

(a) N-0 Case (Under the Normal Condition)

In this section, we will perform a trial calculation of necessary primary reserves.
Unfortunately, there is no globally standardized method to calculate the necessary reserve in frequency control. Therefore, it should be noted that the following description is very challenging study, and no more than a rough estimation.

The goal of this section is to provide a roadmap of frequency quality improvement. Therefore, it is useful to find a relationship between power demand and necessary reserves for frequency control.

In this study, for simplicity, the necessary amount of reserves are considered to be equal to the amount of load fluctuation.[63] Therefore, the mission of this section can also be set to find the relationship between power demand and load fluctuation.

Estimation of the load fluctuation requires statistical analysis of many amount of past record data. We, however, don't have enough time to collect and analyze the data in Bangladesh, and it is, also, very difficult to find out the good correlation factors among the record data because many factors may influence on the load fluctuation such as total demand, weekday/holiday, time zone, power system condition, and so on.

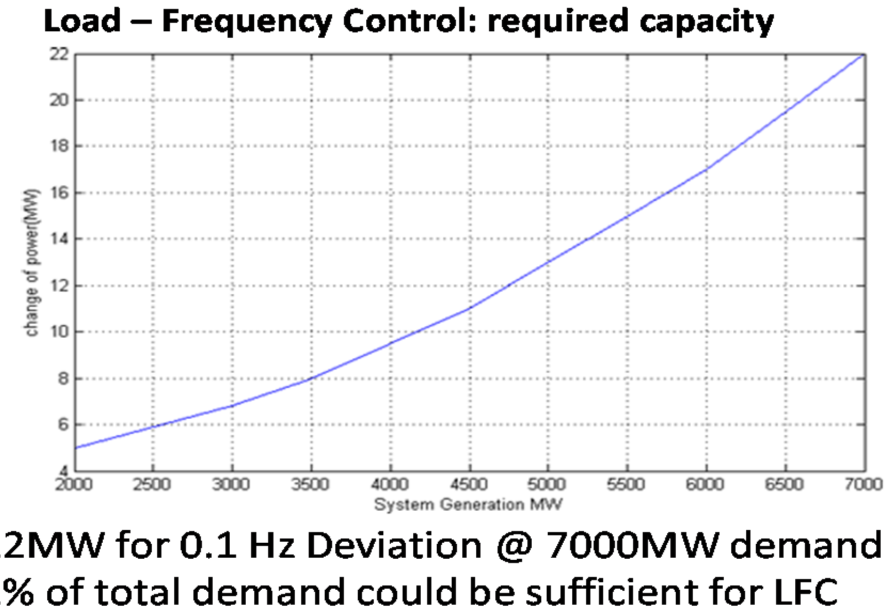
Therefore, we will try to apply the proportional expression between the load fluctuation and power demand obtained by the analyses of load fluctuation in Japan, and to obtain a proportionality constant by using the data of 3 cases in frequency control practice and the frequency fluctuation chart at the time of generator or load tripping fault provided by NLDC.

[63] The frequency fluctuation can be theoretically canceled out by regulating the reserves in simultaneous and commensurate manner in response to the load fluctuation. In fact, it is impossible to make the output from reserves follow the load fluctuation with pinpoint accuracy. Therefore, some frequency deviation is practically allowed (50+/-0.2Hz in TEPCO) due to the control-delay. Thanks to this allowable frequency deviation, necessary amount of reserves is less than the amount of load fluctuation. In this study, however, we set the calculation conditions severer.

The data concerning the frequency control provided by NLDC

Case 1: Load-frequency chart in NLDC

NLDC prepares a chart as shown in Figure 17-14, which indicates the necessary amount of reserves to improve frequency fluctuation by 0.1Hz at a given power demand. For example, the necessary reserves to improve frequency fluctuation by 0.1Hz are 22MW when the power demand is 7,000MW.



Source : NLDC

Figure 17-14 The Necessary Reserve to Improve 0.1[Hz] of Frequency Fluctuation

Case2: HVDC international tie-line tripping fault（Occurred in Dec. 4th 2013）

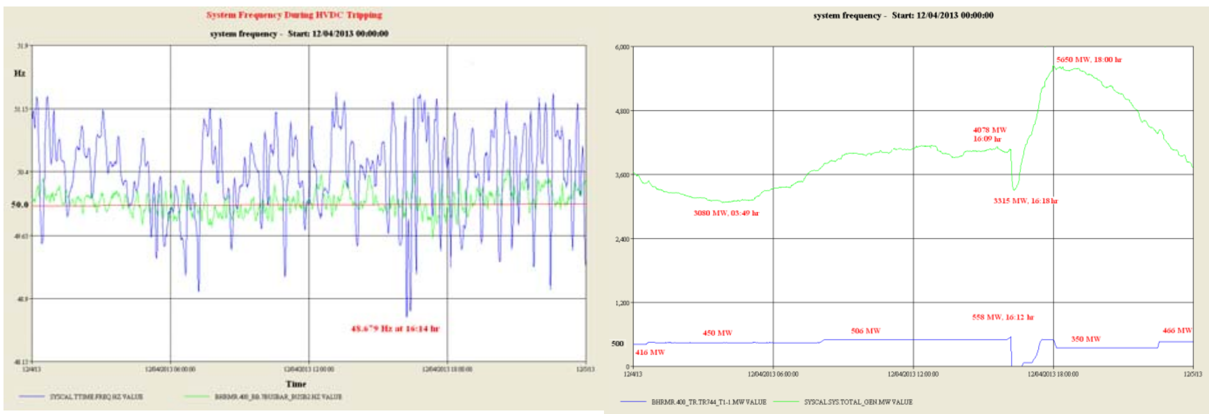


Figure 17-15 Impact of Tripping HVDC Link (System Frequency & Generation Records)

Date & Time	Frequency Hz	Load MW	Generation MW	HVDC Import MW
12/04/2013 16:10:00 s	50.934	3739.832	4060.916	549
12/04/2013 16:11:00 s	51.056	3725.427	4066.471	554
12/04/2013 16:12:00 s	51.06	3715.312	4071.837	558
12/04/2013 16:13:00 s	49.181	3512.534	3638.304	0
12/04/2013 16:14:00 s	48.679	3361.106	3527.44	0
12/04/2013 16:15:00 s	48.702	3183.347	3420.231	0

From the data above, we can estimate that, import power of 558MW from India was suddenly interrupted due to a trip of the HVDC international tie-line. As a result, the total supply decreased sharply from 4,072MW to 3,638MW. At the same time, the load shedding by Under Frequency Relay (UFR) seemed to occur and demand decreased from 3,715MW to 3,512MW.

From this consideration, it can be calculated that the frequency was lowered by 0.1Hz due to the supply shortage of about 12.3MW, under the total demand of 3,715MW.

Case3: Tripping fault of a few units of the generator in Ashuganj area（Occurred in Nov. 12th 2014）

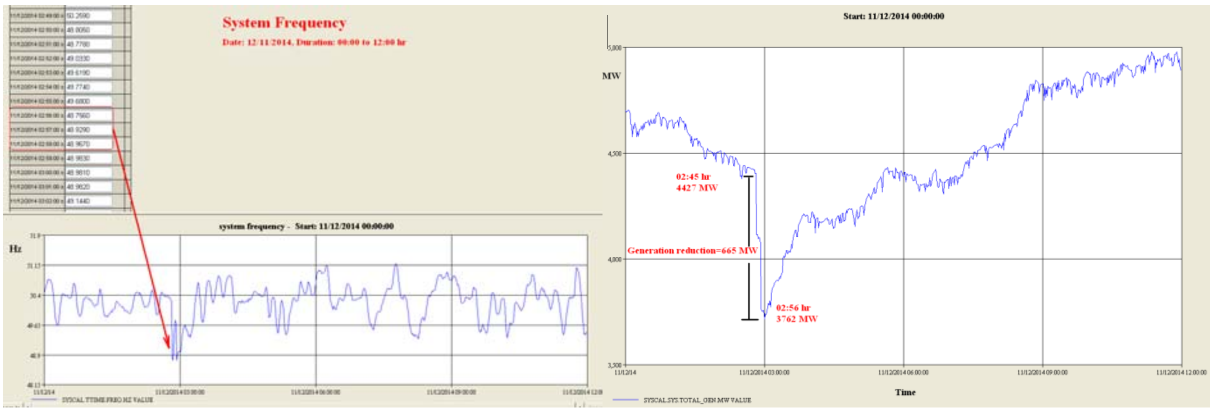


Figure 17-16 Impact of Tripping Generators on the System Frequency

Since the data of load fluctuation has not been provided, we considered that only the generator tripping has occurred and the load-shedding has not occurred. And, in right figure, although NLDC reported that total generation has decreased from 4,427MW to 3,762MW at one shot, there are obviously two events of generator trip by observing the chart closely. From this observation, at the first frequency drop, demand is considered to have decreased down to only about 4,240MW.
In this data, there is no information of the demand, but we consider that total generation output almost equal to the total demand because the frequency, immediately before the fault, was about 50.2 [Hz], which indicates that the demand and supply had been almost balanced.

Based on the consideration above, it can be calculated that the frequency was lowered by 0.1Hz due to the supply shortage of about 12.8MW, under the total demand of 4,427MW.

Trail calculations of necessary reserves for frequency control (load fluctuation)

From the results of 3 cases, we will make a trial calculation of the relationship between demand and load fluctuation.

According to the technical report from Committee of Experts in the Institute of Electrical Engineers of Japan (The technical report No.869, IEEJ), there is a result of statistical analysis that a standard deviation of load fluctuation (σ) is proportional to the square root of the power demand (P). Here, we simply assumed that the load fluctuation (ΔP), in other word, the necessary reserves ($=\Delta P$) is also proportional to the square root of the total demand (P). i.e.

$$\Delta P = \alpha * \sqrt{P} \quad [MW]$$

Assuming that the quantity of reserves consumed and the degree of frequency improved (For example; 0.1 [Hz]) are in proportion to each other, the equation above can be converted into the following equation relationship between demand and the amount of necessary reserve for improving 0.1[Hz]. i.e.

$$\Delta P = \alpha * \sqrt{P} \quad [MW/0.1Hz]$$

Here, the results of Case 1, 2, 3 – relationship between the total power demand and necessary reserves to improve frequency by 0.1Hz, are substituted into the equation. Then, the proportionality constant α can be determined as follows:

$$\Delta P = 0.263*\sqrt{P} \quad [MW/0.1Hz] \quad : \text{Case 1}$$
$$\Delta P = 0.201*\sqrt{P} \quad [MW/0.1Hz] \quad : \text{Case 2}$$
$$\Delta P = 0.193*\sqrt{P} \quad [MW/0.1Hz] \quad : \text{Case 3}$$

Though the calculation results of constant α vary widely from 0.193 to 0.263, hereinafter, we use the equation of case 1 because of that the amount of load fluctuation (necessary reserve) becomes largest.[64]

As a solitary information that can verify the derived equation, there is the useful results of frequency control test that has been carried out in the Khulna power station in May 2015. The outline of this test is shown in Table 17-18.
According to the explanation of NLDC, in this test, they examined the effects of frequency improvements by realizing the action of FGMO by repeating the telephone instructions to power station during the test time. Assuming that the power demand during the test time was around 5,000MW average, the necessary reserve to improve frequency quality by 0.1Hz can be calculated at about 18.6MW from the equation. On the other hand, the frequency fluctuation decreased about from ±1.2 [Hz] to ±0.55 [Hz] by using the gas turbine machine as reserves. From these facts, about 121MW from the rated output 158MW was used for reserves. Though there is, unfortunately, no records of generator output that can support this estimation, but it is not improbable.

Table 17-18 Outline of Frequency Control Test in Khulna Power Station

Date	May 2nd, 2015 (SAT.) 0:00 – 6:00 AM (for 6 hours)
Site	Khulna Power Station (Rated output: 158MW×1 unit, Gas-Turbine, fuel: HSLO: High-sulfur light oil)
Conditions	Realizing the simulated FGMO by repeating the telephone instructions from NLDC shift engineers to Khulna power station.
Total demand	5,870MW (at 0:00 AM) - 4,500MW (at 6:00 AM)
Effectiveness	Before/After the test: 51.33Hz - 48.93Hz (+2.66% -- -2.14%) During the test: 50.70Hz - 49.56Hz (+1.40Hz -- -0.88%)

64 This equation is not consistent with the characteristics of the graph as shown in Figure 17-14. This figure shows the lower convex curve that the rate of increase in amount of necessary reserve rises as demand increases, the above relational equations are clearly the upper convex curve to demand. However, qualitatively, it is considered a load that fluctuates randomly is connected more to the power system as demand increases. If there are many random element, since as a whole variation is suppressed and smoothed, the upper convex curve is believed to be close to actual conditions.

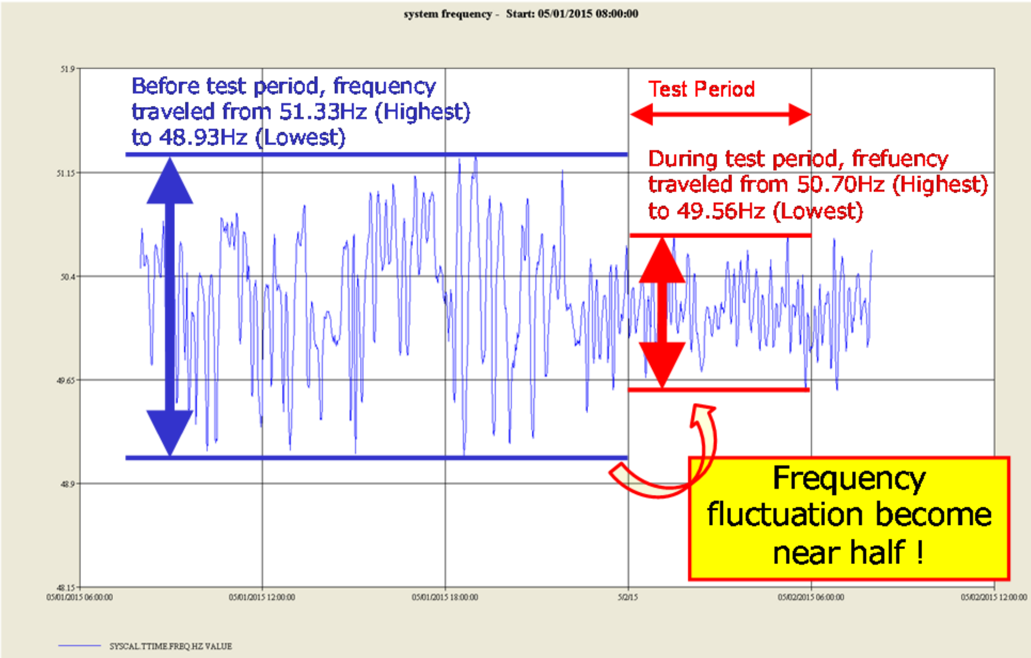


Figure 17-17 Frequency Fluctuation Record during Test Operation in Khulna Power Station

(b) N-1 Case (Under the Emergency Condition)

The case which may cause frequency fluctuations greatly by single apparatus fault is generation tripping or load tripping. As power system diagram, shown in Figure 17-18, since almost all the 400kV, 230kV and 132kV transmission facilities in Bangladesh consist of double-circuit transmission lines and are operated by meshed configuration, it can be said that there are no case in which frequency fluctuates greatly due to the N-1 fault in the AC system.

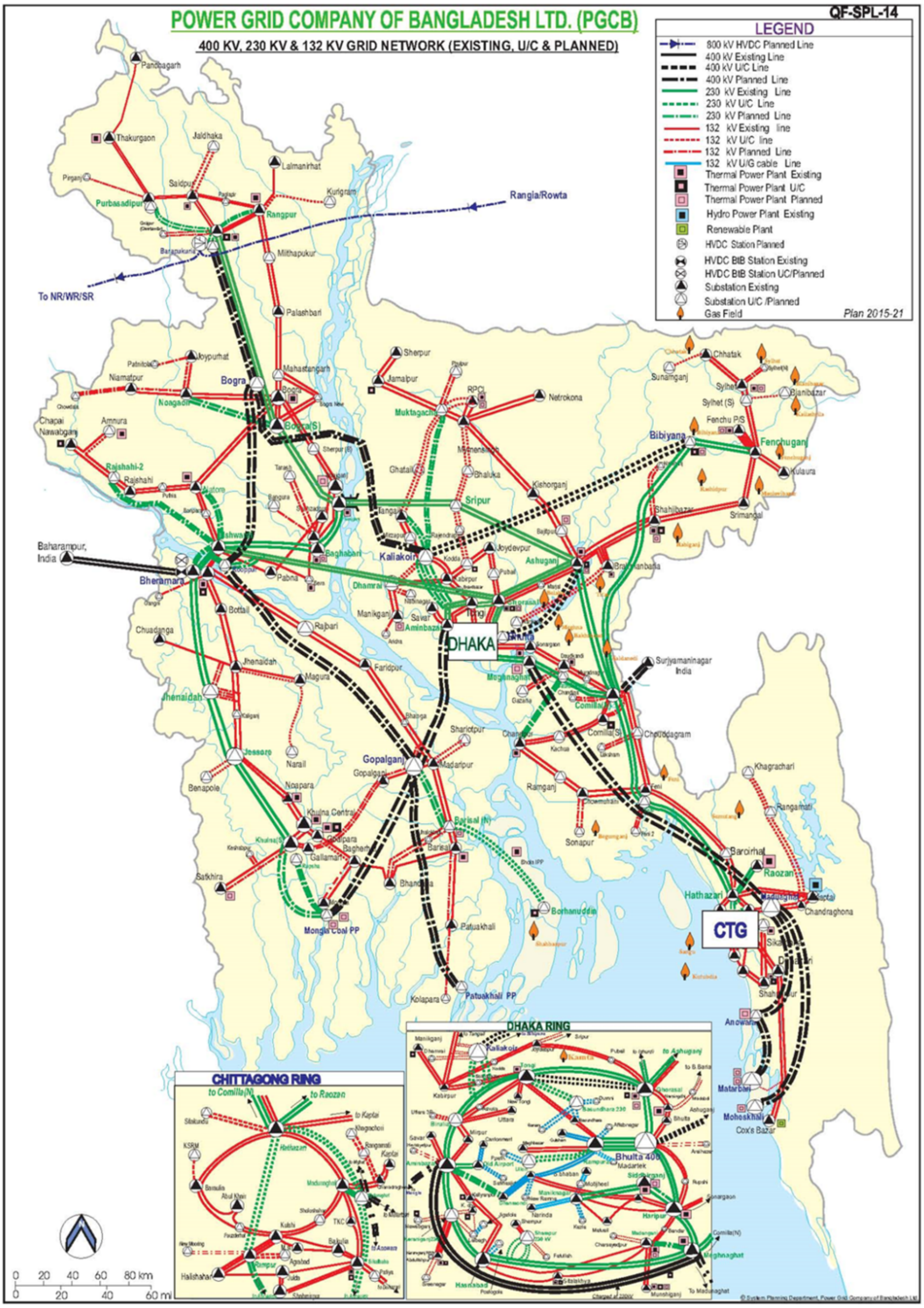


Figure 17-18 Power System Diagram of Bangladesh

It should be considered but rather in the following cases:

- Single generation tripping of maximum capacity
- Import power cut-off due to single apparatus fault such as HVDC transmission line or Back to Back (BTB).

Specific amounts and factors of supply tripping should be considered in the future year development of power system are shown as follows:

Table 17-19 Supply Tripping Amount and Factors Should Be Considered in Each Year

Year	Supply tripping amounts	Factors
2015~2024	500MW	Single apparatus fault of HVDC 500MW
2024~2041	1180MW	Single unit tripping of Roopoor nuclear power plants

In this study, we will check the adequacy of reserves for each year by comparing with these supply tripping amounts.

The important thing is that it is not always perfect even though there is sufficient amount of reserves shown in above table. As shown in Figure 17-19, if the reserve is secured shown in the table, it is possible to finally recover to normal frequency. However, immediately after the generator tripping, the frequency transiently decrease rapidly, since output of generators provided as reserves cannot keep up with sudden loss of supply. The greater a ratio of the generator capacity among the total supply power becomes, the severer this tendency becomes.

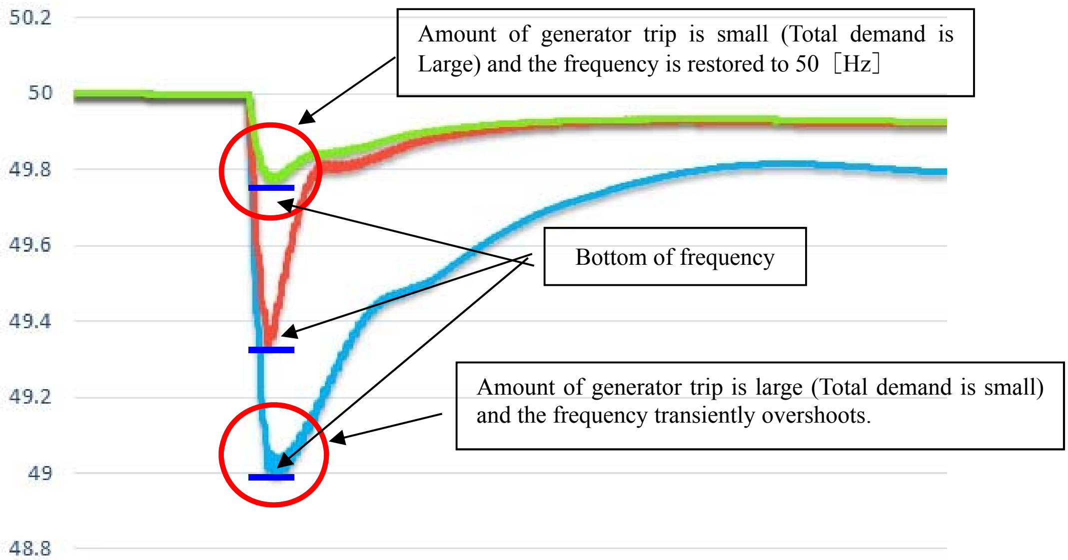


Figure 17-19 Time-shift Image of Frequency Fluctuation at the Time of Generation Tripping

Therefore, for example, if frequency overshoots below the permissible under-frequency range of generator due to the tripping of large capacity generator in the low demand season or time zone, other generators are simultaneously tripped (i.e. reference Figure 17-7), that leads to a further frequency decrease. Then, the power system will be collapsed, so-called, cascading outage occurs. In the worst case, there is a possibility that the whole power system is gone to black out.

Bangladesh has already experienced a black out due to cut-off of about 500MW power import from India via HVDC international tie-line, on November, 2014.

In order to avoid the case like this, the adequate capacity of automatic load shedding by UFR as a back-up scheme. Besides, in the above-mentioned guideline of IAEA, in order to avoid the load shedding that exceeds the permissible range, one nuclear generator capacity in the low demand period is recommended to be selected to be less than 10% of the total demand.

Fig. 16-20 shows the trend of frequency deviation (Δ f) when a sudden trip of Roopoor nuclear power unit (1180MW) occurs under the minimum demand conditions each year after 2024. The bottom of frequency is as shown in Fig. 16-19. A caluculation formula of frequency drop is as follows;

A mathematical relation:

$$\frac{\Delta f}{50}\ [\%/Hz] \times K\ [\%MW/\%Hz] = -\frac{1{,}180}{P}\ [\%MW]$$

where,

K：k-factor of the = 5.0 [%MW/%Hz] (a standard value in TEPCO)
P：Minimum demand each year

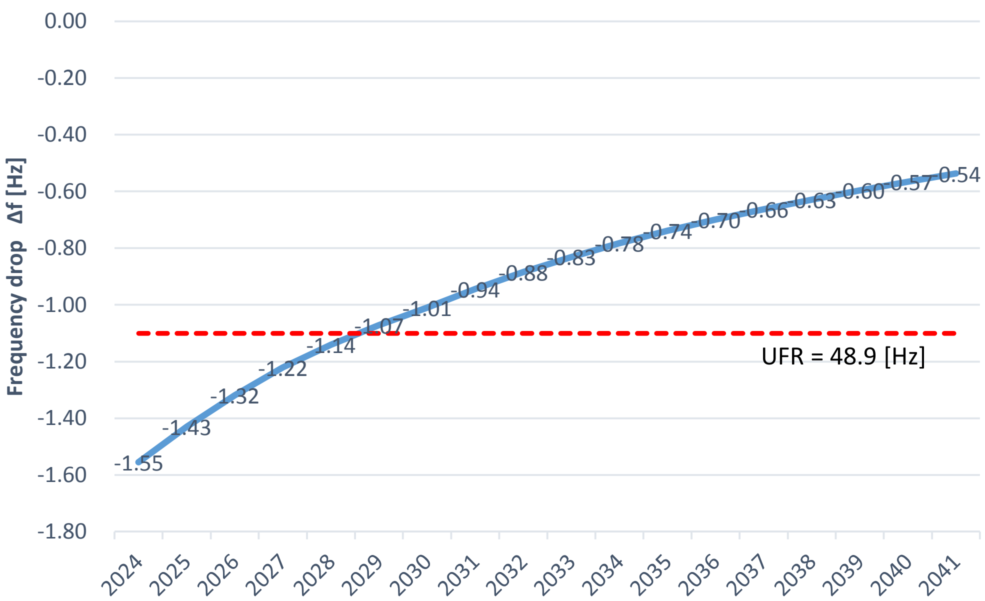


Figure 17-20 Trend of Bottom of Frequency Immediately after a Sudden Trip of Roopoor Unit

As shown in the graph, above, frequency overshoots below the UFR settings: 48.9Hz, due to the trip of Roopoor unit in the low demand season or time zone that leads to load shedding until 2028. However, it should be allowed in order to avoid a cascading outage and blackout.

(3) Verification of Adequacy of Reserves

Figure 17-211 and Figure 17-22 shows the balance of available primary reserves and necessary reserves for improving frequency fluctuation in units of 0.1Hz, from the study results of section 16.5.2 (1) and 16.5.2 (2). Here, prerequisite conditions are as follows:

- The available reserves are painted out green color based on the case of 100% and 80% operation rate in the Table 17-17.
- The necessary reserves are calculated based on the equation $\Delta P = 0.263 \times \sqrt{P}$ (MW/0.1Hz), to improve frequency quality from current situation (assuming +/-1.5Hz) to certain values in +/-0.1Hz segments. Then they are drawn in dashed lines from +/-1.4Hz-quality (+/-0.1Hz

improvement) to +/-0.2Hz-quality (+/-1.3Hz improvement).

➢ When a range painted out green color are on dashed lines, they are the balance point between available and necessary reserve. Therefore the range indicate the trend of frequency quality improvement.

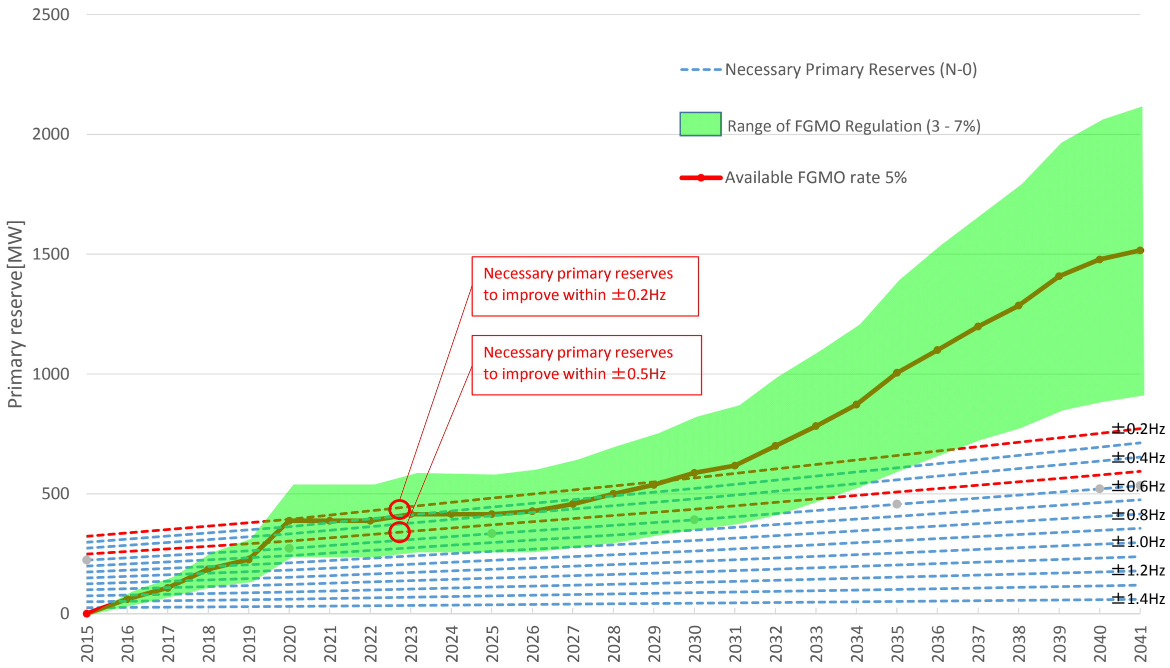


Figure 17-21 The Comparison of Securing the Amount of Necessary Reserve and Available Reserve (The rate of operational generator : 100%)

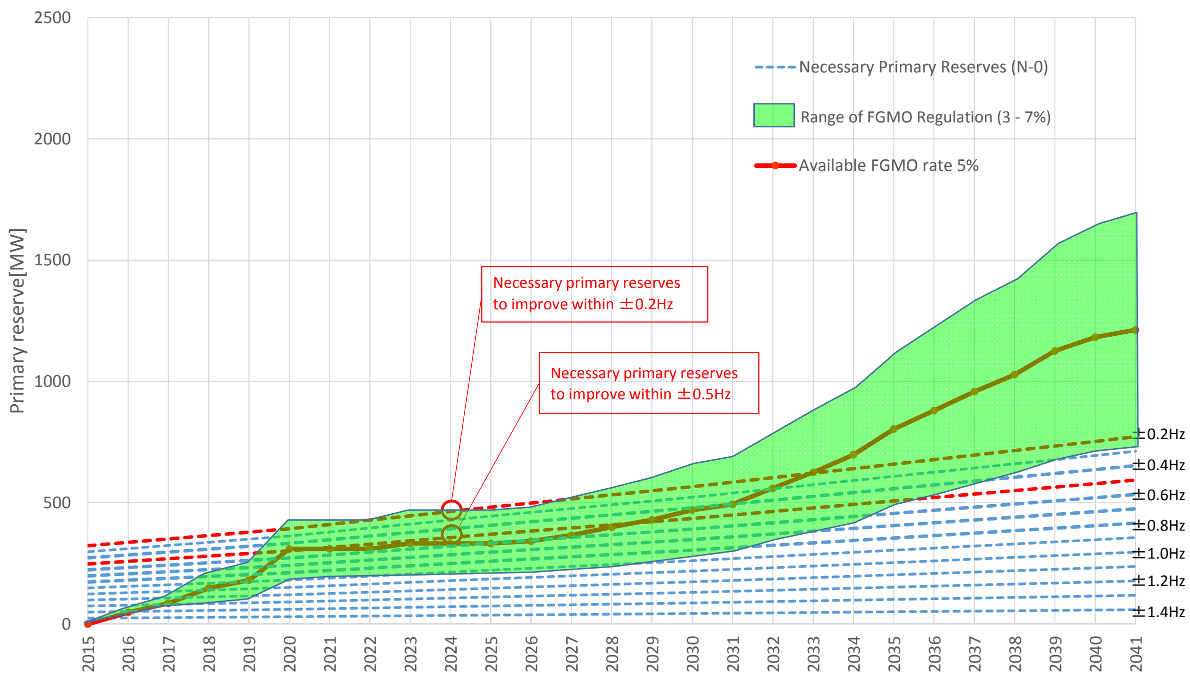


Figure 17-22 The Comparison of Securing the Amount of Necessary Reserve and Available Reserve (The rate of operational generator : 80%)

As shown in Figure 17-21, in ideal condition which the rate of operational generator is 100%, it is expected to be improved within ±0.2 [Hz] which is equivalent to frequency quality of TEPCO in 2037 at latest. However, in reality, the maintenance outages of generation plant is inevitable, and the unplanned maintenance outages also should be taken into account as risk. Figure 17-22 shows the 80% operational-rate case (maintenance outage + unplanned maintenance outage: 20%).
If the rate of operational generator is 80%, there is a possibility that the frequency deviates from the target range of ± 0.2Hz even in 2041. However, as mentiond above, it can be said that there is no big challenges at 80% operational-rate, because it contains a considerable margin upon a trial calculation.

(4) Roadmap for frequency quality improvement

Figure 17-23 shows the future trend of frequency quality improvement when the current frequency fluctuation is assumed to be a ± 1.5Hz, based on the study of demand-supply balance of reserves, shown in Figure 17-22. Here, the plots shown in Figure 17-23 are calculated value of each year, and the curves are quadratic approximate curves obtained from the plots.

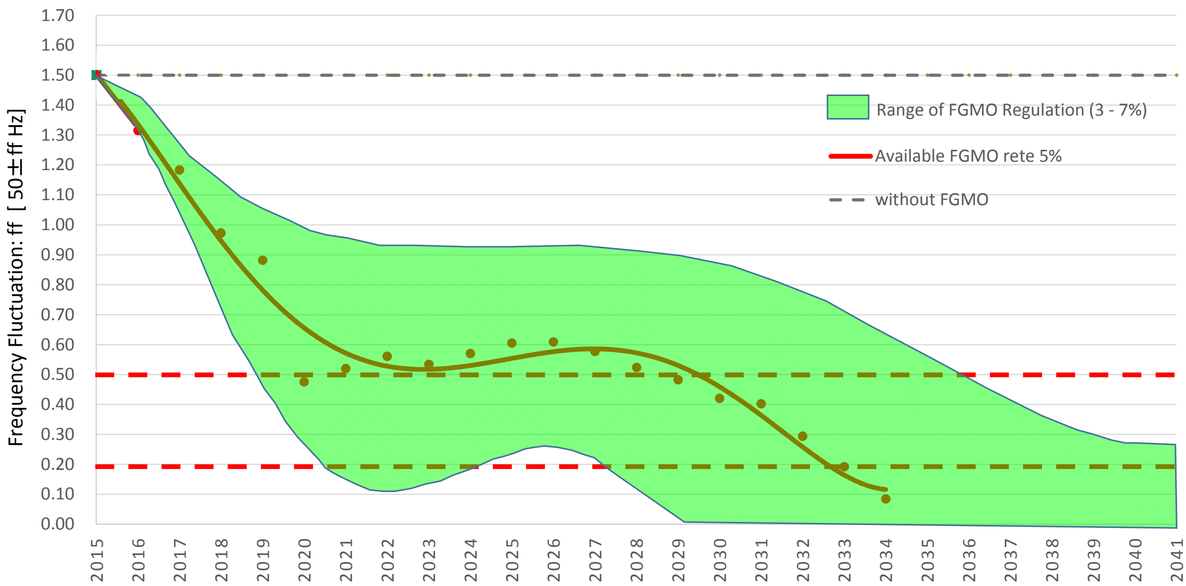


Figure 17-23 Future Roadmap of Improving Frequency Quality

According to Figure 17-22 and Figure 17-23, the followings are remarkable points:

Frequency control in normal condition

- If the effective amount of FGMO is the 5% of total demand as average value, it is possible prospect that the frequency fluctuation can be controlled within ±0.5Hz until the commitment of the Roopoor nuclear generation plant at 2024.
- A risk that the effective amount of FGMO is less than 5% cannot be denied. However, as mentiond above, it is considered that the risk can be ignored because it contains a considerable margin upon the accumulation of necessary primary reserve.
- It is sufficiently possible to secure the reserve in order to improve the frequency quality within ±0.2Hz by 2041.

Frequency control in abnormal condition

- After the first commitment of Roopoor nuclear generation unit at 2024, the frequency drop become remarkable due to the trip of that unit. As a result, the cascading trip of other generators occurs and there is a risk that the cause of blackout.

Therefore the steady accumulate of the primary reserve is an essential. Also, in order to avoid the total blackout, the amount of load shedding by UFR should be secured sufficiently for the time being.

Therefore it is a major challenge for the time being to improve the frequency quality to a level where a nuclear power plant can be stable operation. Then important point for that is as follows:

Institution design, Apparatus design

- Framework to foster economic incentives such as purchase of the reserve by the reasonable price and grant of compensation
- Incorporating FGMO and LFC function into a design specification as interconnection requirement of new generator and implementing the functional tests before commitment. And the FGMO is implemented immediately after commitment.
- The coal-fired thermal power is planned to provide the primary reserve from 50% of them at present. If there is an intension to avoid the load shedding by UFR as much as possible, so that the primary reserve is provided by all of coal-fired thermal power plants for the time being, it is essential for all new generators to incorporate the FGMO and LFC function into the design specification.

Operation and maintenance of conventional apparatuses

- Since conventional generator is also expected to contribute as a further reserve, rehabilitation of generators except for the generators of that is already incorporated into reserve is essential, and it aims to secure several hundred MW of reserve.
- Especially, after the commissioning of nuclear power, in order to secure the reserve in low demand season, take maintenance outage planning into consideration adequately in weekly and the day before, the day demand and supply planning.
- The effect of frequency drop due to the trip of a Roopoor nuclear power unit is big for the time being. Thus in order to avoid the total blackout, at least, it is acceptable to secure the amount of load shedding by UFR which is the rated output of a Roopoor nuclear power unit.

Also in this study it should be noted the following points.

- The trial calculation of the amount of necessary supply reserve is inferred from the record of load variation in Japan.
- The trial calculation of the amount of available supply reserve is inferred from the current power development planning. And because the theoretical calculation of effective amount with FGMO is impossible, it is only inference in the light of the Japanese experience.

Therefore, from now on, on the basis of such records of FGMO which has been scheduled to be carried out in Bangladesh since the end of January 2016, verify its effect. And then it is necessary to brush up a roadmap of the frequency quality improvement again.

17.6 Actual Condition of EMS/SCADA System in NLDC for Load Frequency Control (LFC)

As long as current operation rule allows current frequency deviation (±1.0Hz), instruction by phone is still acceptable. However, in order to improve the quality toward the level of developed countries (±0.05Hz~0.2Hz), utilization of automatic control will be indispensable condition, so the urgent enhancement of FGMO by each generation unit and LFC by SCADA/EMS in NLDC is strongly desired.

17.6.1 Installed functions in NLDC system

At present, there is a France (Areba) –built SCADA/EMS in NLDC, which has a function of LFC within it, but it has not connected to the Generators owned by IPPs nor has it set the data to work well.

Table 17-20 Functions of SCADA/EMS and Current Status of Usage

Functions	Outlines	Current Problem
SCADA Functions (Monitoring of the power system)	Monitor status change of power system by receiving supervisory and telemetry (hereinafter TM) data from RTU. When detected status change and deviation of TM values, it will inform the operator through operation display. Following are monitored; - Frequency - Voltage - Power Flow - Post-fault Analysis	Information display failure on the system monitoring panel is recognized. Reasons as follows; - Failures existing in tele-communication between NLDC and substations. Failure occurs at substations including high voltage substation, substation apparatuses such as Trd, IED, RTU, power supply equipment installed at the substations. - Intermittent tele-communication between NLDC and other companies - Online information supply excluded from contract - Substation facilities mainly owned by PGCB, however do have substations owned by other company. - PGCB owns some power plants as well.
Load Frequency Control (LFC)	Maintain primary frequency regulation capacity. LFC function controls power output of generators based on frequency deviation, and maintain frequency in adequate range. Frequency control is accomplished through generator governor response (primary frequency regulation) and LFC.	Current problems includes the following; - Grid Code, Power Purchase Agreement(hereinafter PPA) arrangements are not suitable for LFC and Automatic Generation Control(hereinafter AGC) - No disclosure of Generation Parameters. Despite above, no complaints from customers about the frequency variation are received, since 60 % of the customers are not using electronic products (even used, only fan or lighting) Poor power quality is not a problem with motivation to solve, and there is no penalty to PGCB for providing such electricity.
Voltage and Reactive power control (VQC)	This function send reactive power signal to generators to regulate voltage targeted to this function. Reactive power signal originates from operators' key input value.	Voltage condition of each region is as below; - West, and North: In poor condition due to long transmission line, and lack of generators. Deployment of line voltage regulator, static tap changer, shifting to higher voltage may be a solution. - South: Generally in good condition. Voltage is high at night, and low in daytime. - East: In good condition due to existence of large generator. High voltage is maintained. Shunt reactor deployment is recommended when in high voltage. (Unsure whether exists.)
State Estimation, Network Security Analysis, and System Optimization	Real time contingency analysis for N-1 Security Real time monitoring of P-V curve and Voltage Stability	Problems regarding the state estimation includes the following; - There are places in result where the estimated value (pink) and measured value (green) are quite different. - Measured values not delivered in timely manner, and data update not completed in time. Regulation condition was poor. No regulated interface existed between EMS and SCADA system.
Economic Dispatch Control (EDC)	Economic Dispatch Control (EDC) calculates economic dispatch output schedule for each generator of different efficiency to control its power output depending on the change of power demand. EDC is the short-term determination of the optimal output of a number of electricity generation facilities, to meet the system load, at the lowest possible cost, while serving power to the public in a robust and reliable manner. Scheduling / Real-Time Dispatching.	- EDC function was unused. - Generators operate in accordance to power generation planning at the power plants, hence NLDC is not involved in power generation plan.
Demand Forecast and Generation Scheduling	The Demand Forecast Function calculates total demand from weather forecast information and the past record data, and allocates most economical generation schedule of each generators by Generation Scheduling Function. The demand forecast function predicts the gross demand for the next day by using multiple regression analysis based on previous data, past weather conditions, type of the day (day of the week, singular point, etc.), and weather forecast	In Japan, dispatching systems receive weather information from the Japan Meteorological Agency. Weather forecast is important information because electricity demand differs significantly with even a 1 degree Celsius difference in maximum temperature. The Demand Forecast Function calculates total demand from weather forecast information and the past recorded data, and allocates most economical generation schedule of each generators by Generation Scheduling Demand. Lack of long term demand forecast program is a problem, and is needed. Desk calculation would be fine, if actual data analysis is possible.

	information	
Recording, Archiving	Event recording shall be displayed on monitor when an event occurs. Also the recorded data shall be able to be referred (displayed) on monitor. Post-Fault Diagnosis Web Server for other Customer/administrative Services	The operating staff is creating the daily report by hand, and it is not utilizing the record data which the system collected Failure history is preserved NLDC system is not connected to the outside world. Only within the NLDC.
Maintenance of database	Database modification for addition/deletion of power system components.	Dedicated maintenance team is present. DB of the new substation and outgoing Matarbari are also being handled by the same team.
Configuration n Control	Real-time Monitoring of SCADA/EMS network status	Configuring component devices in the system configuration screen and confirmation of RTU state is possible. RTU status screen: Green is healthy, purple is disconnected (which also includes future reserve). As preparation for power failure of NLDC, backup power supply such as a diesel engine and UPS are available.

17.6.2 Logic diagram of load frequency control in CLDO system in TEPCO

In order to implement the LFC by the system in NLDC, operation data settings of each generator is required as indicated in the Table 17-20.
Unfortunately, relevant documents regarding the specification and necessary items of LFC have not been provided, so it is difficult to start the practical works toward the realization of LFC.

(1) Necessary minimum data for LFC in TEPCO (for reference)

Figure 17-24 illustrates the processing flow diagram of LFC in TEPCO. As shown in this figure, LFC process is relatively simple due to an independence from EDC (Economic Dispatching Control). According to the diagram, Data settings of following items may be enough to operate frequency control and time difference correction:

Telemetry Data
- Current frequency (deviation from 50Hz)
- Current time difference
- Current status of LFC mode (whether the generation unit can respond to the LFC signal or not)
- Current status of operation (In/Out of service), current output
- Current status of remaining margin in response to the up/down signal by LFC.

Internal Data
- Target frequency [Hz] = 50Hz
- TD Threshold (Threshold time to start time difference correction) [sec.]
- ΔF Correction (Frequency correction when starting the time difference correction) [Hz]
- Dead band of LFC [Hz]
- Allocation settings to the generators [%]
- Limiter settings of LFC signal [%]

In case of NLDC system in Bangladesh, there may be possibility to realize the LFC by beginning with simple and small scale trial, similarly to TEPCO's system.

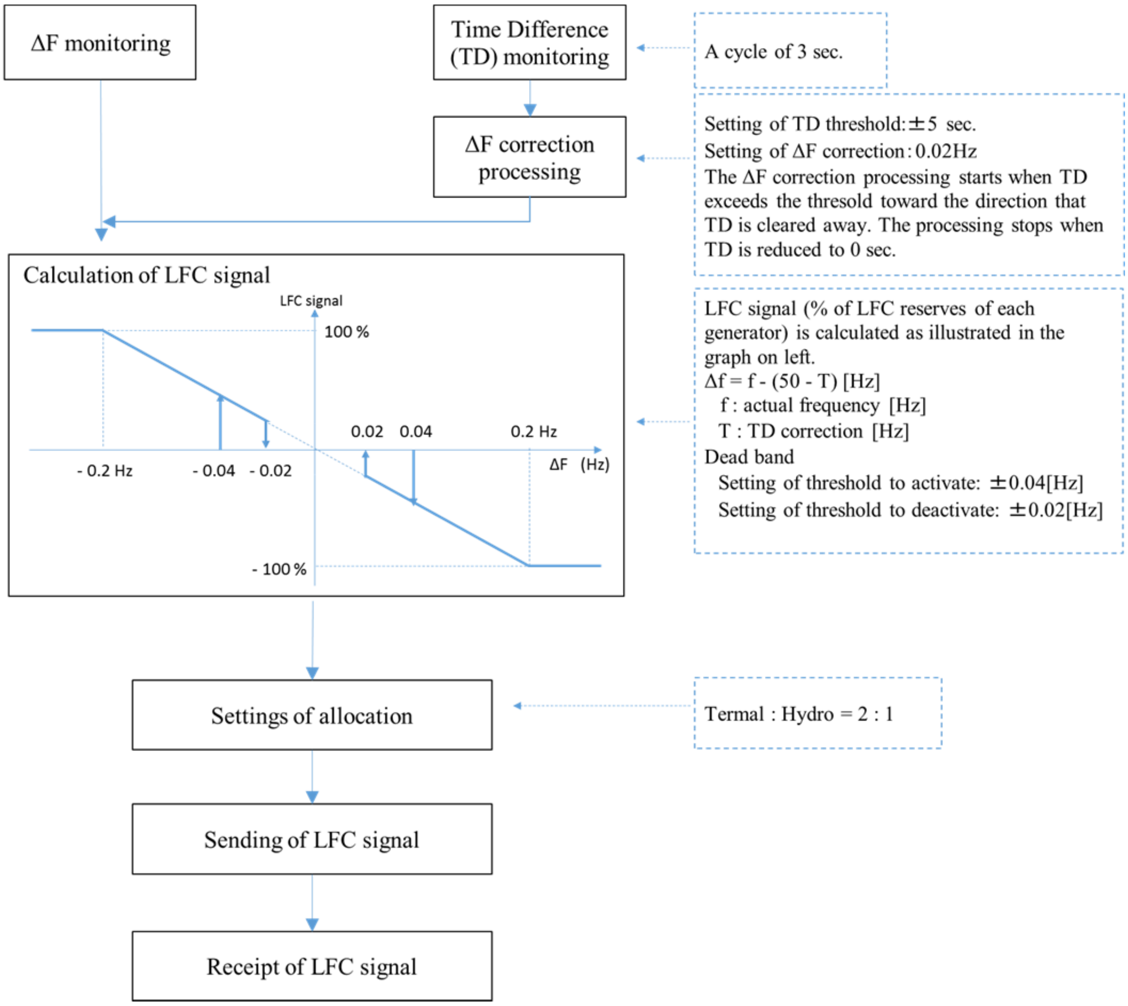


Figure 17-24 Flow Diagram for LFC in TEPCO

17.6.3 Early Applicableness of Load Frequency Control by NLDC System

We conducted a survey by questionnaire to the existing generating stations. Thanks to an enormous efforts and cooperation by BPDB, following 7 power stations kindly gave us their responses. According to the results of survey, there is no useful data or documents including LFC flow diagram, except one station:

- Barapukuria Coal Power Plant
- Bheramara Power Plant
- Haripur 100MW Power Station
- Sylhet 150MW Combined Cycle Power Plant
- Rangpur 20MW Gas Turbine Power Station
- Saidpur 20MW Gas Turbine Power Station
- Dohazari-Kailiaish 100MW Peaking Power Station

Therefore, there is no choice except to target the newly installed generating units for LFC. It is essential to take the function into consideration when preparing the specifications or designing, and to agree to cooperate among NLDC, Generators and manufacturers to provide and perform data O&M.

It will take several years to set the project on its way, and it is still uncertain to catch up with the development and commencement of nuclear power generation in 2024.

17.6.4 Solution - Early Applicableness of FGMO

On the other hand, FGMO has high potential of prompt and wide expansion because:

- Obligation of equipment and operation of Free-Governor Mode has already been stipulated in Grid Code.
- FGMO by a part of gas-turbine generators has already agreed and started to execution. (Refer to 17.5.2 (3))
- FGMO can realize each generating unit alone. It does not need to be controlled by central system such as SCADA/EMS in NLDC and to develop or improve the communication channels on a large scale.

Remaining challenge is to enforce the obedience to the rules and to monitor and regulate generators to perform FGMO from the commencement of operation.

Chapter 18 Thermal Power Plant O&M

18.1 Outline

This section describes the contents of thermal O&M briefly.

18.1.1 Ascertaining actual conditions in Bangladesh

Based on a list of existing power stations, the JICA survey team carried out a narrowing of the target power stations based on selection criteria, discussed this with the working group, and then decided the target power station.

Table 18-1 The Target Power Station List

BPDB Annual Report 2012-2013

Name of powerplant	For		COD (Year)	Type	Fuel	Installed	Derated	Plant factor	Efficiency (NET)	
	O&M	C/C				(MW)	(MW)	(%)	(%)	
Rauzan #1		○	1993	ST	Gas	210	180	23.94	27.98	*1
Rauzan #2		○	1997	ST	Gas	210	180	15.80	28.89	*1
Ashuganji #3、#4、#5	○	○	1987/87/88	ST	Gas	450	430	88.56	33.88	
Siddhirganj	○	○	2004	ST	Gas	210	150	56.98	30.32	
Barapukuria #1,#2	○		2009/2009	ST	Coal	250(125*2)	200	75.37	27.56	
Chandpur	○		2012	CC	Gas	163	163	49.68	37.27	
Haripur GT1,GT2,GT3		○	1987	GT	Gas	32*3	60	53.33	21.16	
Ghorasal #3,#4	○	○	1987/89	ST	Gas	420(210*2)	360	69.53	31.09	
Ghorasal #5,#6	○	○	1995/99	ST	Gas	420(210*2)	380	33.72	28.76	
Tongi		○	2005	GT	Gas	105	105	38.38	25.93	
Baghabari		○	2001	GT	Gas	100	100	87.52	28.29	
Shahjibazar		○	2000	GT	Gas	70(35*2)	66	76.36	25.53	
Fenchuganj	○		2011	CC	Gas	104	104	49.08	30.06	
Sylhet		○	2012	GT	Gas	150	142	51.96	29.16	

*1) Rauzan power station 1)lack of gas causes low availability
2)large scale of its generation capacity
Because of above reasons, Rauzan power plant also listed in candidate plants list.

Source: JICA PSMP2015

Based on the list, the JICA survey team visited the thermal power stations to ascertain and gather information on the actual conditions.
*refer to 18.3.2 O&M actual conditions

Table 18-2 Actual Condition Interview Sheet

Maintenance plan	Based on a manual and experience, the maintenance plan is made Approved by BPDB
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	
-Budget approval	Period awaiting plan and expense approval in BPDB
-Procurement schedule	Because, after budget approval, a bid will be carried out. After contract approval, equipment procurement will done.
-Shut down permission	Shut down permission will be done by Power Div after procurement.
Manufacture support for daily	None
Daily maintenance	Maintenance staff of power station
Major inspection	Maintenance staff of power station and

	manufacturers of major equipment
Safety for staff	No management *only BPDB manual basically No periodic safety education
Efficiency management	No management *only calculate monthly average No periodic performance test
Fuel analysis	No analysis
Environmental regulations	No regulation *DOE is going to determine the regulation level in the near future
Report for Head office	Made by operator (handwritten)
Equipment issues	*Does not reach rated output *There are some problems, but related information is very limited.
Staff issues	Inside BPDB, short of human resources
Training system	*OJT *Only lecture training *Lack of technology for operation and maintenance

Source: JICA PSMP2015

Categorized and arranged for "staff", "equipment and plan & approve", "budget" and "information".
*refer to 18.3.3 Staff to 18.3.6 information and 18.3.7 summary,gathering for each item

Table 18-3 Information Categorized Sheet

Staff	*Under-education and only lecture education training center *Low security awareness *Discrimination towards the post due to education before entering a company
Equipment and maintenance plan	*Does not reach rated output * Plan realization of the periodic inspection is low *Delay in the shutdown permission. In some cases, a few years *No manufacturer support *Low consciousness of efficiency
Budget	*Takes a long time for the budget approval *No permission for LTSA
Information	*Trouble addressing based on own experience *There is no active support from the manufacturer *There is no information sharing among the power stations

Source: JICA PSMP2015

18.1.2 Problem

Issue for "staff", "equipment and plan & approve", "budget", "information"
*refer to 18.4.5 issues

Table 18-4 Issues in Each Category

Staff	*There is no effective training center or curriculum for Staff
Equipment and maintenance plan	*Delay in maintenance plan approval and shutdown permission because there is no mid-long term maintenance plan. * Shutdown permission not given because of lack of generation capacity. *Lack of technical skill due to lack of information *Does not reach rated output
Budget	*No mid-long term maintenance plan.
Information	*No information sharing strategy

Source: JICA PSMP2015

18.1.3 Countermeasures

Countermeasures are separated and written for “equipment and plan & approve” and “staff, budget and information”.
For “equipment and plan & approve”, the JICA survey team suggested that steam turbine rehabilitation and combined cycle remodeling are able to use Japanese technology.
For “staff, budget and information”, first of all, the key point is “information”; thus, the JICA survey team suggested “information strategy”. Human resource development is also an important issue; therefore, the team suggested “training center”.
The details are mentioned in the following sections.

18.6 Rehabilitation plan
18.7 Combined cycle power generation remodeling plan
18.8 Information strategy
18.9 Training center

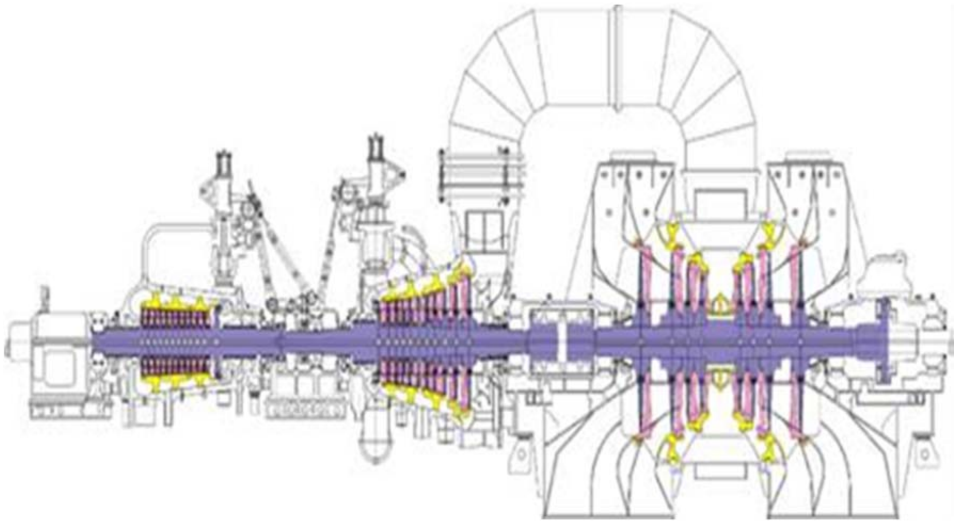
Table 18-5 Countermeasure of Each Category

Equipment and maintenance plan	Rehabilitation of steam turbine
	Combined cycle power generation remodel
	Information strategy
Staff・budget・information	Information strategy
	Human resource development(training center)

Source: JICA PSMP2015

18.1.4 Rehabilitation

The target rehabilitation equipment is Steam turbines; therefore, before the site visit, the JICA survey team selected Ghorasal Units 4 and 5 and Siddhirganj power station as target sites.



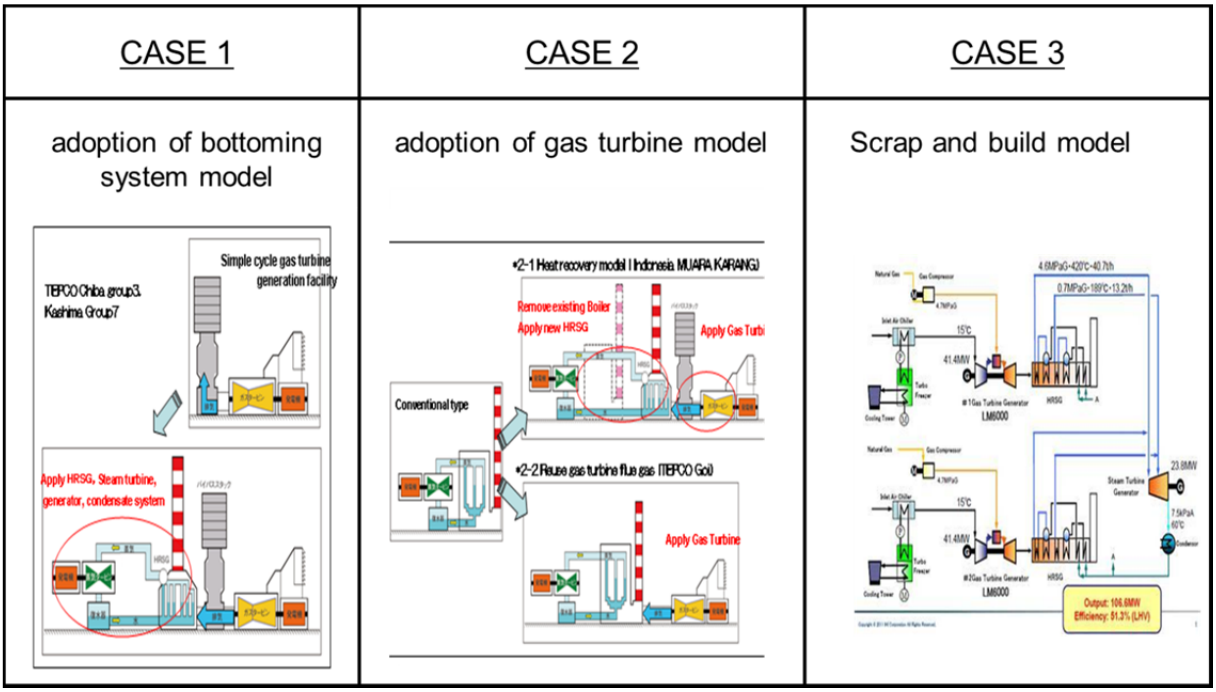
Source: JICA PSMP2015

Figure 18-1 Steam Turbine Rehabilitation Scope

But, after the site investigation, because Siddhirganj power station has generation trouble and a power generation limitation (=150MW), the JICA survey team had to exclude it from the target sites. At Ghorasal power station, because unit 4 is carrying out a major overhaul and unit 5 has maintenance planned for next February, and because they want more generation capacity if they have a rehabilitation plan, they did not accept the rehabilitation idea.

18.1.5 Combined cycle power generation remodeling plan

Based on the actual situation in Bangladesh, which has uneasiness over its power supply, the JICA survey team studied 3 types of combined cycle power generation remodeling plan. Case 3, “build and scrap”, is the most suitable for Bangladesh because it can maintain power supply ability. Build and scrap model does not have any mechanical limitation of its capacity if the area has enough space basically, but because this remodeling plan utilize existing transmission facilities and natural gas supply system, there for, there are at least two limitations, one of them is transmission facilities capacity and the other one is amount of natural gas supply limitation. By the reason mentioned above, the JICA survey team suggested 100MW class small CCGT, and also its short start time characteristics and high effectiveness. BPDB head office and PGCB both agreed to this idea, then advised the locations of Fenchuganj and Haripur for a candidate site. Thus, the JICA survey team prepared Fenchuganj and Haripur site plans, and discussed with Fenchuganj power station and EGCB which would hopefully be the owner of the new Haripur.
As a result, Fenchuganj and EGCB both needed a bigger capacity generation plant, such as 250MW or more, and they did not agree to the 100MW combined cycle power generation remodeling plan.



Source: JICA PSMP2015

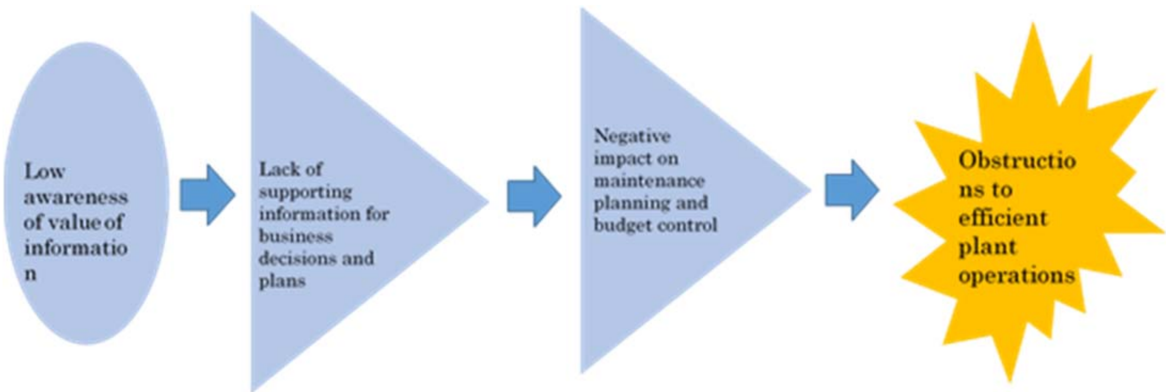
Figure 18-2 Type of Combined Cycle Power Generation Remodeling Plan

18.1.6 Information/data sharing strategy

The biggest challenge the power sector in Bangladesh faces today, power shortages, can be broken down into smaller problems (obstructive factors), some of which can be solved by implementing information management and sharing.

Survey results indicate that the key problems reside in the three core activities of the power generation business: plant operation, failure response and repair & maintenance planning. The challenges are mainly caused by the absence of sufficient information and process disruption.

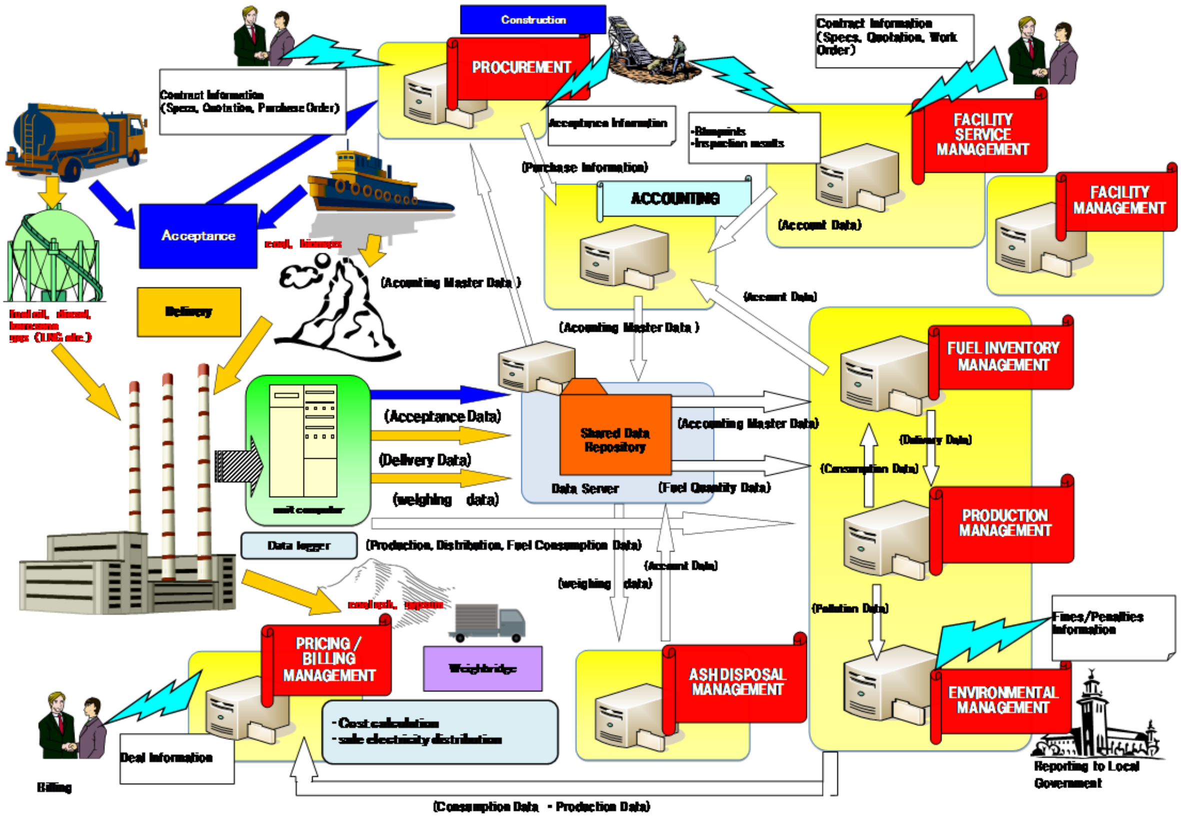
In particular, a lack of supporting data for practicing preventive maintenance and planning and creating a feasible budget is the key problem which needs to be addressed as a priority. In efforts of facility operation and maintenance, efficient handling of a wide variety of large volume data is the key to success.



Source: JICA PSMP2015

Figure 18-3 Low Awareness of Significance of Information Management

From an enterprise perspective, the business objectives of the organization as a whole need to be achieved; therefore, key performance indicators are to be introduced. It is important for the top management to define meaningful indicators and keep monitoring them. One of the findings from the survey is that the inefficiency in information collection processes hinders effective use of information in decision making. Analytical use of various types of information helps the organization take corrective actions smoothly.

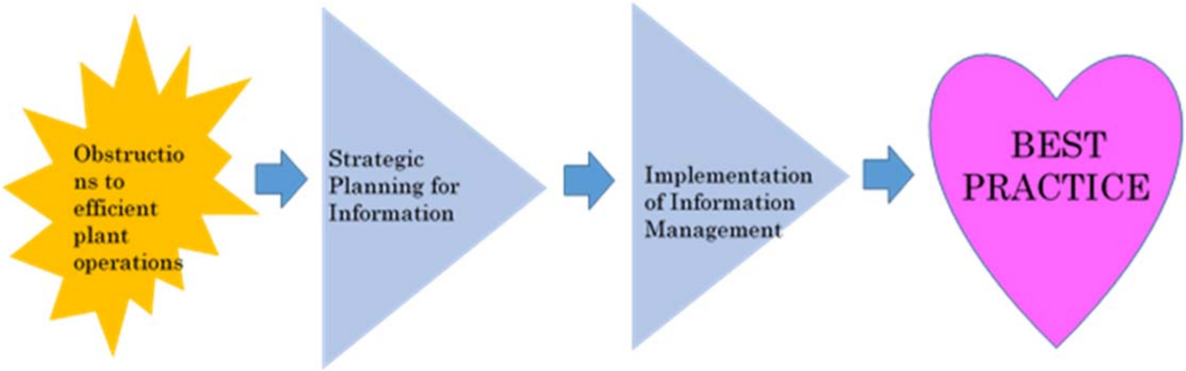


Source: JICA PSMP2015

Figure 18-4 Future of the Power Plant Information Management System

Our proposals emphasize implementation of the strategic use of information across the core business activities of the power generating business. The implementation process consists of a series of steps: Plan, Do, Check, Act. This PDCA cycle is a powerful tool to use in business performance improvement activities. The cycle can be enforced throughout the organization by information sharing and collaboration among business units. The top management is expected to create an information management strategy to define and control information flows and process interactions.

Once the processes are established and the information for sharing is defined, it is very easy to make a plan, take an action, measure the efficiency and apply the results in decision making. One of our objectives is to enforce this improvement cycle throughout the organization by implementing information sharing and collaboration among the business units. As an implementation model of a modern power sector, our proposal also contains an overview of the conceptual model of information management for a power plant in Bangladesh.

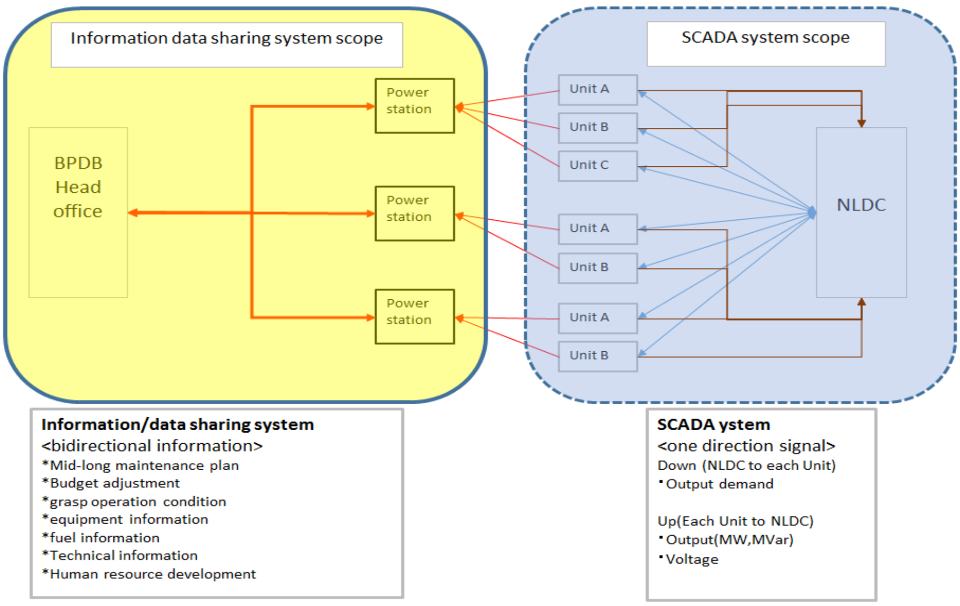


Source: JICA PSMP2015

Figure 18-5 Implementation of Information management towards Best Practice

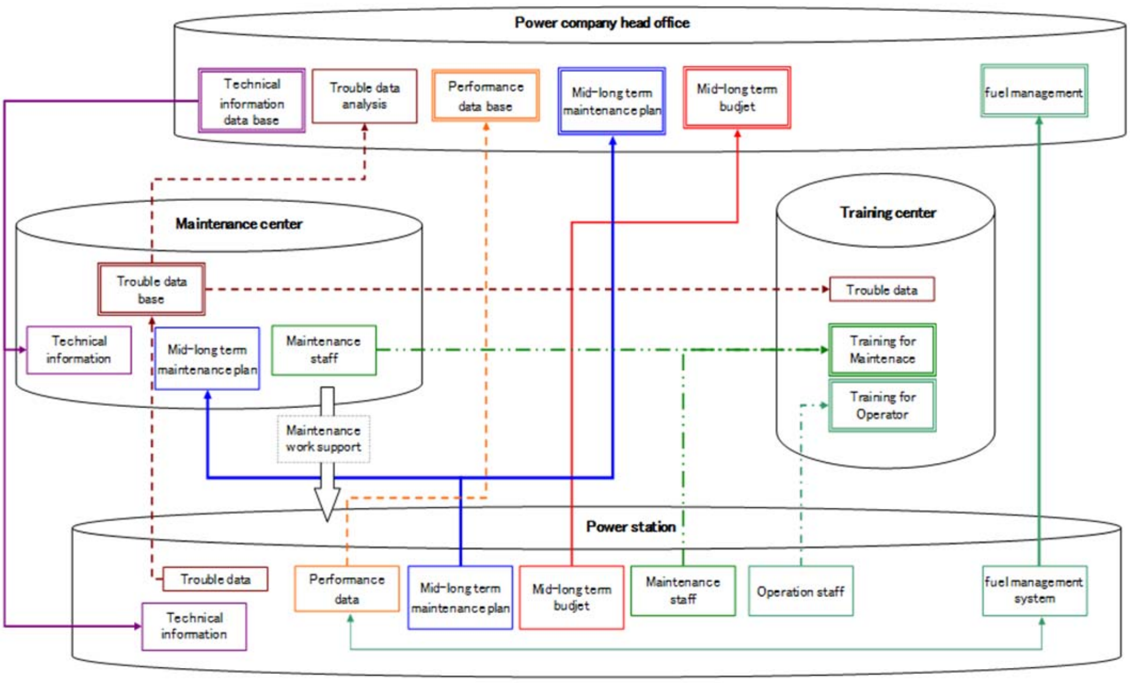
In order to implement the proposed information management model, the concepts of an information sharing platform and functions are also shown. Finally, requirements in preparation for implementation which need to be addressed are listed for further survey.

In order to achieve the proposed plan, a conceptual model of the information management system is shown in Figure 18-40. The requirements for the implementation of the system are also listed in Table 18-24, and these need to be addressed in further surveys.
The figure below shows the scopes of the information management system and the SCADA system, which connects the dispatch center and the power plants.
The SCADA system is an independent network system which does not share its purposes with the information management system.



Source: JICA PSMP2015

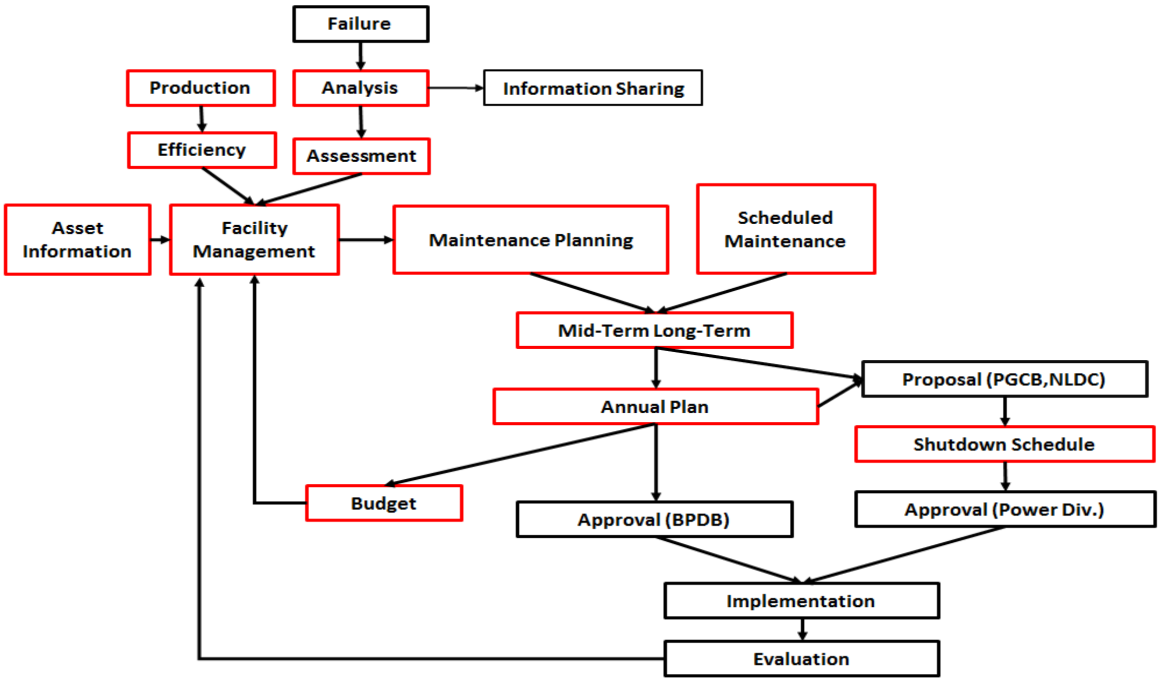
Figure 18-6 Scope of Information Sharing System and SCADA System



Source: JICA PSMP2015

Figure 18-7 Illustration of Information Sharing System

The information management system provides an integrated method of information control across the organization. By ensuring the implementation processes, positive outcomes in O&M can be expected, which leads to a best practice such as that achieved in Japan. In the figure below, the items in the red boxes are within the scope of the target system.

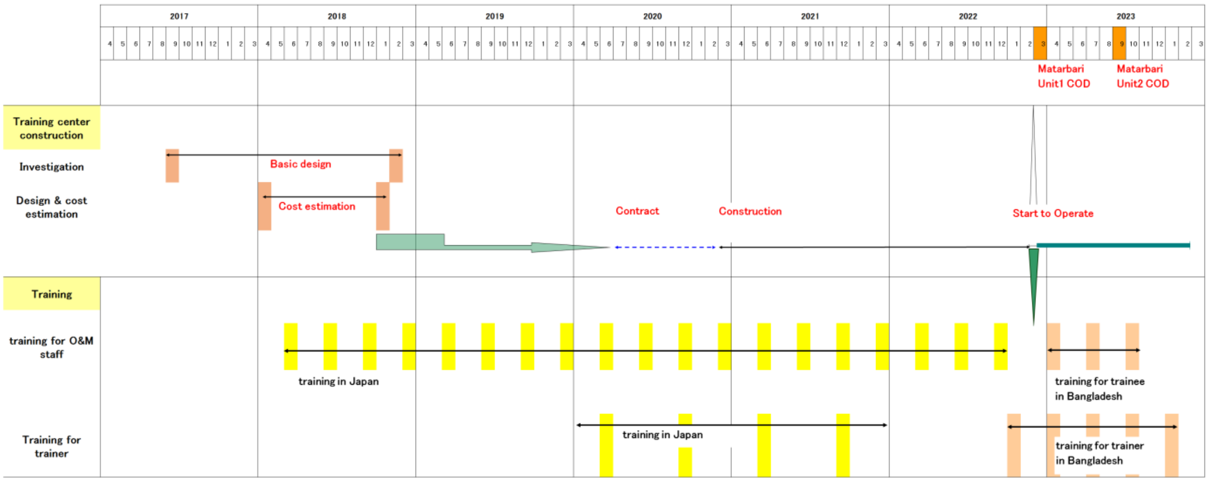


Source: JICA PSMP2015

Figure 18-8 O&M Best Practice Supported by Information Sharing System

18.1.7 Training center

For human resource development, it is suggested that the training center should have real equipment, and also that trainees can get many kinds of experience. The training center needs “equipment”, “a good curriculum”, “good trainers” and “rotation for trainers”. The following drawing shows the schedule plan for the training center whose target is “Matarbari”, which is the first USC in Bangladesh.
*refer to 18.9.7 schedule



Source: JICA PSMP2015

Figure 18-9 Schedule Plan for Training Center Construction

18.2 Basic Survey for Bangladesh Thermal Power

18.2.1 Equipment

The existing power stations and those planned for construction are as follows.

Data source : PGCB Daily Gen, Petro Bangla Daily, Summit power, GTCL Daily, TGTDCL, PGCL, BCMCL, BPDB AR 11-12, Project list 2014

Serial Number of PGCB	Plant name	Configuration	Original installed capacity (MW)	Derated capacity at 2015/01 (MW)	Generation Capacity 2012-2013 (MW)	Sector	Producer (Source: PGCB)	Commercial Operation Date
1a	Ghorasal Power Station ST-1	55 MW ST; Unit-1	55	85	48	Public	BPDB	1974
1a	Ghorasal Power Station ST-2	55 MW ST; Unit-2	55		30	Public	BPDB	1976
1b	Ghorasal Power Station ST-3	210 MW ST; Unit-3	210	170	180	Public	BPDB	1986/9/14
contracted?	ST-3 repowering plan	add 206MW GT				Public	BPDB	2017/Feb.
1c	Ghorasal Power Station ST-4	210 MW ST; Unit-4	210	180	180	Public	BPDB	1989/3/18
1d	Ghorasal Power Station ST-5	210 MW ST ;Unit-5	210	190	190	Public	BPDB	1994/9/15
1e	Ghorasal Power Station ST-6	210 MW ST ; Unit-6	210	190	190	Public	BPDB	1999/1/31
under evaluation	ST-6 repowering plan	add 206MW GT						2017/Dec
2	Ghorashal 100 MW QRPP (Aggreko)	128x0.85MW	100	100	100	Private	QRPP 3yrs, Aggreko	2010/8/23
3	Ghorashal 45 MW QRPP (Aggreko)	50x0.85	45	45	45	Private	QRPP 3yrs, Aggreko	2010/8/10
4	Ghorashal MAX Power 78MW	4x19.6MW	78	78	78	Private	RPP, Max power	2011/5/27
5	Ghorasal(Regent) 108MW	108MW (34*3.35MW)	108	108				
6	Haripur GT-1	BPDB 33MW / PGCB 32 MW	32	60	20	Public	SBU, BPDB	1987
6	Haripur GT-2	BPDB 33MW / PGCB 32 MW	32		20	Public	SBU, BPDB	1987
6	Haripur GT-3	BPDB 33MW / PGCB 32 MW	32		20	Public	SBU, BPDB	1987
7	Haripur 412MW CCPP	412MW (1on1)	412	412		Private	IPP	2014/March?
8	Haripur NEPC (HFO) 110MW	110MW (8x15MW)	110	110	85	Private	IPP	1999
9	Haripur Power CCPP 360MW , AES	360MW (GT:235MW+ST:125MW)	360	360	360	Private	IPP	2001/5/23
10	Meghnaghat CCPP , AES	450MW (GT:150MW*2+ST:150MW)	450	450	450	Private	IPP	2002/11/26
11	Meghnaghat/Meghnagat IEL (100MW)	100MW QRPP (5 Yrs) IEL, 12x8.9MW	100	100	100	Private	IEL	2011/5/8
12(new)	Meghnaghat CCPP(Summit power) 203MW	203MW (2*110MW) , SC GT	203	203		Private		
under construction	Meghnaghat 300-450 MW CCPP Unit-2 (315MW)	(ST:115MW to N,o12) GT203MW				Private	N/A	2014
13	Madanganj/Modanganj (Summit) 102MW	102MW (6x17.08MW)	102	100	100	Private	QRPP 3yrs, Summit power	2011/4/1
14	Keraniganj (Powerpac) 100MW QRPP	100 MW (8x14.4MW)	100	100	100	Private	RPP 5years, Power pack	2012/3/27
15	Narshingdi/Narsindi (REB Doreen)	22MW (8x2.9MW)	22	22	22	Private	SIPP, REB, Doreen Generation and systems	2008/12/21
16a	Siddhirgonj Power Station (ST) 210MW	210 MW Steam Turbine	210	150	150	Public	BPDB	2004/9/3
16b	Siddhirgonj Power Station (GT-1 & GT2) 210MW	BPDB 2*120MW / PGB 210MW (2x105 MW) G/T	210	210	210	Public	EGCB	#1:2011/12/1, #2:2012/2/5
17	Siddhirgonj (Desh) 96MW QRPP	96MW (96x1.2MW)	100	98	96	Private	QRPP 3yrs, Desh energy	2011/2/17
18	Siddhirganj / Siddhorganj (Dutch-Bangla) 100 MW	100MW (12x8.9MW)	100	100	100	Private	RPP 5yearsm Dutch Bangla power	2011/7/21
19	Pagla (DPA Power QRPP) 50MW	50MW (100x0.5MW) DPA Power	50	50	50	Private	QRPP 3yrs	2010/11/24
20	Gangnagar , (Narayanganj) 100MW PP (Orion)	102MW	102	102		Private	IPP	2014/6/3
21	Summit Power Ltd (Dhaka) (disaggregated follows)	6*3.67MW+2*6.97MW*14*8.73MW	146	146	146	Private	SIPP, REB	2006/12/16
retired	Madhabdi 35 MW REB	N/A	N/A	N/A	N/A	Private	REB, Summit power	
retired	Ashulia 45 MW REB	N/A	N/A	N/A	N/A	Private	REB, Summit power	
retired	Maona 33 MW SIPP	N/A	N/A	N/A	N/A	Private	REB, Summit power	2009
retired	Rupganj 33 MW SIPP	N/A	N/A	N/A	N/A	Private	REB, Summit power	2009/6/9
22	Gazipur 50MW (RPCL)	52MW (6*8.9MW)	52	52	52	Public	IPP, RPCL	2012/7/1
23	Tongi Power Station (105MW)	105MW Gas Turbine	105	105	105	Public	BPDB	2005/3/28
Dhaka area								
24a	Raujan,Chittagong Power Station ST: Unit-1, 210MW	210 MW S/T	210	180	180	Public	BPDB	1993/3/28
24b	Raujan,Chittagong Power Station ST: Unit-2, 210MW	210 MW S/T	210	180	180	Public	BPDB	1997/9/21
25	Raozan/ Raujan 25 MW PP (RPCL)		25	25	25	Public	RPCL	2013/5/3
26(COD)	Baraka-Patanga/Patenga 50MW(Barakafulla)		50	50		Private	IPP	
27(on test)	Chittagong Energy pack		no data			Private	IPP	
28	Karnafuli Hydro Power Station	40MW; Unit-1	40	230	30	Public	BPDB	1962
28	Karnafuli Hydro Power Station	40MW; Unit-2	40		40	Public	BPDB	1962
28	Karnafuli Hydro Power Station	50MW; Unit-3	50		50	Public	BPDB	1982
28	Karnafuli Hydro Power Station	50 MW; Unit-4	50		50	Public	BPDB	1988
28	Karnafuli Hydro Power Station	50 MW; Unit-5	50		50	Public	BPDB	1988
29a	Chittagong Sikalbaha ST (60MW)	60MW	60	40	40	Public	BPDB	1984
29b	Sikalbaha Peaking GT (150MW)	150MW	150	150	150	Public	BPDB	2010/8/18
30	Sikalbaha (Energis)	35MW	no data	35		Private	RPP	
retired?	Shikalbaha RPP 55MW	55 MW (4x12.5MW+2x11.9MW+1x3MW)	55		53	Private	RPP 3yrs	2010/6/5
31	Hathazari 100MW peaking PP	100MW (11x8.9MW) Peaking PP	98	98	100	Public	BPDB	2011/12/23
32	Sangu, Dohazari-Kalaish 100MW peaking	102MW (6x17MW)	102	102	100	Public	BPDB	2011/12/30 or 2012/1/1
33	Juldah/Julda (Acorn) 100MW(8*13.45MW)	100MW (8x13.45MW)	100	100	100	Private	RPP 5years, Acorn Infra.Service	2012/3/26
34	Barabkunda/Barobkundo SIPP 22MW	22MW (8x2.90MW)	22	22	22	Private	SIPP, PDB	2009/5/23
35	Malancha, Ctg EPZ (United) 36MW	36MW (5*8.73MW+3*9.34MW ?)	36		30	Private		
Chittagong area								
36a	Ashugonj Power Station Unit-1,-2 , 64MW*2	128MW (64MW*2)	128	97	55	Public	APSCL	1970
36b	Ashugonj Power Station Unit-3, 150MW	150MW ST	150	135	140	Public	APSCL	1986
36c	Ashugonj Power Station Unit-4, 150MW	150MW ST	150	129	150	Public	APSCL	1987
36d	Ashugonj Power Station Unit-5, 150MW	150MW ST	150	134	140	Public	APSCL	1988
36e	Ashugonj GT-2 (56MW)	56MW	56	40	40	Public	APSCL	1986
36f	Ashuganj/ashugonj Engines 50MW	53MW (16x3.35MW)	53	45	51	Public	APSCL	2011/4/30
37	Ashugonj RPP (Precision) 55MW	55MW (15x4MW)	55	55	55	Private	RPP 3yrs	2010/7/4
38	Ashuganj Aggekko 95MW	95MW (96x1.1MW) ←増出力(80MW;82*1.1MW)	95	95	80	Private	RPP 3years, Aggreko	2011/5/31→
39	Ashuganj United Power 53MW (14*4MW)	53MW (14x4MW)	53	53	53	Private	RPP 3years, United Ashugonj power	2011/6/22
40	Ashuganj (Midland) 51MW	51MW (6*9.34MW)	51	51		Private		2013/12/6
41	Brahmanbaria (Aggreko) 85MW	85MW (86*1.1MW) ←増出力(70MW;72*1.1M)	85	85	70	Private	QRPP 3yrs, Aggreko	2011/6/30 →
42	Titas Daudkandi/Doudkandi 50MW peakingPP	52MW (6x 8.92MW)	52	52	52	Public	BPDB	2011/10/29
43	Chandpur CCPP 150MW	163MW (GT:106MW, ST:57MW)	163	163	163	Public	BPDB	2012/GT mar/ST:2012/7/1
44	Feni (Doreen) 22MW	22MW (8X 2.94MW) , Feni	22	22	22	Private	SIPP, BPDB	2009/2/16
45	Feni Mohipal (Doreen) 11MW	11MW (4*2.9MW)	11	11	11	Private	SIPP, REB, Dreen Generation and systems	2009/4/22
46	Jangalia, Summit, 33MW(4*8.73MW)	33 MW (4x8.73MW)	33	33	33	Private	SIPP, BPDB, Summit power	2009/5/12
47(new)	Lakdhanvi-52MW	52MW	52	52		Private	IPP	
48	Summit power, Comilla 25MW	25MW (3*3.67MW+2*6.97MW)	25	25	25	Private	SIPP, REB	
Comilla area								

Serial Number of *PGCB*	Plant name	Configuration	Original installed capacity (MW)	Derated capacity at 2015/01 (MW)	Generation Capacity *2012-2013 (MW)*	Sector	Producer *(Source: PGCB)*	Commercial Operation Date
49	RPCL CCPP (Mymensingh CCPP) 210MW	210MW (4*35MW+70MW)	210	202	197	Private	IPP	1999/11/20
50	Tangail (Doreen) 22MW	22MW (8*2.9MWor 2.5MW?)	22	22	22	Private	SIPP, BPDB	2008/11/12
Mymensingh area								
51a	Fenchugonj Comb. Cycle (CCPP-1) 97MW	DPDB 97MW (GT:2x32MW, ST:33MW)	97	80	90	Public	BPDB	1994-95
51b	Fenchugonj Comb. Cycle (CCPP-2) 104MW	GT:2x35MW, ST:35MW	104	90	104	Public	BPDB	2011/10/26
52	Fenchugonj/Fenchuganj (Barakatullah) 51 MW	51MW (19*2.9MW)	51	51	51	Private	RPP 15yrs	2009/10/18
53	Fenchuganj Energyprima 44MW	44MW (12*3.3MW + 5*2MW)	44	44	44	Private	RPP, energy prima	2012/2/15
54	Hobiganj (Confidence-EP) 11MW	11MW(4*2.9MW)	11	11	11	Private	SIPP, REB	2009/1/10
retired	Shahjibazar Power Unit-5,6 ,38MW	38 MW	38	N/A	0	Public	BPDB	
55	Shahjibazar GT: Unit- 8,9 , 70MW	BPDB/PGCB 70MW (2*35MW)	70	66	66	Public	BPDB	2000
ECNEC Approved	Shahibazar conversion 105MW	ST35MW 増設計画	N/A					2017/june
56	Shahjibazar (Shahibazar, Sahzinazar) 86MW	86MW (32x2.90MW)	86	86	86	Private	RPP 15yrs	2009/2/9
57	Shahjibazar (, Sahzinazar) , Energyprima) 50MW	50MW (27x2.0MW)	50	50	50	Private	RPP 3yrs	2008
58	Sylhet 150 MW	BPDB 150MW / PGCB 142MW	150	142	142	Public	BPDB	2012/3/28
under evaluation	Sylhet conversion 150MW→225MW	add 75MW	N/A			Public	BPDB	2017/jan
59	Sylhet 20MW GT	20MW	20	20	20	Public	BPDB	1986
60	Sylhet (Energyprima), Kumargoan, 48MW	48MW (29x1.95MW)	48	50	50	Private	RPP 3yrs	2008
61	Shahjahanulla/ Shajahanulah power Com 25MW	3*9.34MW	25	25				2013/11/1
62	Sylhet (Desh) , Kumargao/kumkargoan , 10MW	10MW (6*1.95MW)	10	10	10	Private	RPP 15yrs	2009/3/15
Shihet area								
63	Bheramara GT Unit-1, -2,-3 , 60MW	60MW (3*20MW) GT	60	46	16	Public	BPDB	1976/76/80
64	Bheramara (Quantum) 105MW	BPDB 110MW/ PGCB:105MW (12x8.5MW+2x6MW+2x13MW)	105	105	105	Private	RPP 3yrs	2010/12/31
65	Bheramara HVDC Interconnector 500MW (直流送電)	500MW	500	500				2013/11/1
66a	Khulna ST 110MW	110 MW Steam Turbine	110	55	55	Public	BPDB	1984
66b(ritered in 2013)	Khulna ST 60MW	60 MW Steam Turbine	60	N/A	30	Public	BPDB	1973
67	Khulna (KPCL-1) 110MW	110MW (19x6.5MW)	110	110	110	Private	IPP	1998
68	Khulna (KPCL-2) ,Summit power , 115MW	115MW (7x17MW) , QRPP (5 Yrs)	115	115	115	Private	IPP,KPCL	2011/6/1
69	Faridpur 50MW peaking	54MW (8*6.89MW), Peaking PP	54	54	54	Public	BPDB	2011/11/4
70	Khulna 150MW GT	158MW(GT)	158	158		Public	NWPGCL	2013/9/23
(70b contructed)	Khulna 150MW GT→ 225MW (ST75MW,CCPP)	75MW(ST)	N/A			Public		2015/sep
retired	Khulna RPP(Aggreko) 40MW	40MW (50x0.80MW)	40	N/A	40	Private	RPP 3yrs	2008
74	Khulna Aggreko 55MW	55 MW (71*0.85MW)	55	55	55	Private	QRPP 3yrs	2010/8/10
71	Gopalganj/Gopalgonj/ Gopanlgonj 100MW peaking PP	109MW (16*6.98MW)	109	109	109	Public	BPDB	2011/9/29 or 2011/11/16?
72	Noapara/ Nowapara (Quantam) 105MW	101MW (5x9.9MW+6x9.5MW+2x9.2MW)	105	101	101	Private	RPP 5years,Quantum power system	2011/8/26
73	Noapara/ Nowapara (Khanjahan Ali) 40MW(5*8.5MW)	40MW (5*8.5MW), QRPP (5 Yrs)	40	40	40	Private	RPP, khan Jahan Ali	2011/5/28
Khulna area								
75	Barisal GT : Unit-1 20MW	20 MW Gas Turbine	20	30	16	Public	BPDB	1984
75	Barisal GT : Unit-2 20MW	20 MW Gas Turbine	20		16	Public	BPDB	1987
76	Bhola (Venture) 33MW	34.5 MW	33	33	33	Private	RPP 3yrs	2009/7/12
Barisal area								
77a	Baghabari GT 71MW	71MW Gas Turbine	71	71	71	Public	SBU, BPDB	1991
77b	Baghabari GT 100MW	100MW Gas Turbine	100	100	100	Public	SBU, BPDB	2001
ECNEC Approved	Baghabari 100MW conversion→ 150MW	add 50MW→ 150MW	N/A					2017/June
78	Baghabari 50MW peaking PP	52MW (6*8.9MW)	52	52	52	Public	BPDB	2011/8/29
79 (retired in 2013)	Westmont GT, Baghabari	2x45MW	90	N/A	70	Private	IPP	1999
80	Bera Peaking 70MW	71MW (9*8.29MW)	71	71	71	Public	BPDB	2011/10/28
81	Amnura 50MW, Sinha Power	50MW (7*7.79MW),	50	50	50	Private	RPP 5years, Sinha power	2012/1/13
82	Katakhali, Rajshahi (Northern) 50 MW	50MW (6*8.92MW)	50	50	50	Private	RPP, NPSL	2012/5/23
83	Katakhali 50MW Peaking PP	50MW (6*8.7MW)	50	50		Public	BPDB	2012/12/1
84:COD	Sirajganj/Sirajigonj CCPP (150→225MW完工) NWPGCL	210MW (GT:150MW. ST:75MW)	210	210		Public	NWPGCL	GT 2012/9/1→2014/May?
85	Santahar 50MW peaking	50MW (6*8.7MW)	50	50		Public	BPDB	2012/12/1
86	Bogra (GBB) 22MW	22MW (6*4MW)	22	22	22	Private	RPP 15yrs	2008
87	Bogra Energyprima 20MW	20MW (5*3.3MW+5*2MW)	20	20	20	Private	RPP 3yrs, energy prima	2011
88	Ullapara (Summit) 11MW	11MW (4*2.9MW)	11	11	11	Private	SIPP, REB, Summit power	2009/3/2
89(COD)	Natore 52MW / Raj Lanka /Rajshahi	52MW (6*8.92MW)	52	52				2014/1/24
Rajshahi area								
90	Barapukuria ST : Unit-1,2 , 250MW	2x125MW	250	200	200	Public	BPDB	2006
91	RangpurGT 20MW	20MW Gas Turbine	20	20	20	Public	BPDB	1988
92	Syedpur/Saidpur GT 20MW	20MW Gas Turbine	20	20	20	Public	BPDB	1987
93	Thakurgaon (RZ) 47MW	BPDB:55MW / PGCB:47MW(20x1.5MW+21x1.1MW)	47	40	47	Private	RPP 3yrs	2010/8/2
Rangpur area								

Source: JICA PSMP2015

Figure 18-10 List of Existing Power Plants

Serial Number of *PGCB*	Plant name	Configuration	Original installed capacity (MW)	Derated capacity at 2015/01 (MW)	Generation Capacity *2012-2013 (MW)*	Sector	Producer *(Source: PGCB)*	Commercial Operation Date
test run	Ghorasal/ Ghorashal, Narsingdi/Narsindl 100 MW PP	108MW	108			Private	IPP	2014/july→
under construction	Munshiganj (Kathpotti) 50 MW PP	53MW	53			Private	IPP	2014/sep →
under construction	Chittagong (Patenga/potiya) 100 MW PP	108MW	108			Private	IPP	2014/oct→
under construction	Bhola 225 MW CCPP : SC GT 125MW ←150MW ?	GT 125MW ←150MW ?	150			Public	BPDB	2014/Nov→
under construction	Ashuganj 225MW CCPP : SC GT Umit 150MW	GT 150MW	150			Public	APSCL	2014/dec→
under construction	Ashuganj 225MW CCPP : SC ST Unit 75MW	ST 75MW	75			Public	APSCL	2015/June
under construction	Bibiana #2 341MW CCPP(Summit) : SC GT Unit	222MW(GT)	222			Private	BPDB	2015/jan
under construction	Kodda, Gazipur 150 MW PP	150MW	150			Public(BPDB-RPCL)	BPDB	2015/Feb
under construction	Jangalila, Comilla, 52MW peaking	52MW	52					2015/mar
under construction	Ashuganj (South) 450 MW CCPP	373MW (CCGT)	373			Public	APSCL	2015/june
contructed	Co'xbazar 60MW PP	60MW	60			Private		2015/june
under construction	Ashuganj 195MW Modular PP	195MW	195			Public	APSCL	2015/june
under construction	Siddhirganj 335MW CCPP : GT 200MW	200MW GT	200			Public(EGCB)	EGCB	2015/june
under construction	Siddhirganj 335MW CCPP : ST 135MW	135MW ST	135			Public	EGCB	2016/march
under construction	Biblana #2 341MW CCPP : SC ST Unit	119MW(ST)	119			Private	BPDB	2015/july
under construction	Bhola 225 MW CCPP : SC ST 70MW	ST 70MW	70			Public	IPP	2015/aug
contructed	Keraniganj 100MW PP (re-locate from khulna)	100MW	100			Private	IPP	2016/jan
under construction	Narayanganj 53MW	53MW	53			Private	REB	2016/jan
contructed	Manikganj 55MW PP	55MW	55			Private	REB	2016/march
Approved by Purchase Committee	Fenchuganj 50 MW PP	50MW	50			Private	IPP	2016/march
LOI	Munshiganj (Kathpotti) 50 MW PP	50MW	50			Private	IPP	2016/june
under construction	Bosila, Keraniganj, 108MW CCPP(CLC power)	108MW(GT)	108			Private	IPP	2016/june
under construction	Nababganj/ Nababgonj 55MW PP	55MW	55			Private	REB	2016/june
PPA	Kusiara 163MW CCPP	163MW	163			Private	IPP	2016/june
contructed	Chapai nababganj 104MW PP	104MW	104			Public	BPDB	2016/june
ender	Kaptai Solar 8MW	8MW	8			Public	BPDB	2016/june
Tender	Hatiya hybrid (Diesel Generator/solar) 7MW	7MW	7			Public	BPDB	2016/june
Approved by Purchase Committee	Sorishabari 3MW solar	3MW	3			Private	IPP	2016/june
contructed	Shahjibazar CCPP : GT216MW	GT 216MW	216			Public	BPDB	2016/june
contructed	Shahjibazar CCPP : ST 116MW	ST 116MW	116			Public	BPDB	2017/march
NOA,	Sikalbaha 225 MW CCPP : GT	150MW(GT)	150			Public	BPDB	2016/sep
NOA,	Sikalbaha 225 MW CCPP : ST	75MW(ST)	75			Public	BPDB	2017/june
NOA,	Sirajganj #2, 225MW CCPP : SC GT	150MW	150			Public	NWPGCL	2016/sep
NOA,	Sirajganj #2, 225MW CCPP : SC ST	70MW	70			Public	NWPGCL	2017/june
PPA	Sirajganj 367MW CCPP : SC GT	249MW GT	249			Private	IPP	2016/sep
LOI	Sirajganj 367MW CCPP : SC ST	118MW ST	118			Private	IPP	2017/june
PQ&RFP evaluattion	Dhorola 30MW solar park	30MW	30			Private	IPP	2016/dec
under evaluation	Bibiana south 383MW CCPP ,SC GT	GT 252MW	252			Public	BPDB	2017/jan
under evaluation	Bibiana south 383MW CCPP ,SC ST	ST 131MW ; conbined 383MW	131			Public	BPDB	2018/jan
contructed	Ashuganj (North) CCPP 381MW	381MW	381			Public	APSCL	2017/jan
2014→2017	Ghorasai 363MW CCPP : SC GT Unit 254MW	254MW GT	254			Public	BPDB	2017/march
2015→2018	Ghorasai 363MW CCPP : SC ST Unit 109MW	109MW ST	109			Public	BPDB	2018/jan
2015→2017	Bheramara 414MW CCPP : SC GT Unit 260MW	260MW GT	260			Public	NWPGCL	2017/march
contructed	Bibiana #3 CCPP 400MW GT:274MW	274MW GT	274			Public	BPDB	2017/march
contructed	Bibiana #3 CCPP 400MW ST:126MW	126MW ST	126			Public	BPDB	2018/jan
contructed	Barapukuria 275MW, Unit 3	274MW ST	274			Public	BPDB	2018/jan
contructed	Maowa, Munshiganj 522MW coal fored pp(Orion)	522MW	522			Private	IPP	2018/jan
contructed	Khulna 630 MW Coal fired pp (Orion)	630MW	630			Private	IPP	2018/jan
N/A	International Grid Connection	500MW	500					2018/dec
LOI	Chittagong 282MW Coal fired PP (Import coal)	282MW	282			Private	IPP	2019/march
LOI	Dhaka 282MW Coal fired PP (import coal)	282MW	282			Private	IPP	2019/march
PPA	BIFPCL, Rampal, Coal fired PP 1,320MW	1,320MW	1320			Public	BIFPCL	2019/June
	Chittagong 1000MW CCPP(LNG)	1,000MW	1000			Public	BPDB	2019/Dec
LOI	Chittagong 612MW Coal fired PP S.alam group (Import coal)	612MW	612			Private	IPP	2020//Jan
LOI	Dhaka 635MW coal fired pp (Orion)	635MW	635			Private	IPP	2020/Jan
preliminary	LNG based 1,000MW CCPP	1,000MW	1000			Public	BPDB	2020/June
FS	Moheskhali 1,200MW coal fired PP (JV Huadian/ECA)	1,200MW	1200			Public	BIFPCL	2021/June
LOI	Chittagong 612MW Coal fired PP S.alam group (Import coal)	612MW	612			Private	IPP	2021/Jan
FS finish	Matarbari 1,200MW coal fired PP	1,200MW	1200			Public	CPGCL	2021/Dec
	BPDB and CHHKLChina JV ,Chittagong,Co'x Bazar	1,320MW	1,320			Public	BCFPCL	
	Patuakhali , Barisal Patuakhali	!,320MW	1,320			Public	CMC-NWPGCL	
	Moheskhali PP ,Chittagong,Co'x Bazar	!,320MW	1,320			Public	-	
	1,320MW PP with South Korea (West Generation Power Compa	1.320MW	1,320			Public	WGPC	
	Chittagong-Anowara PP , Chittagong, Anowara	1,320MW	1,320			Public	-	
	Munshiganj 600-800MW PP	800MW	800			Public	-	
	Ashuganj Coal- based pp , Barisal	1,320MW	1,320			Public	APSCL	
	Barapukuria 300MW financed by ECA, Rangpur,Dinajpur	300MW	300			Public	BPDB	
	Bashkhali 600MW, chittagong (Bangladesh Machine Tools Facto	600MW	600			Private	BMTFL	
	Mirersorai Chittagong 150MW Commercial pp (Chittagong powe	150MW	150			Private	BSRM	

Source: JICA PSMP2015

Figure 18-11 List of Planned Power Plants

(1) O&M target site selection
To ascertain the O&M situation in Bangladesh as a whole, the JICA survey team carried out screening with the following selection criteria. The team also considered the rehabilitation target site and combined cycle power generation remodeling plan target site.

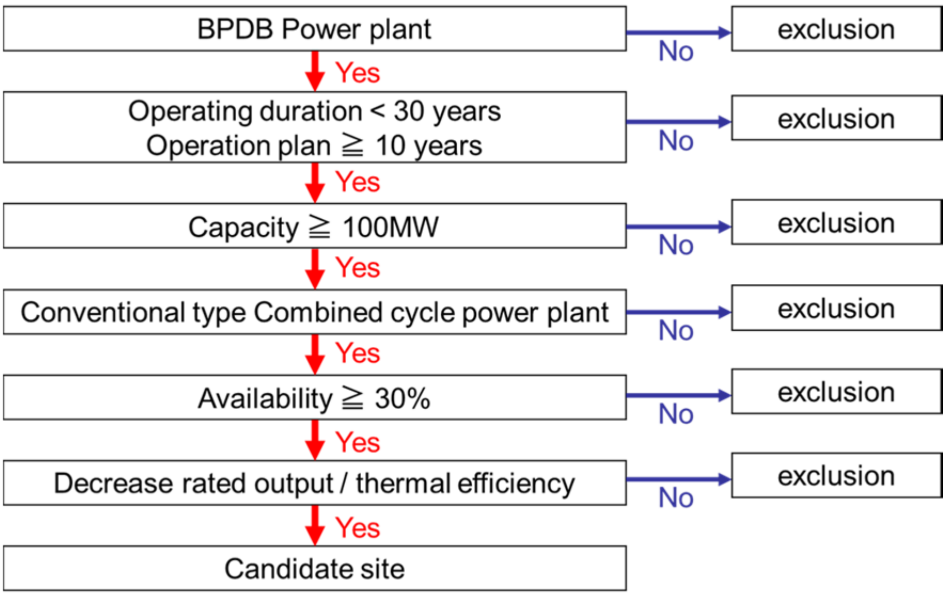
(2) Screening criteria and grounds
(a) BPDB owned
Grounds: BPDB is the largest generation public company in Bangladesh, and thus, cooperation can be expected for the JICA survey team investigation

(b) Operation period: more than 10 years, less than 30 years
Grounds: if more than 10 years, they have enough experience
a unit more than 30 years old can have large-scale malfunctions, and if it underwent rehabilitation or combined cycle power generation remodeling more than 10-20 years' stable operation could not be expected.

(c) More than 100MW
Grounds: hard to expect a rehabilitation effect for a small power unit

(d) Availability more than 30%
Grounds: means it is a very useful plant; thus, it will be operated more.

(e) The output or efficiency decreasing
Grounds: can expect rehabilitation effect.



Source: JICA PSMP2015

Figure 18-12 Site Selection

After site selection, the JICA survey team submits the target site list and discusses it with working group members. Finally, the target site list is decided.

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Name of powerplant	For		COD (Year)	Type	Fuel	Installed	Derated	Plant factor	Efficiency (NET)	
	O&M	C/C				(MW)	(MW)	(%)	(%)	
Rauzan #1		○	1993	ST	Gas	210	180	23.94	27.98	*1
Rauzan #2		○	1997	ST	Gas	210	180	15.80	28.89	*1
Ashuganji #3、#4、#5	○	○	1987/87/88	ST	Gas	450	430	88.56	33.88	
Siddhirganj	○	○	2004	ST	Gas	210	150	56.98	30.32	
Barapukuria #1,#2	○		2009/2009	ST	Coal	250(125*2)	200	75.37	27.56	
Chandpur	○		2012	CC	Gas	163	163	49.68	37.27	
Haripur GT1,GT2,GT3		○	1987	GT	Gas	32*3	60	53.33	21.16	
Ghorasal #3,#4	○	○	1987/89	ST	Gas	420(210*2)	360	69.53	31.09	
Ghorasal #5,#6	○	○	1995/99	ST	Gas	420(210*2)	380	33.72	28.76	
Tongi		○	2005	GT	Gas	105	105	38.38	25.93	
Baghabari		○	2001	GT	Gas	100	100	87.52	28.29	
Shahjibazar		○	2000	GT	Gas	70(35*2)	66	76.36	25.53	
Fenchuganj	○		2011	CC	Gas	104	104	49.08	30.06	
Sylhet		○	2012	GT	Gas	150	142	51.96	29.16	

*1) Rauzan power station 1)lack of gas causes low availability
2)large scale of its generation capacity
Because of above reasons, Rauzan power plant also listed in candidate plants list.

Source: JICA PSMP2015

Figure 18-13 Target Site List

After site investigation, the JICA survey team writes down the next section.

18.3 Actual O&M Situation

18.3.1 Power station situation

(1) Rauzan thermal power station (main fuel : natural gas)

Basic information : COD unit 1: 1993, unit 2: 1997
Capacity (COD) : 210MW, 210MW
Capacity (Now) : 180MW, 120MW

Organization chart: Non-acquisition

Table 18-6 Rauzan Thermal Power Station

Maintenance plan	Unidentified
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Cannot get shutdown permission because of lack of power supply
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	Manufacture
Safety for equipment	Firefighting system
Safety for staff	Has safety rules *there is a human accident data book
Efficiency management	Monthly average efficiency calculated by SAE
Fuel analysis	No analysis

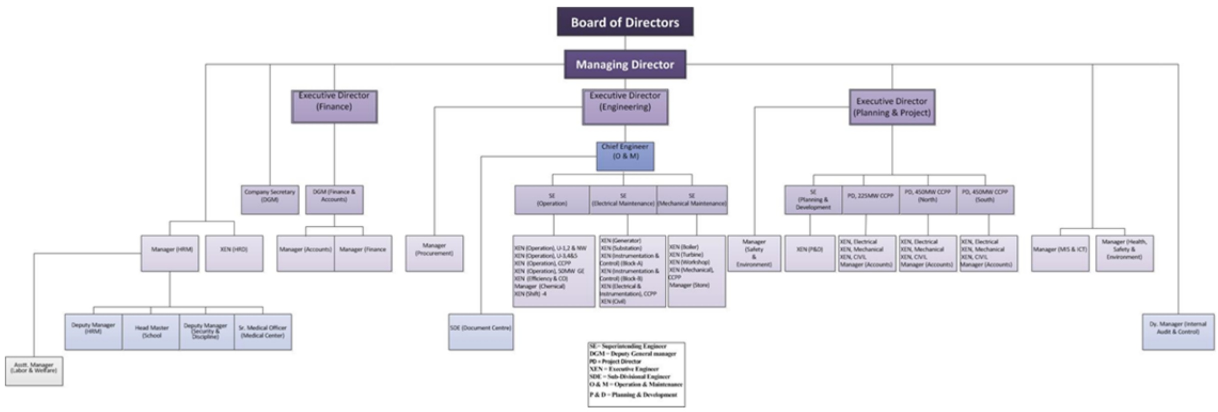
Environmental regulation	Unidentified
Organization for operation	13 staff/shift (10 operators for 2 units, shift-leader, shift sub-leader, supervisor), 3 shifts
Patrol for site	Unidentified
Plant condition report	Operator checks and records every 2 hours
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*No root cause analysis for unit 2 explosion and there are also no countermeasures *Does not reach rated output
Capacity limitation	Yes
Future plan	Unit 2 has a plan for large scale repair at next outage by Chinese manufacturer
Peculiar information	These plants can operate until facility replacement parts disappear
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	They have not received enough gas, but they believe gas will be supplied

Source: JICA PSMP2015

(2) Ashuganj thermal power station (main fuel : natural gas) units 3, 4 and 5

Basic information : COD unit 3: 1986, unit 4: 1987, unit 5: 1988
Capacity (COD) : 150MW, 150MW, 150MW
Capacity (Now) : 135MW, 129MW, 134MW

Organization chart:



Source: Ashuganj thermal power station

Figure 18-14 Ashuganj Organization Chart

Table 18-7 Ashuganj Thermal Power Station

Maintenance plan	Chief engineer
Maintenance plan basic idea	Few days' short stop maintenance and every 3 months maintenance
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Cannot get shutdown permission from Power div
Manufacture support for daily	Unidentified
Daily maintenance	Maintenance staff
Major inspection	Unidentified
Safety for equipment	Firefighting system
Safety for staff	Health and safety section was established in 2013. *in emergency, contact hospital and head office (*there is no communication chart)
Efficiency management	Monthly average efficiency calculated by efficiency section
Fuel analysis	No analysis
Environmental regulation	No (there is no emission monitor)
Organization for operation	6 staff / shift, 4 groups, 3 shifts
Patrol for site	Every 2 hours
Plant condition report	Operation group makes operation log sheet. It includes unit start up/shut down events and trip events
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*Does not reach rated output *High pressure heater tube leak
Capacity limitation	Yes
Future plan	Combined cycle power generation remodeling plan sequentially
Peculiar information	None
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	No

Source: JICA PSMP2015

(3) Siddhirganj thermal power station (main fuel : natural gas)

Basic information : COD 2004
Capacity (COD) : 210MW
Capacity (Now) : 150MW

Organization chart: Non-acquisition

Table 18-8 Siddhirganj Thermal Power Station

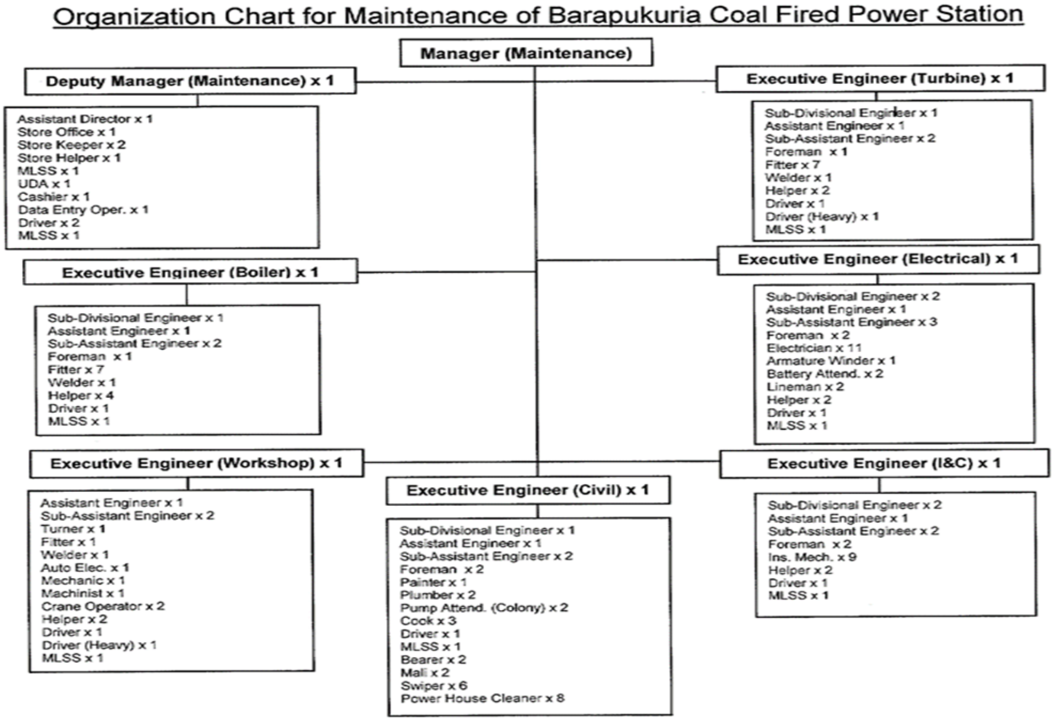
Maintenance plan	Unidentified
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Unidentified
Reason to disturb it	Unidentified
Manufacture support for daily	Yes (Russian company)
Daily maintenance	Maintenance staff *there is a workshop
Major inspection	Unidentified
Safety for equipment	Firefighting system
Safety for staff	No record
Efficiency management	Monthly average efficiency only
Fuel analysis	No analysis
Environmental regulation	Unidentified
Organization for operation	9 staff/shift (operator *4, Engineer *5) 4 groups/3 shifts Others:11 staff for local (day shift)
Patrol for site	Once/shift
Plant condition report	Operation group makes operation log sheet every hour. *auxiliary equipment switch over test (there is a monthly schedule)
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output
Capacity limitation	Yes - 150MW (Generator has trouble)
Future plan	None
Peculiar information	Unidentified
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	Uneasy *the generation output is 110MW degree because of shortage of gas supply

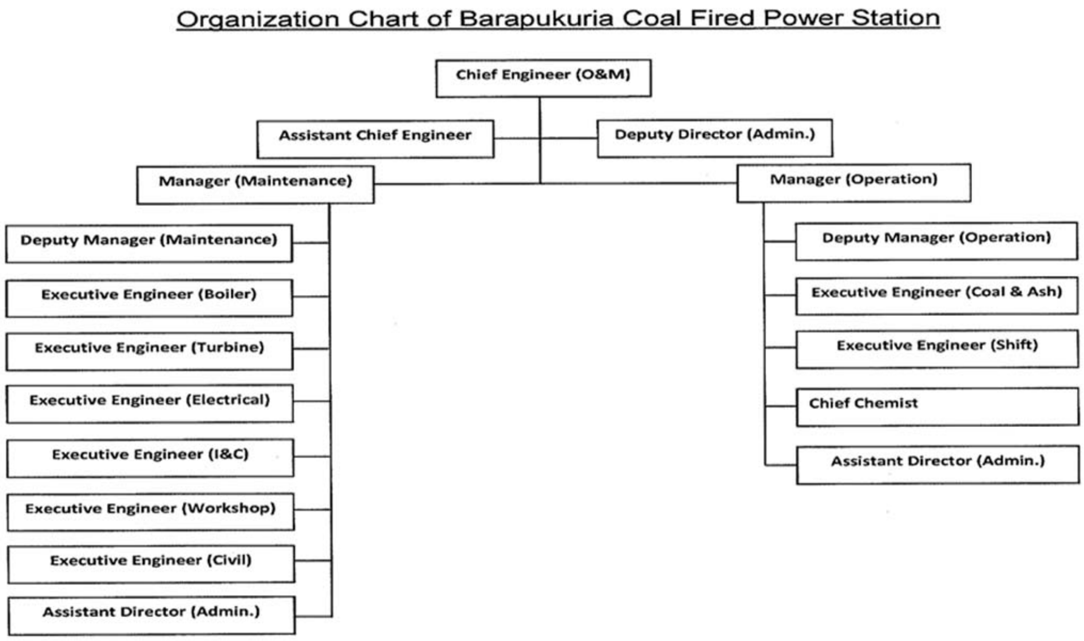
Source: JICA PSMP2015

(4) Barapukuria thermal power station (main fuel : Coal)

Basic information : COD 2005
Capacity (COD) : 250MW (125MW*2)
Capacity (COD) : 180MW

Organization chart:





Source: Barapukuria thermal power station

Figure 18-15 Barapukuria Organization Chart

Table 18-9 Barapukuria Thermal Power Station

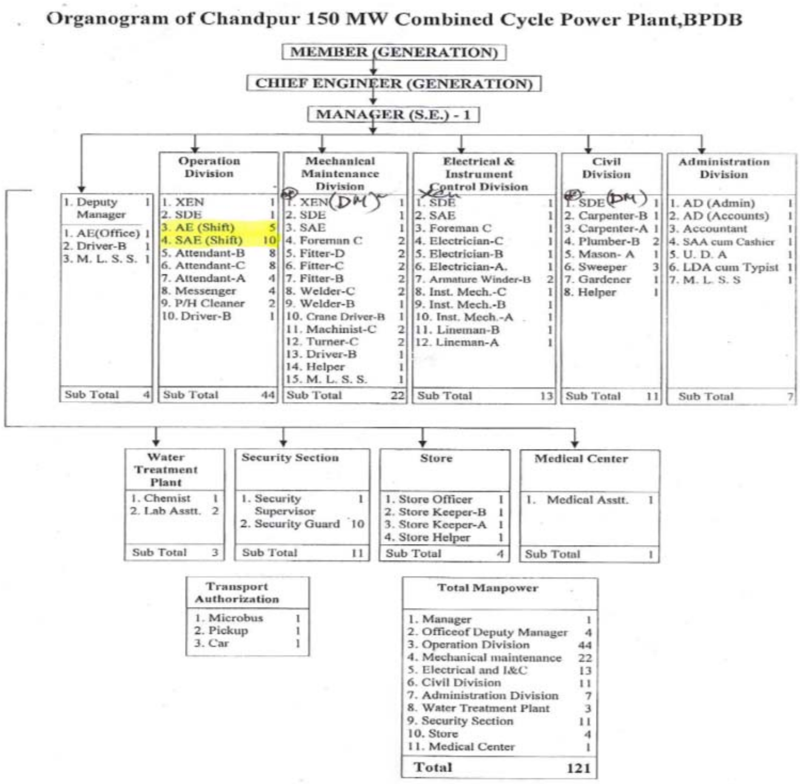
Maintenance plan	Executive engineer, approved by manager
Maintenance plan basic idea	Boiler inspection every 2.5 months, major inspection every 4 years *They have a 3 year maintenance plan
Feasibility of maintenance plan	*Boiler minor inspection will be held as scheduled *major maintenance has never been carried out since COD.
Reason to disturb it	BPDB: budget issue Power Div: shutdown permission issue
Manufacture support for daily	Unidentified
Daily maintenance	Maintenance staff *they have spare parts based on 10 years' experience
Major inspection	Main equipment (boiler, turbine): manufacture other portions: maintenance staff
Safety for equipment	Firefighting system
Safety for staff	BPDB guideline only *there are no individual rules, and no safety section in power station. *if a person is injured, they submit a report to BPDB head office
Efficiency management	Monthly average efficiency only *No performance test
Fuel consumption	2,400ton/day for 2 units
Fuel analysis	*they do analysis every day, but if heat value is not over/under 6,100kcal/kg +/-10%, then they use 6,100kcal/kg, the same as the construction period value.
Environmental regulation	Nox: 150ppm、Sox: 277ppm
Organization for operation	4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	*Operation group makes operation log sheet. *auxiliary equipment switch over test
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *because coal includes small stones, it breaks coal mill equipment
Capacity limitation	180MW (because mill cannot operate at rated speed)
Future plan	None
Peculiar information	Bituminous coal (6,100kcal/kg +/-10%) They cannot inspect boiler equipment by themselves
Staff issues	Unidentified
Training system	OJT and using BPDB training center

Source: JICA PSMP2015

(5) Chandpur thermal power station (main fuel : natural gas)

Basic information	:	COD 2012
Capacity (COD)	:	163MW
Capacity (Now)	:	163MW

Organization chart:



Source: Chandpur thermal power station

Figure 18-16 Chandpur Organization Chart

Table 18-10 Chandpur Thermal Power Station

Maintenance plan	Executive - electrical engineer, - operator, - mechanical engineer -> plant manager Finally, BPDB approves
Maintenance plan basic idea	No original maintenance plan *just finished warranty period
Feasibility of maintenance plan	Ignorance *because, during construction period, they have priority over other plants
Reason to disturb it	-
Manufacture support for daily	None *they consider making a contract with manufacture
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff + overseas expert company (Indian engineering) *Indian engineering company cooperates with Tongi thermal power station

Safety for equipment	Firefighting system
Safety for staff	They have BPDB guideline, and also helmets and gloves, but nobody cares *There is no penalty for not following a manual ・Staff can take lectures at BPDB training center
Efficiency management	Monthly average efficiency calculated by operation sector *performance test carried out during commissioning period only *managed by performance acceptance committee
Fuel analysis	No analysis *using fixed value that was established in commissioning period because same gas field's gas has same content
Environmental regulation	No regulation
Organization for operation	9 staff /shift (engineer *3, skilled technician) 5 groups, 3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	None
Capacity limitation	None
Future plan	None
Peculiar information	None
Staff issues	Because salary is low, the human resources they developed flow out to other power stations *short of staff
Training system	OJT *every member of staff goes to training center at Tongi twice/year *the contents are mainly lectures
Uneasiness concerning natural gas supply	Unidentified

Source: JICA PSMP2015

(6) Ghorasal thermal power station (main fuel : natural gas)

Basic information : COD unit 4: 1989, unit 5: 1995
Capacity (COD) : 210MW, 210MW
Capacity (Now) : 180MW, 190MW

Organization chart: Non-acquisition

Table 18-11 Ghorasal Thermal Power Station

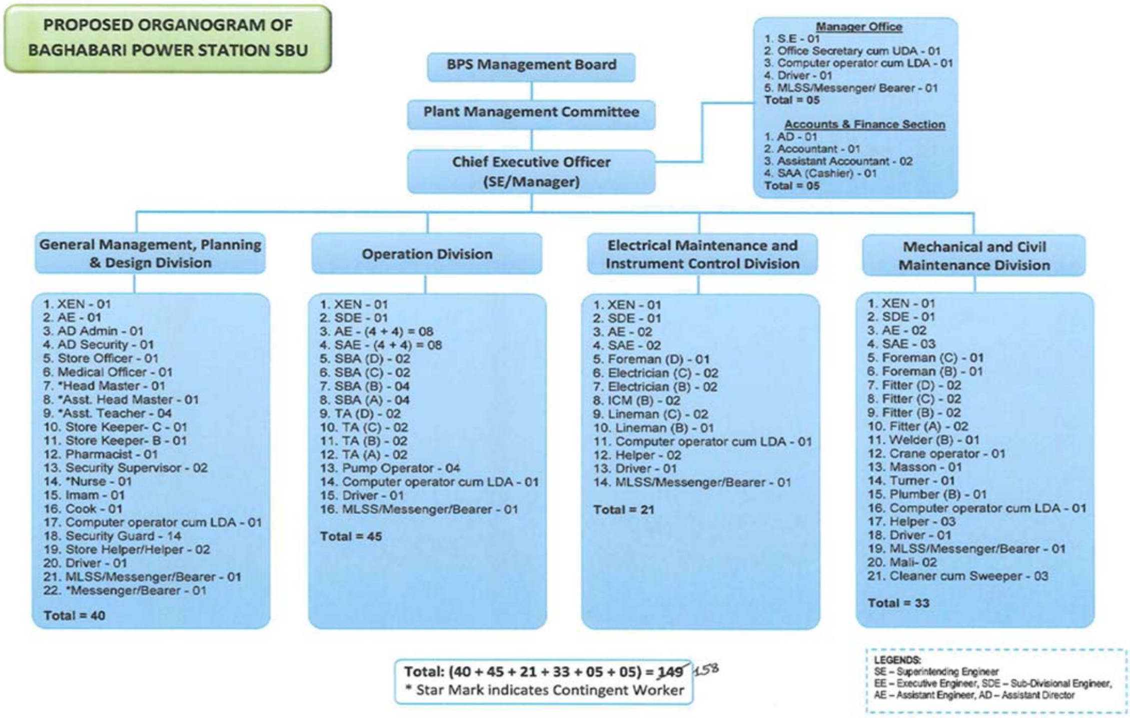
Maintenance plan	4 section managers make, -> plant manager approves, BPDB approves finally
Maintenance plan basic idea	Make every year
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Unidentified
Manufacture support for daily	None *No contract, no support *basically, there is no contract
Daily maintenance	Maintenance staff + workshop
Major inspection	Main: Maintenance staff, Some portion: manufacture
Safety for equipment	Firefighting system
Safety for staff	BPDB guideline
Efficiency management	Calculated by efficiency division every day *Monthly average report to head office *No performance test
Fuel analysis	No analysis
Environmental regulation	Unidentified
Organization for operation	Engineers: 5 groups/3 shifts Technicians: 4groups/3 shifts 5 officers, 25 staff /2 units Total of 20 officers and 100 staff for 4 control rooms; Units 1 & 2, units 3 & 4, units 5 & 6 and network
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *Overhaul need for 25 year old plant *DCS and exciter have to be replaced
Capacity limitation	Yes
Future plan	Unit 5 will have overhaul from Feb 2016 Units 3 & 6 have a repowering plan with duck burner in flue gas duck Unit 7 is under construction (target 365MW)
Peculiar information	None
Staff issues	No problem
Training system	OJT They have training center *the contents are mainly lectures *every member of staff attends a 60 hour lecture per year
Uneasiness concerning natural gas supply	No

Source: JICA PSMP2015

(7) Baghabari thermal power station (main fuel : natural gas)

Basic information : COD unit 1: 1991, unit 2: 2001
Capacity (COD) : 71MW (Flame 7B), 100MW (Flame 9E)
Capacity (Now) : 71MW, 100MW

Organization chart:



Source: Baghabari thermal power station

Figure 18-17 Baghabari Organization Chart

Table 18-12 Baghabari Thermal Power Station

Maintenance plan	Engineer + Plant manager > BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	*Approve -> purchase order -> shutdown permission; this flow takes a long time *BPDB does not allow LTSA contracts. Before periodic maintenance, they have to buy every needed spare part and consumable part. It also takes a long time
Manufacture support for daily	None *need contract with manufacture
Daily maintenance	Maintenance staff
Major inspection	CI: maintenance staff HGPI, MI: GE
Safety for equipment	Firefighting system

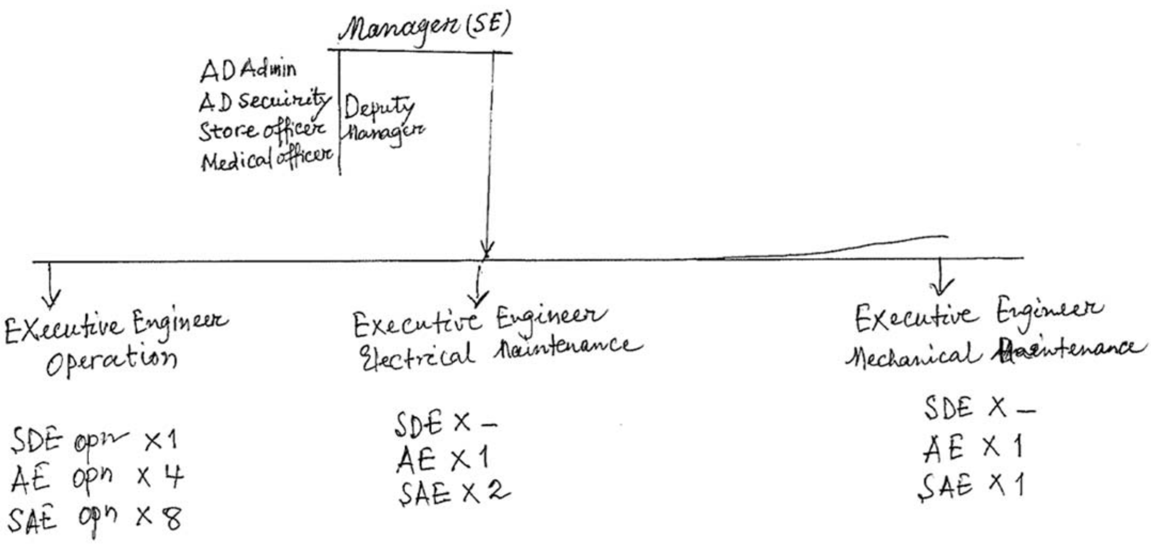
Safety for staff	They have BPDB guideline, and also helmets and gloves, but nobody cares
Efficiency management	Calculated by shift engineer every day *Monthly average report to head office *No performance test
Fuel analysis	No analysis Getting analysis data from gas company *the analysis data is similar to EPC analysis data during commissioning period
Environmental regulation	Every 2 years, they have DOE survey
Organization for operation	5 staff/shift (Shift engineer *1, service assistant *1, assistant (electric) engineer *1, turbine attendant *1, data sampling *1) 4 groups (total 20 staff)/3 shifts
Patrol for site	Unidentified
Plant condition report	Electric engineer, turbine engineer make each part of a daily log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	None
Capacity limitation	None
Future plan	Unit 2 has combined cycle power generation remodeling plan (100MW→150MW)
Peculiar information	None
Staff issues	No problems
Training system	OJT No curriculum for training BPDB training is theory lecture mainly
Uneasiness concerning natural gas supply	Unidentified

Source: JICA PSMP2015

(8) Shahbazar thermal power station (main fuel : natural gas)

Basic information	:	COD 2000 (GT 2 units)
Capacity (COD)	:	35MW (Flame 6B)*2
Capacity (Now)	:	35MW*2

Organization chart:



Source: Shahijbazar thermal power station

Figure 18-18 Shahjibazar Organization Chart

Table 18-13 Shahjibazar Thermal Power Station

Maintenance plan	Maintenance staff, -> plant manager coordinate, finally BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Have to wait for shutdown permission from Power Div
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	CI, HGPI: Maintenance staff MI: manufacture support
Safety for equipment	Firefighting system
Safety for staff	At the time of introduction, training only *they have a concept
Efficiency management	Monthly average efficiency only *No performance test
Fuel analysis	No analysis
Environmental regulation	No regulation (no CEMS)
Organization for operation	5 staff/shift (chief *1, sub chief *1, operator *3) 4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *basic information
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Before major inspection they have to purchase all needed spare parts, so cannot proceed as scheduled
Capacity limitation	None

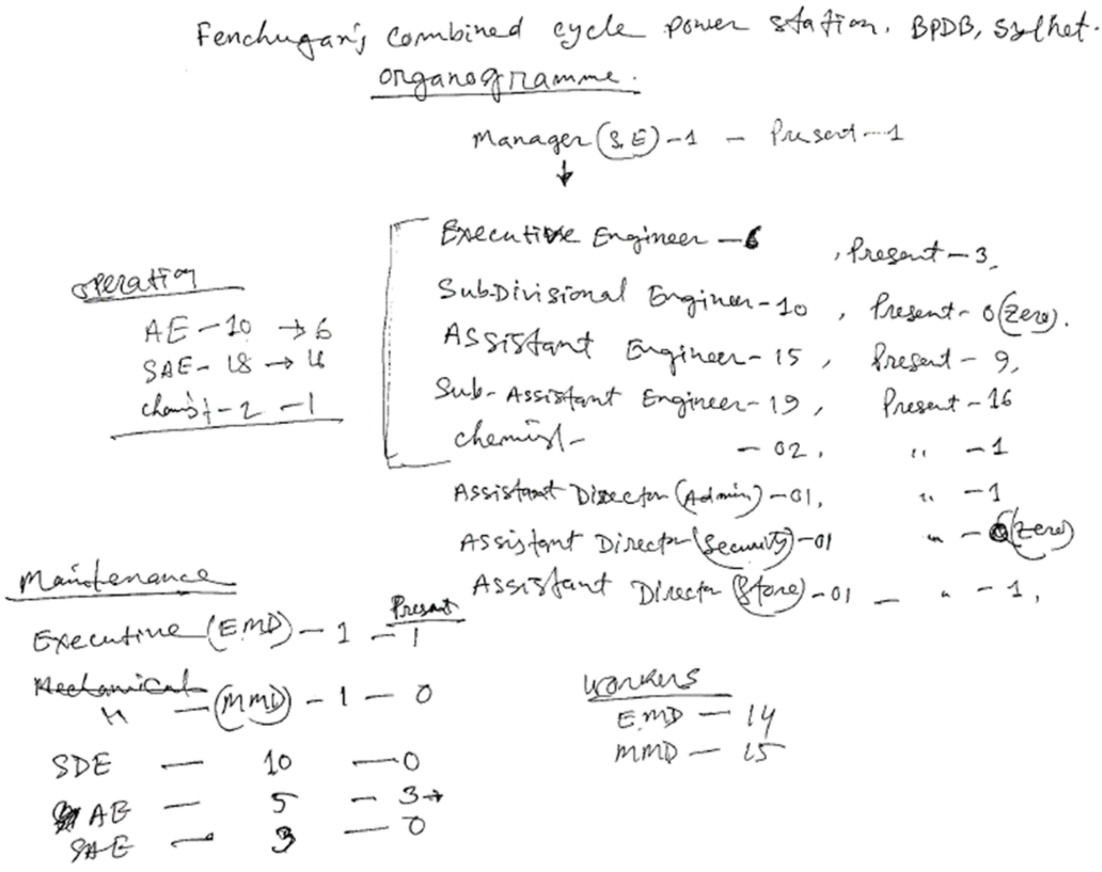
Future plan	70MW -> 105MW (add ST)
Peculiar information	Considering combined cycle power generation remodeling plan, because it can generate more with same amount of gas, and improve efficiency
Staff issues	None
Training system	OJT *need maintenance/operation skill improvement
Uneasiness concerning natural gas supply	Unidentified

Source: JICA PSMP2015

(9) Fenchuganj thermal power station (main fuel : natural gas)

Basic information : COD unit 1: 1995, unit 2: 2011
Capacity (COD) : 97MW, 104MW
Capacity (Now) : 62MW, 66MW

Organization chart:



Source: Fenchuganj thermal power station

Figure 18-19 Fenchuganj Organization Chart

Table 18-14 Fenchuganj Thermal Power Station

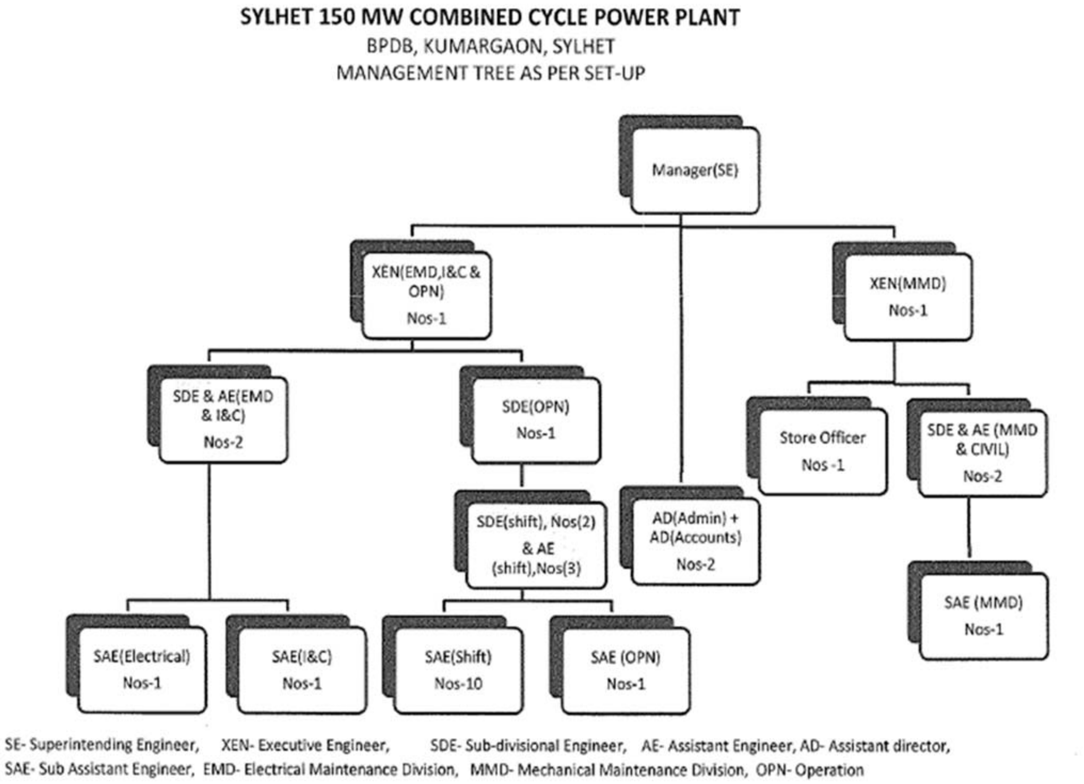
Maintenance plan	Chief engineer -> BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Waiting for shutdown permission from Power Div

	*BPDB approval -> parts purchase -> shutdown permission
Manufacture support for daily	None *when trouble happens, they correspond with neighboring power plant staff
Daily maintenance	Maintenance staff
Major inspection	CI, HGPI: maintenance staff MI: GE
Safety for equipment	Firefighting system
Safety for staff	Have a concept, but there is nothing actually implemented
Efficiency management	Monthly average efficiency only *No performance test
Fuel analysis	No analysis
Environmental regulation	No regulation
Organization for operation	5 staff/shift (chief *1, sub-chief *1, operator *3) 4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *hand writing is official
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *unit 1 is made by a Japan team There is no problem with the facilities, which have already passed 20 years. *unit 1 has 2 GTs, and they basically needed major inspection at 48,000 hours, but they have already passed 65,000 hours because inspection could not proceed as scheduled. Therefore, combustion temperature has to be decreased and, as a result, output also goes down. *unit 2, which is made by a China team, is only 5 years past COD, but it has a lot of trouble. *2 GTs did not change combustion; therefore, they have to decrease combustion temperature. They do not have LTSA, and they cannot change combustion periodically.
Capacity limitation	Already passed gas turbine maintenance timing. To prevent gas turbine trouble, they have to decrease combustion temperature; therefore, both units' output decreases.
Future plan	Next year, first major overhaul for unit 1 (already operated 20 years)
Peculiar information	4 gas turbines have decreased combustion temperature GT1: 22MW, GT2: 26MW, GT3&4: 22MW
Staff issues	Staff need to move every 2-3 years; therefore, difficult to keep skilled staff
Training system	OJT
Uneasiness concerning natural gas supply	No *because near the gas field

(10) Sylhet thermal power station (main fuel : natural gas)

Basic information : COD 2012
Capacity (COD) : 150MW
Capacity (Now) : 150MW

Organization chart:



Source: Sylhet thermal power station

Figure 18-20 Sylhet Organization Chart

Table 18-15 Sylhet Thermal Power Station

KPI	None
Maintenance plan	Staff -> BPDB approves
Maintenance plan basic idea	No plan *because they had a warranty period to 10 November 2014
Feasibility of maintenance plan	As scheduled during warranty period
Reason to disturb it	No
Manufacture support for daily	Yes *they have an LTSA (to 2019) and, during major inspection, Ansaldo will support them (includes 6 engineers) Expect GT, if they have contract to manufacture, they can get support
Daily maintenance	Staff + SEC (EPC) advisor
Major inspection	CI, HGPI: maintenance staff MI: not decided yet (because just finished warranty

	period)
Safety for equipment	Firefighting system
Safety for staff	They have BPDB guideline, but nobody cares *There is no penalty for not following a manual
Efficiency management	Monthly average efficiency only *no management
Fuel analysis	No analysis *using fixed value that was established in commissioning period
Environmental regulation	No regulation (no monitor) *requirement to EPC : under Nox 30ppm
Organization for operation	7 staff/shift (Shift in charge *1, shift supervisor *2, operator *4) 5 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *hand writing is official
Report for Head office	Monthly report made by operator (handwritten) Operation group makes operation log sheet
Equipment issues	Air quality is bad; need air filter replacement frequently. *3 years' experience. They know that the quality of Chinese products is bad, but Japanese products are expensive. It is difficult for them to buy Japanese products
Capacity limitation	None
Future plan	They have combined cycle power generation remodeling plan (150→225MW) *Now at final stage of this plan.
Peculiar information	Base load plant *during rainy season, they need to keep about 70MW; easy to control system frequency
Staff issues	None
Training system	OJT *BPDB has a training center, and every member of staff attends a 60 hour lecture per year. *the contents are mainly lectures, with no real machines.
Uneasiness concerning natural gas supply	None

Source: JICA PSMP2015

18.3.2 Summary of actual O&M situation

To summarize the information on the power stations which the JICA survey team visited, mentioned above:

Table 18-16 Summary of BPDB Thermal Power Stations

Maintenance plan	According to manual and experience ➔ BPDB approval
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	
－Budget approval	Waiting for BPDB budget approval
－purchase	After approval of budget, start bidding, sign contract, then get equipment and parts
－shutdown permission	Waiting for shutdown permission from Power Div
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff and manufacture (for major equipment)
Safety for staff	Only have BPDB guideline *there is no periodic education on safety
Efficiency management	Nobody cares *only calculate average for one month *no periodic performance test
Fuel analysis	No analysis
Environmental regulation	No regulation *there is no regulation now, but DOE plans to devise this in the near future
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*Does not reach rated output *There are many problems, but information sharing, such as the cause correspondence, is limited
Staff issues	* Shortage of human resources in BPDB, and their being used in a variety of positions worsens this problem
Training system	*OJT *Only theoretical lectures in training center *Need maintenance/operation skill improvement

Source: JICA PSMP2015

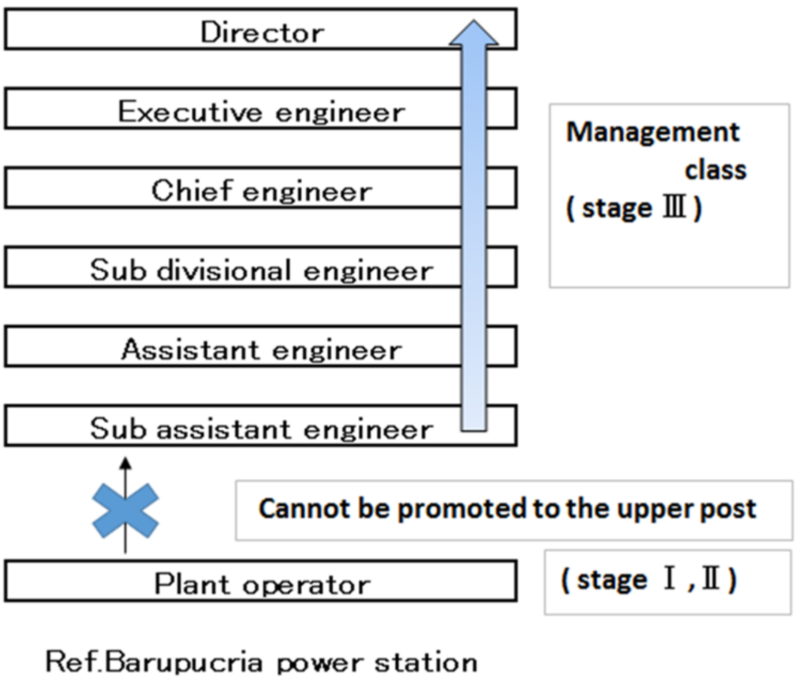
The JICA study team has divided the things it gathered in the list mentioned above into "staff", "facilities, repair plan", "budget" and "information" and organized the information.

18.3.3 Staff

(1) Curriculum and organization in a power station in Bangladesh
Curriculum in Bangladesh as follows:
Stage I : from kindergarten to standard X

(SSC: Standard Secondary Certificate: graduate high school level in Japan)
Stage Ⅱ: ⅩⅠ～ⅩⅡ (HSC: Higher Secondary Certificate; graduate professional school level)
Stage Ⅲ: Admission for undergraduate

Organization of thermal power station as follows:



Source: JICA PSMP2015

Figure 18-21 Education and Organization

The upper figure is an example from Barapukuria, but all power stations are thought to be similar. Depending on education before the entering a company, some people cannot attain the engineer post.

(2) Lack of education, shortage of staff
BPDB has 6 training centers, but these are basically only for lecture training. The contents of the training centers' lectures are theory and the experience of seniors. And there is no training with actual equipment. The place that people can experience real duties is the power station only. Only a few power stations have training centers and are educating staff; the others cannot educate their staff with training facilities.
In addition, staff at the power station is conclusively lacking for the personnel required. It was supposedly the case that one held an additional post of three posts depending on the power station. In addition, some staff whom they trained transfer to other BPDB power stations.

(3) Safety for staff
They have the BPDB guideline, but nobody cares. One of reasons is that there is no penalty for not following a manual, and then there is the cultural side. In addition, consciousness of safety is very low, probably because the power station shutdown period will not be very long.

18.3.4 Facilities, repair plan

(1) Periodical maintenance and feasibility of parts replacement
Because maintenance cannot proceed following the plan, many power stations worry about their facility. Gas turbine equipment is a particular problem, because hot gas path parts need periodic

replacement, but this cannot be done; thus, they have to decrease the firing temperature to protect the equipment and this causes power output decrease. One of reasons is that they do not have an LTSA agreement with the manufacturer and there is a delay in budget approval.

(2) Shutdown permission
Because of the delay in getting shutdown permission from Power Div (sometimes, it takes 2-3 years), it also causes delays in periodic maintenance.

(3) Does not reach rated output
Some power stations have to operate with malfunctions.

(4) Efficiency
Do not care about power plant efficiency. Consciousness of maintaining efficiency and efficiency improvement is not felt. Therefore, they do not care about fuel gas analysis. But everyone wants to introduce the newest high efficiency power plant.

(5) Manufacturer support
Without a contract, manufacturers do not support them or submit related information.
If a malfunction happens, every power station performs trouble correspondence with neighboring power station staff.

18.3.5 Budget

(1) It takes a long time for budget approval, so power plant maintenance cannot proceed.
(2) BPDB does not allow LTSA with manufacturers.

18.3.6 Information

(1) Trouble addressing depends on own experience.
(2) Without a contract, manufacturers do not submit related information.
(3) Do not have other power stations' information except via direct contact.

18.3.7 Summary

Summary of above conditions item by item.

Table 18-17 Summary

Staff	*Lack of education and only theoretical lecture curriculum *Low safety awareness *Discrimination towards the post due to education before entering a company
Facilities, repair plan	*Does not reach rated output *Cannot proceed with periodic maintenance as scheduled *Delay in shutdown permission *No manufacturer support *Do not care about power plant efficiency
Budget	*Delay in budget approval *No permission for LTSA
Information	*Trouble addressing depends on own experience *There is no information submitted

	*There is no positive information sharing among power stations

Source: JICA PSMP2015

18.4 Issues

Report about the issues.

18.4.1 Staff

The existing training center only has a lecture curriculum, and there is no training using concrete facilities. Staff have to do On the Job Training (OJT). Therefore, staff only get knowledge through the OJT. Thus, there is no place where they can learn what they must not do, and also no chance to learn what they cannot do on the site. In other words, there is no place to experience what happens when they go too far. And some power stations have a training center, but there are shortages of information for education and organization. In conclusion, there is no effective curriculum or facility. So, the construction of a facility that possesses concrete facilities and an education curriculum is needed. This facility should not only be for BPDB power station staff, but also loaned out for a fee to other companies. This would improve the Bangladesh power sector's O&M skills.
The training center will be mentioned in the following section.

18.4.2 Facilities, repair plan

Almost all power stations mentioned the delay in maintenance work. Through the site visits, the JICA survey team found that during the process of making the maintenance plan to implementing it, there were 2 key points: one of them is BPDB budget approval, and the other one is shutdown permission from Power Div.

(1) Approval of maintenance plan and budget
BPDB has to check all of the plants' maintenance plans and budget. But every power plant submits its plan and budget one by one. It is thought that it is hard to make an objective, rough estimate of the necessary expense for BPDB as a whole beforehand. As a result, after ascertaining the whole plan and budget, they approve each power plant's plan, and this causes delays in approval. In conclusion, a maintenance plan for several years for all power stations is not gathered in objective form and this is an issue.

(2) Shutdown permission
It seems that Power Div does not have all power plants' maintenance plans; therefore, there are few judgment grounds to shut down a power station in a particular time. It is necessary to coordinate with individual power stations and to judge accordingly and, as a result, judgment for the shutdown permission is late.
The above 2 items cause time delays.

(3) Does not reach rated output
There are several kinds of reasons, like lack of power supply, inability to shut down and repair, lack of information for repair work, inability to get manufacturer support and the long time taken to purchase needed parts and, because of these reasons, many power units cannot reach rated output.

(4) LTSA
Regarding gas turbine plants, many power stations are not allowed to make LTSA contracts with manufacturers. The purposes of LTSAs are as follows: on-time parts supply, emergency correspondence, and measures for technical issues. However, because these power stations do not have LTSAs, they depend on past experience to deal with malfunctions. Combustion also needs replacing every 1-2 years, but because combustion needs budget approval and shutdown permission they have to

wait, they cannot replace things on time, and then they have to operate at a decreased output.

(5) Efficiency
They do not care about power plant efficiency. In the near future, Bangladesh needs to import LNG from overseas. This means that fuel prices are getting high, and generation costs are getting high. The Bangladesh government plans to introduce high efficiency thermal power units, improve average thermal efficiency, and reduce fuel costs. Japan also does the same, so it is a good idea, but there are some problems. For example, they do not analyze every day and every hour efficiency, and do not carry out performance tests just after maintenance work is done. These items are needed to ascertain the change in situation after the maintenance operation period. In Japan, because almost all fuel has to be imported, fuel cost reduction is a very important issue in every sector; thus, each sector has its own targets and takes measures. Bangladesh also needs targets and to take measures.
Bangladesh faces the following problems.

Severe condition of power supply:
-> Power plant cannot shut down but has to operate
-> Power plant stops suddenly
-> Power supply decreases
-> Other power plants have to operate

Due to this, it is in a “negative spiral”.

18.4.3 Budget

Budget and plan approval takes a long time as mentioned above, and this issue is caused by information not being gathered in an "objective" manner. Therefore, BPDB approves each power station’s maintenance plan and budget only after fixing all of the plant maintenance plans.
The issue of LTSAs also exists. Because an LTSA includes a technical issue treatment fee, it is more expensive than only purchasing needed parts, but it includes a “certain supply of periodic replacement parts” and “needed parts will be supplied when emergency trouble happens”. Considering the actual situation, LTSA is a useful and efficient countermeasure for stable operation.

18.4.4 Information

Actual conditions depend on past experience and measures taken for malfunctions. They cannot get manufacturer support and there is no positive information sharing among power stations. It also means that power station staff’s technical levels stop at some point, because they cannot get any more information. If they can share trouble-related information, they can learn suitable countermeasures and prevent the trouble from happening again. To achieve this, they need an information sharing strategy.

18.4.5 Summary

Table 18-18 Summary

Staff	There is no curriculum or concrete facilities to develop staff
Facilities, repair plan	*Budget approval and shutdown permission are delayed because there is no mid-long term maintenance information *Cannot repair because of shortage of power generation *Lack of technical skill due to lack of information *Do not care about power plant efficiency *Does not reach rated output
Budget	*No mid-long term maintenance plan

Information	*Lack of information strategy

Source: JICA PSMP2015

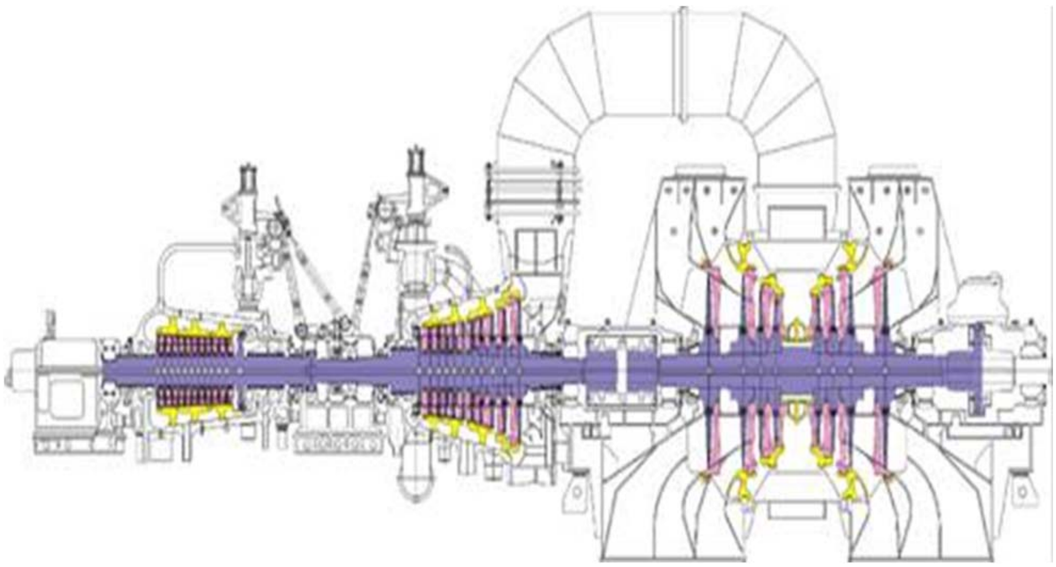
18.5 Countermeasures

18.5.1 Outline of countermeasures

For the issues mentioned in 18.4.5 , “staff”, “facilities, repair plan”, “budget”, and “information”, the JICA study team suggests the following measures.

(1) Facilities, repair plan
Here, the JICA survey team suggests measures for the issues of “Does not reach rated output” and “efficiency improvement”. For recovering output or efficiency, the rehabilitation of facilities or combined cycle power generation remodeling are effective. Firstly, we introduce Japanese technology.

(a) Steam Turbine rehabilitation
There are many steam turbine products made by the turbine manufacture, LMZ, in the former Soviet Union, in Bangladesh. These LMZ steam turbines are already aged, and the original design efficiency is lower than that currently. In the LMZ series, Japanese manufacturers have rehabilitation experience of LMZ210 that was designed in the 1960s. The content of rehabilitation is mainly using the newest design blade. They have rehabilitation experience in Bulgaria, in 2010 and 2011, and finished the work successfully. Each steam turbine improved its output about 10-15MW. Therefore, rehabilitation is suitable for LMZ210MW and is a good selection. Detailed study is mentioned in 18.6 Rehabilitation.

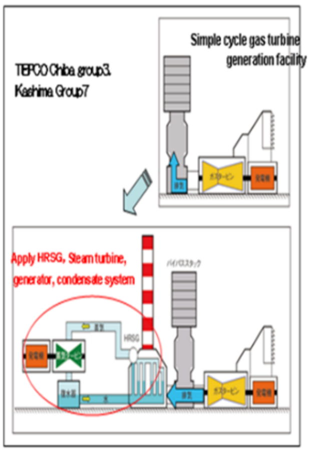
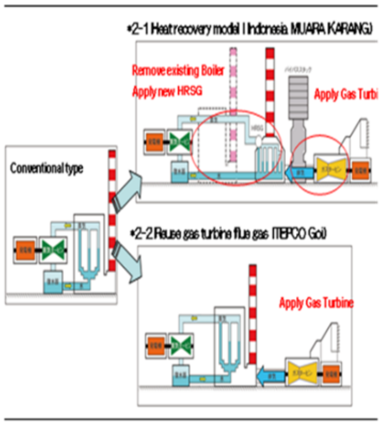
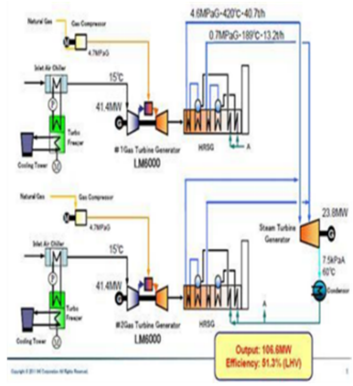


Source: JICA PSMP2015

Figure 18-22 Steam Turbine Rehabilitation

(b) Combined cycle power generation remodeling plan
For high efficiency and output reinforcement of the existing power stations, remodeling to combined cycle is one of the ideas. For combined cycle remodeling, there are two types of combined cycle applicable (CASE 1 and CASE 2) and the scrap & build model (CASE 3). CASE 1 is “Adoption of the bottoming system model” (HRSG, Steam turbine, generator and condensate system), and CASE 2 is “Adoption of Gas turbine model”. A bottoming system model has been adopted at TEPCO’s “Chiba thermal power station group No.3” and “Kashima thermal power station group No.7”. As for “Adoption of gas turbine model”, there are two types of model. One of them is the Heat recovery model (*2-1) which entails removing the existing boiler and installing a gas turbine and HRSG. The

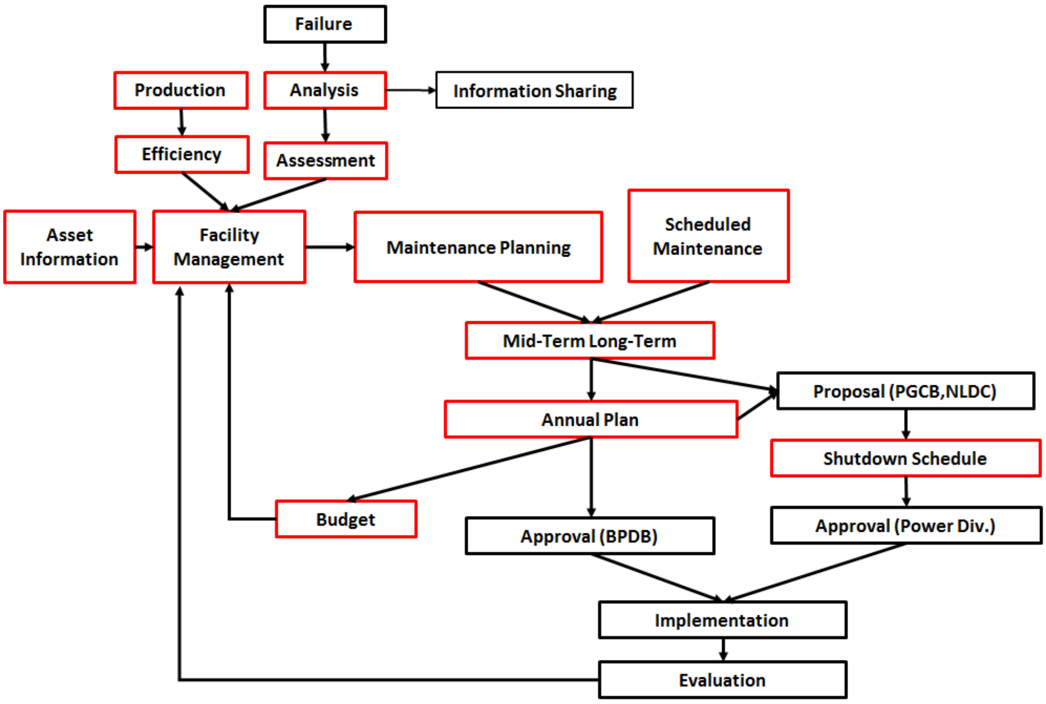
other one is the exhaust reuse model (*2-2) which entails installing a gas turbine, and the existing boiler reuses the exhaust gas of the gas turbine. The former (*2-1) has been adopted at "MUARA KARANG Power plant" in Indonesia, and the latter (*2-2) has been adopted at TEPCO's "Goi thermal power station unit No.6".
Detailed study is mentioned in 18.7 Combined cycle power generation remodeling plan.

CASE 1	CASE 2	CASE 3
adoption of bottoming system model	adoption of gas turbine model	Scrap and build model
		

Source: JICA PSMP2015

Figure 18-23 Combined Cycle Power Generation Remodeling Plan

(2) Staff, budget, information
For power station administration, information becomes important over all of the maintenance plan, budgets and techniques for facilities. Through the site survey, lack of information sharing and poor management causes many problems in various places. The generation company must understand the importance of information management and use this knowledge throughout its operations. To achieve this, they must utilize the visualization of data, timely data collection and data sharing, and it is necessary to promote the PDCA cycle of the business. In addition, training facilities and a training system which implements a system for personnel training are important measures. To promote information utilization, they can manage things like a periodic inspection schedule and the budget for shutdown timing for each power plant, and can prevent blackouts and power supply over/under. This will also allow effective management for the power plants. The following figure shows a sample from Japan. The red boxes show an example of effectively utilizing information.



Source: JICA PSMP2015

Figure 18-24 O&M Best Practice Supported by Information Sharing System

In addition, Japanese utilities adjust the gap between supply and demand by coordinating it with the power grid control system section when making the maintenance plan. The following figure shows the flow of maintenance plan - supply-demand gap ascertainment before the adjustment.

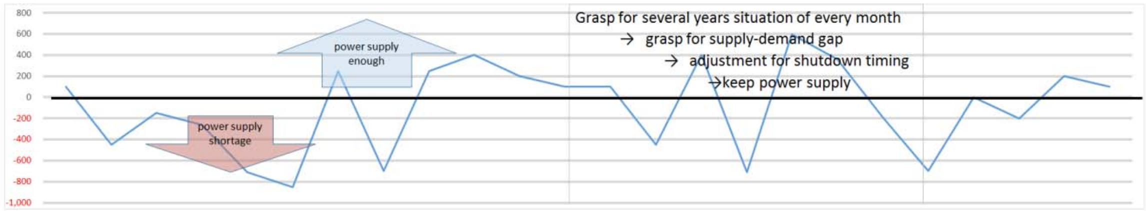
Maintenance plan for several years

maintenance plan	Year1												Year2											
Plant	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Plant A ; 450MW	○	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○
Plant B ; 660MW	○	○	○	-SD-	-SD-	-SD-	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○
Plant C ; 350MW	○	○	○	○	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○
Plant D ; 200MW	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○
Plant E ; 100MW	○	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○
Plant F ; 600MW	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○	○	○	○	-SD-	-SD-	-SD-	○	○
Plant G ; 550MW	○	○	○	○	○	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	-SD-	○	○	○	○
Plant H ; 550MW	○	-SD-	-SD-	○	○	○	○	○	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○	○	○
Plant I ; 400MW	○	○	○	○	○	-SD-	○	○	○	○	○	○	○	○	○	○	○	-SD-	-SD-	○	○	○	○	○

Compare with demand forecast, ascertain supply-demand gap

power supply ability	Year1												Year2											
Plant	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Plant A ; 450MW	450	450	450	450	0	0	450	450	450	450	450	450	450	450	450	0	450	450	450	450	450	450	450	450
Plant B ; 660MW	660	660	660	0	0	0	660	660	660	660	660	660	660	660	660	0	660	660	660	660	660	660	660	660
Plant C ; 350MW	350	350	350	350	350	350	350	0	0	350	350	350	350	350	350	350	350	350	350	0	350	350	350	350
Plant D ; 200MW	200	200	200	0	0	200	200	200	200	200	200	200	200	200	200	0	200	200	200	200	200	200	200	200
Plant E ; 100MW	100	100	100	100	0	0	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	100
Plant F ; 600MW	600	600	600	600	600	600	600	0	600	600	600	600	600	600	600	600	600	600	600	0	0	0	600	600
Plant G ; 550MW	550	550	550	550	550	550	0	0	550	550	550	550	550	550	550	550	550	550	0	0	550	550	550	550
Plant H ; 550MW	550	0	0	550	550	550	550	550	550	550	550	550	550	0	550	550	550	550	550	550	550	550	550	550
Plant I ; 400MW	440	440	440	440	440	0	440	440	440	440	440	440	440	440	440	440	440	0	0	440	440	440	440	440
total of supply	3,900	3,350	3,350	3,040	2,490	2,250	3,350	2,400	3,550	3,900	3,900	3,900	3,900	3,350	3,900	2,590	3,800	3,460	2,910	2,400	3,300	3,300	3,900	3,900
demand forecast	3,800	3,800	3,500	3,300	3,200	3,100	3,100	3,100	3,300	3,500	3,700	3,800	3,800	3,800	3,500	3,300	3,200	3,100	3,100	3,100	3,300	3,500	3,700	3,800
Supply-demand(MW)	***100***	***-450***	***-150***	***-260***	***-710***	***-850***	***250***	***-700***	***250***	***400***	***200***	***100***	***100***	***-450***	***400***	***-710***	***600***	***360***	***-190***	***-700***	***0***	***-200***	***200***	***100***

Making graph



Source: JICA PSMP2015

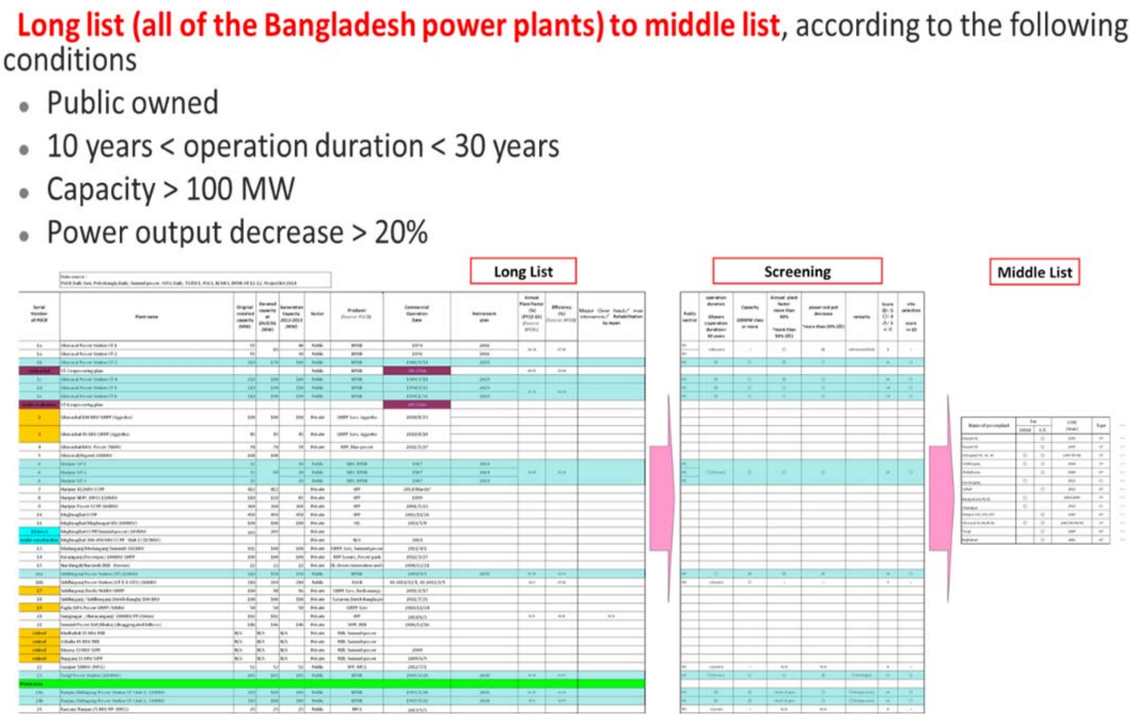
Figure 18-25 Illustration

Before the adjustment of the maintenance plan, making a graph like that shown above and reviewing the maintenance plan is needed to proceed with periodic maintenance. Of course, it also needs to be shared with PGC. To forecast several years into the future, the budget plan needs to be connected to the maintenance plan.
Information is mentioned in 18.8 Information strategy; training is mentioned in 18.9 Training center.

18.6 Rehabilitation

18.6.1 Rehabilitation examination

According to 18.2.1 (1) O&M target site selection, target sites were selected. The following is an illustration of the selection.



Source: JICA PSMP2015

Figure 18-26 Long-Mid List Selection Illustration

Middle List (21 plants of 12 sites) to short list, according to the following conditions

- Land space
- Grid capacity
- Gas supply

Middle List

Name of powerplant	For O&M	For C/C	COD (Year)	Type	Fuel	Installed (MW)	Derated (MW)	Plant factor (%)	Efficiency (NET) (%)	Working group	Donor	visited	visit plan
Rauzan #1		○	1993	ST	Gas	210	200	21.55	31.26	×		2014/11/29	-
Rauzan #2		○	1997	ST	Gas	210	180	15.80	32.53	×			
Ashuganji #3, #4, #5	○	○	1987/87/88	ST	Gas	450	390	97.64	36.16			2014/11/30	-
Siddhirganj	○	○	2004	ST	Gas	210	150	56.98	32.63			2014/12/3	-
Barapukuria #1,#2	○		2009/2009	ST	Coal	250(125*2)	200	75.37	31.47				2015/3/8-3/9
Chandpur	○		2012	CC	Gas	163	163	49.68	39.38				2015/3/23
Tongi		○	2005	GT	Gas	105	105	38.38	27.07	○			2015/3/24
Ghorasal #3,#4,#5,#6	○	○	1987/89/95/99	ST	Gas	420(210*2)	360	69.53	33.68	×	○		2015/3/25
Shahjibazar		○	2000	GT	Gas	70(35*2)	66	76.36	25.63		○		2015/3/29
Fenchuganj	○		2011	CC	Gas	104	104	49.08	31.95				2015/3/30
Sylhet		○	2012	GT	Gas	150	142	51.96	29.86		○		2015/3/31
Baghabari		○	2001	GT	Gas	100	100	87.52	28.36		○		2015/4/1
Haripur GT1,GT2,GT3		○	1987	GT	Gas	32*3	60	38.09	21.26				2015/4/2

O: World Bank "A Power Sector Investment Strategy Framework for Bangladesh, July 2014"

JICA Survey Team will investigate ADB and other donor in next site survey

Short List

Select 3-4 sites for Conversion / Rehabilitation

Source: JICA PSMP2015

Figure 18-27 Mid-Short List Selection Illustration

Because they are adopting the LMZ 210MW type steam turbine, Ghorasal #4 & #5 and Siddhirganj were selected as steam turbine rehabilitation candidate sites, and budget and calculation of the cost-effectiveness were estimated as follows.

18.6.2 Cost-effectiveness

Estimated cost for steam turbine replacement is about 30 million US dollars, and its output will increase about 10MW. Estimated operation years will be 30 years, but other equipment will not be replaced; therefore, we are using boiler operation years. Generally, the operation period of a boiler is 30 years; thus, the estimated operation period is 30 years - boiler operation years.

	Site name	Target unit	COD	capacity condition: installed	de-rated	remarks	New	output increase	Estimated Cost	Unit price	Efficiency: after	now	Manufacture support	Remaining plant life after rehabilitation (plant life time 30years)	Year cost
				A	B	C	D	D-C	Mill dollar	mill dollar / MW					Mill dollar
ST rehabilitation	Ghorasal	Unit4	1989	210	180	180	190	10MW	30	3.0	improved	37.8 (*3) / 28.8 (*2)	Toshiba	5	0.60
	Ghorasal	Unit5	1994	210	190	190	200			3.0				9	0.33
	Siddhirganj	Unit1	2004	210	110	110(gas limitation)	120			3.0		33.8 (*1)		19	0.16

Source: JICA PSMP2015

Figure 18-28 Cost-effectiveness of Turbine Rehabilitation

Estimated cost to increase power output is 3 million US dollars/MW. Considering Boiler operation years, investment cost per year is as follows.

Ghorasal unit 4	0.6 million US dollars/year
Ghorasal unit 5	0.33 million US dollars/year
Siddhirganj	0.16 million US dollars/year

However, when the JICA survey team visited the power station, the staff mentioned that Siddhirganj's

Power unit generator has a problem and it has a 150MW limitation. Unless the generator is repaired, there is no point in pursuing steam turbine rehabilitation. Therefore, it is excluded as a target.

18.6.3 Power station comments

According to the above idea, the JICA survey team got some comments from Ghorasal power station.
*Currently, unit 4 is under overhaul, and unit 5 will start overhaul from next February.
Therefore, they are not thinking of rehabilitation with huge expense.
*They need the idea that the output greatly increases, like unit 3 and unit 6
An answer on turbine rehabilitation where Japanese technology could be utilized was not provided.

18.7 Combined Cycle Power Generation Remodeling Plan

18.7.1 Combined cycle power generation remodeling examination

According to 18.2.1 (1) O&M target site selection, target sites were selected the same as for turbine rehabilitation. Based on the target power station selection, the JICA survey team carried out further target narrowing. The characteristics of each plan, CASE 1, CASE 2 and CASE 3, and narrowing method are as follows:

(1) CASE 1 Adoption of the bottoming system model
Adoption of the bottoming system model is adopting HRSG, Steam turbine, generator and condensate system in the existing gas turbine plant. Operation years of the existing gas turbine is the important point. The JICA survey team found that BPDB already has plans to upgrade gas turbines currently in operation to combined cycle power generation. If the gas turbine has already been operating for 10 years or more, maintenance and modification is needed for the gas turbine itself before combined cycle remodeling. Because of the basic philosophy of site selection, the JICA survey team selected an operation period of more than 10 years; therefore, an old gas turbine's combined remodeling plan needs gas turbine rehabilitation, and so, the adoption of a bottoming system has technical and cost difficulties.

(2) CASE 2 Adoption of Gas turbine model
Adoption of the gas turbine in the existing boiler-turbine plant. Before the site visits, the JICA survey team regarded Ghorasal power station unit 3 – unit 6 and Ashuganj power station units 3, 4 and 5 as target candidates for combined remodeling. However, Ghorasal power station already has a plan for combined cycle remodeling for unit 3 and unit 6, and unit 4 and unit 5 do not have enough space to adopt gas turbines. In addition, Ashuganj power station has a scrap and build plan until 2023: they will scrap units 3, 4 and 5, then build combined cycle power generation plants in sequence. For Siddhirganj power station, although there is enough space to build, because steam turbine generation has a problem the steam turbine generation needs to be repaired first. Therefore, the JICA survey team decided to remove it as an examination candidate.

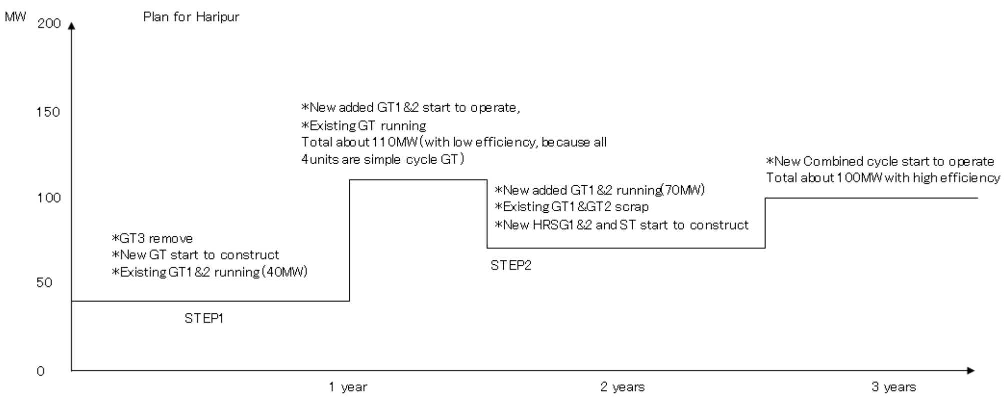
(3) CASE 3 Scrap & build (S&B) model and build & scrap (B&S) model
This case means to scrap the existing power plant first, then build a new combined cycle power generation plant. First of all, the scrap and build (S&B) plan is not suitable for Bangladesh, because scrapping the existing power generation plant first causes severe conditions for the Bangladesh power grid system.
This plan needs more than 2 years from shutdown and scrap to start of power generation. Therefore, the JICA survey team proposes the build and scrap (B&S) model - that is, construct a new gas turbine and start operation first, then scrap the existing power plant and construct a new HRSG and steam turbine next. It is a very severe situation to build a new gas turbine next to an operating Power plant, and it is also risky to construct new equipment because the underground situation is not clear. However, thinking about the current situation in Bangladesh, it is an unavoidable method.

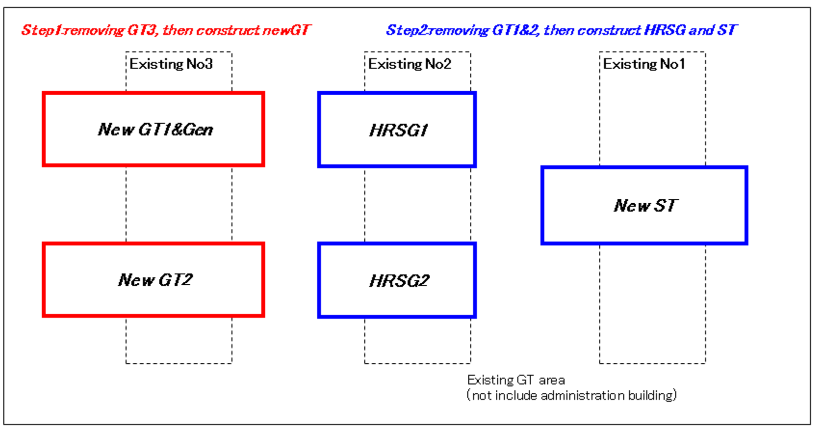
Combined cycle power generation remodeling case	Target site	Target unit	Propriety	reason
Adoption of the bottoming system model	Shahibazar	35MWGT	×	Gas turbine is too old to remodel
	Baghabari	100MWGT	×	Gas turbine is too old to remodel
	Sylhet	150MWGT	×	They have combined cycle power generation remodeling plan
Adoption of Gas turbine model	Ghorasal	unit4,5	×	No space
	Ashuganj	unit 3,4,5	×	will be retired till 2023 and they have CCGT construction plan
	Siddhirganj	unit1	×	Generator problem
Scrap & build (S&B) / build & scrap (B&S) model	Fenchuganj	unit 1,2	○	-
	Haripur	1,2,3GT	○	-

Source: JICA PSMP2015

Figure 18-29 Application Judgment by Each case

Below is an illustration of the Haripur B&S construction schedule and the layout for Haripur and Fenchuganj.



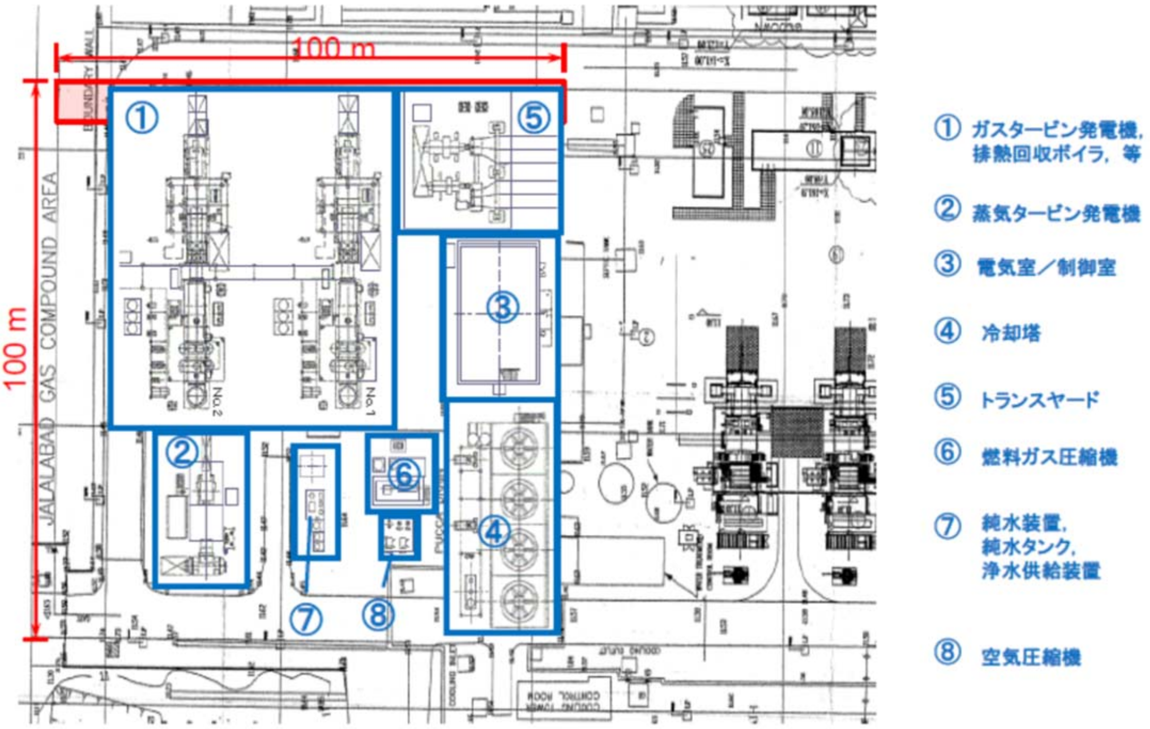


Source: JICA PSMP2015

Figure 18-30 B&S Schedule Illustration

Source: JICA PSMP2015

Figure 18-31 Haripur Layout



Source: JICA PSMP2015

Figure 18-32 Fenchuganj Layout

18.7.2 Frequency instability problem in Bangladesh and small class gas turbine combined cycle generation plant

One of the problems that the electricity sector in Bangladesh has is that the band of the frequency is big (more than 50Hz +/-1Hz). To stabilize this frequency instability problem, it is very effective, due to the following reasons, to install the latest combined cycle plant.

Reasons:

(1) It is a very short time from long term shutdown to startup complete.
(2) High efficiency during low load operation.

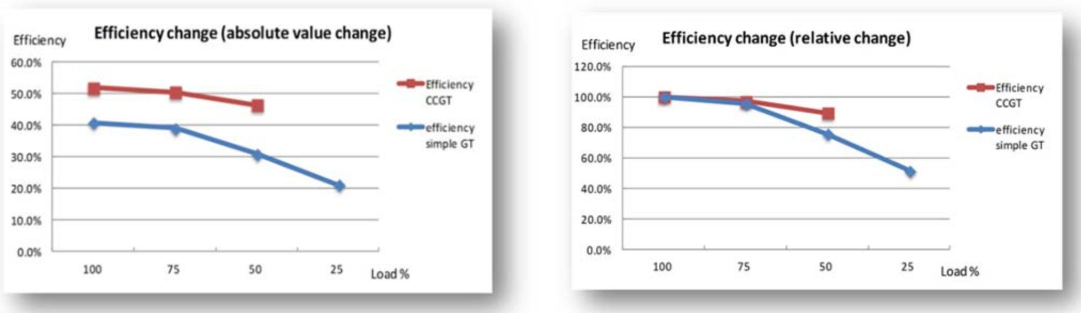
(1) First of all, concerning the startup period, it only takes 2 hours just after cold start up to full load operation, as per the following figure. This means that if you know demand peak just 2-3 hours before, you only order start up for this small combined cycle plant and the plant startup finishes just on time.

Plant capacity	Hot start (daily start)	Cold start (weekly start)	efficiency
400MW Class CCGT	1hour	6hours	50%
100MW Class CCGT	0.5hour	2hours	50%
Simple GT	0.5hour		40%(new one) 30%(old one)

Source: JICA PSMP2015

Figure 18-33 Short Start Time Characteristics and Efficiency

(2) The following figure shows efficiency change with load %. The newest combined cycle plants can maintain high efficiency compared with a simple cycle gas turbine plant.



Source: JICA PSMP2015

Figure 18-34 The Efficiency Comparison

From this, it is very significant to install a 100MW class combined cycle power generation plant to solve frequency instability.

18.7.3 Cost-effectiveness

For Fenchuganj or Haripur, it is expected to cost about 220 million US dollars (rate: ¥120 Japanese yen/dollar) for a 100MW class combined cycle power plant, and the unit price of 1MW is about 2.2 million US dollars. Details are as follows.

Table 18-19 Cost Estimation

No.	Item	バングラデシュ対象案件	
		Total	Ratio
		[MJPY]	%
	JICA Finance Portion		
A.	**Power Plant Construction and Associated Works (EPC Cost)**	**15,070**	**57%**
A1.	Power Block	**12,000**	
A2.	B.O.P	**571**	
A3.	Civil & Erection	**2,499**	
		0	
B	**LTSA, Training and Spare Parts**	**2,233**	**9%**
B1.	6-year LTSA Cost for Gas Turbine	**1,582**	
B2.	Training	**133**	
B3.	Spare Parts	**517**	
C.	**Consulting Service**	**1,741**	**7%**
D.	**Contingency**	**3,185**	**12%**
D1.	Price Contingency on A, B & C 5%	2,126	5%
D2.	Physical Contingency on A, B, C & D1 5%	1,058	5%
E	Interest During Construction 0.01%	0	
F	Commitment Charge (exempted) 0.0%		
	Total of JICA Finance Portion (A-F)	**22,228**	**85%**
	Non Eligible Portion		
G.	**Land Preparation 除却工事 (20% of EPC仮定)**	**3,014**	**11%**
G1.	Removal of Existing facilities		
G2.	Price Contingency		
G3.	Physical Contingency		
H.	**Administration Cost 0.50%**	**126**	**0%**
	* 0.5% of A-D & G		
I.	**Custom Duties, VAT and Withholding Tax**	**886**	**3%**
I1.	VAT on 25% of A, B, D & G (except contingency of C) 17.0%	656	25%
I2.	Custom Duties on Foreign Portion of A, B, D & G (exempted) 0.0%	0	
I3.	Withholding Tax on Consulting service fee except for expenses 20.0%	348	20%
	Total of Non Eligible Portion (G-I)	**4,026**	**15%**
	Grand Total (A-I)	**26,255**	**100%**

Source: JICA PSMP2015

18.8 Information Strategy

18.8.1 Presumptions

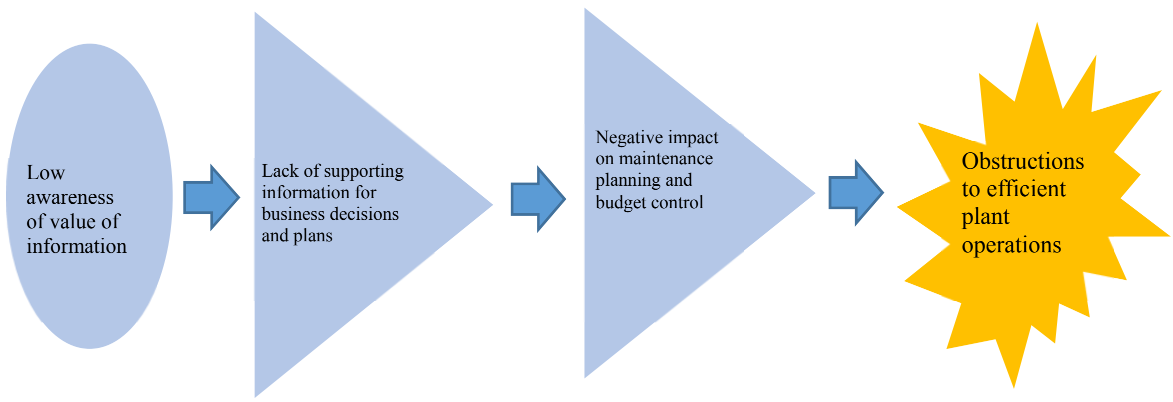
As mentioned in the previous sections, some of the problems in operation and maintenance can be solved by installing new facilities and rehabilitating ongoing facilities. This section explains that the main problems the country faces can be broken down into smaller problems, some of which are caused by lack of information. Based on the survey results, our team made a hypothesis that the following descriptions of the current situation may be connected with the risk factors which cause the problems.

Table 18-20 Conventional Information Management Practices and Risk Factors

Category	Current Situation	Risk Factors	Affected Performance Factors
Acquisition of Plant Data	No data logger Manual meter reading	Human errors Time inaccuracy	Accuracy
Recording of Plant Data	Paper based	Human errors Overheads	Accuracy
Delivery of Plant Data	Verbal conversation	Miscommunication	Accuracy
Other Information Handling	Paper documentation	Document loss Data obsolescence Access/reference inconvenience	Accuracy Efficiency Responsiveness
Reporting	One month delay in monthly report writing	Slow decision making Negative Impact on maintenance planning and scheduled shutdown	Efficiency Readiness Responsiveness

Source: JICA PSMP2015

According to the survey results, the descriptions of information handling show how information management is typically performed at the power plants. However, the overall impression of the results implies that there is a big problem in the mindset of the plant workers, who are satisfied with the conventional way of information handling. Lack of motivation for improvement in their work performance can be the biggest problem when the risk factors may cause negative outcomes in terms of accuracy, efficiency, responsiveness and readiness. The figure below shows how the efficiency in plant operations is affected by the low awareness of information handling.



Source: JICA PSMP2015

Figure 18-35 Current Situation and Obstructive Factors

18.8.2 Information management strategy

In response to impending demand growth, the power sector of Bangladesh is trying its best to keep the facilities operating. The plant operators know that their facilities are deteriorating faster than those which are properly maintained. A problem lies in the absence of sufficient information to answer a simple question: How much faster?

The survey results are mainly based on information gathered through interviews and meetings with the sector representatives. The findings indicate that there are some challenges in information management. In particular, lack of supporting data for practicing preventive maintenance, planning

and creating a feasible budget are the key problems which need to be addressed in priority.
Power generation companies nowadays are familiar with a range of activities, each of which is driven by the economic value of the significance of managing information. As measurable achievements are always expected, it is clear that continuous performance monitoring is key to successful plant operations. An integrated strategy for information management through the entire lifecycle of a power plant is required to facilitate effective data acquisition and sharing. This section explains how to implement information management in a modern power sector, and shows an overview of the conceptual model of information management for a power plant in Bangladesh.

18.8.3 Goal and objectives

(1) Goal of Information Management in Power Generation Sector of Bangladesh
Our goal is to achieve the best practice for a modern power sector in the field of Operation and Maintenance by facilitating a business process cycle to run towards improvement based on measurable achievement.

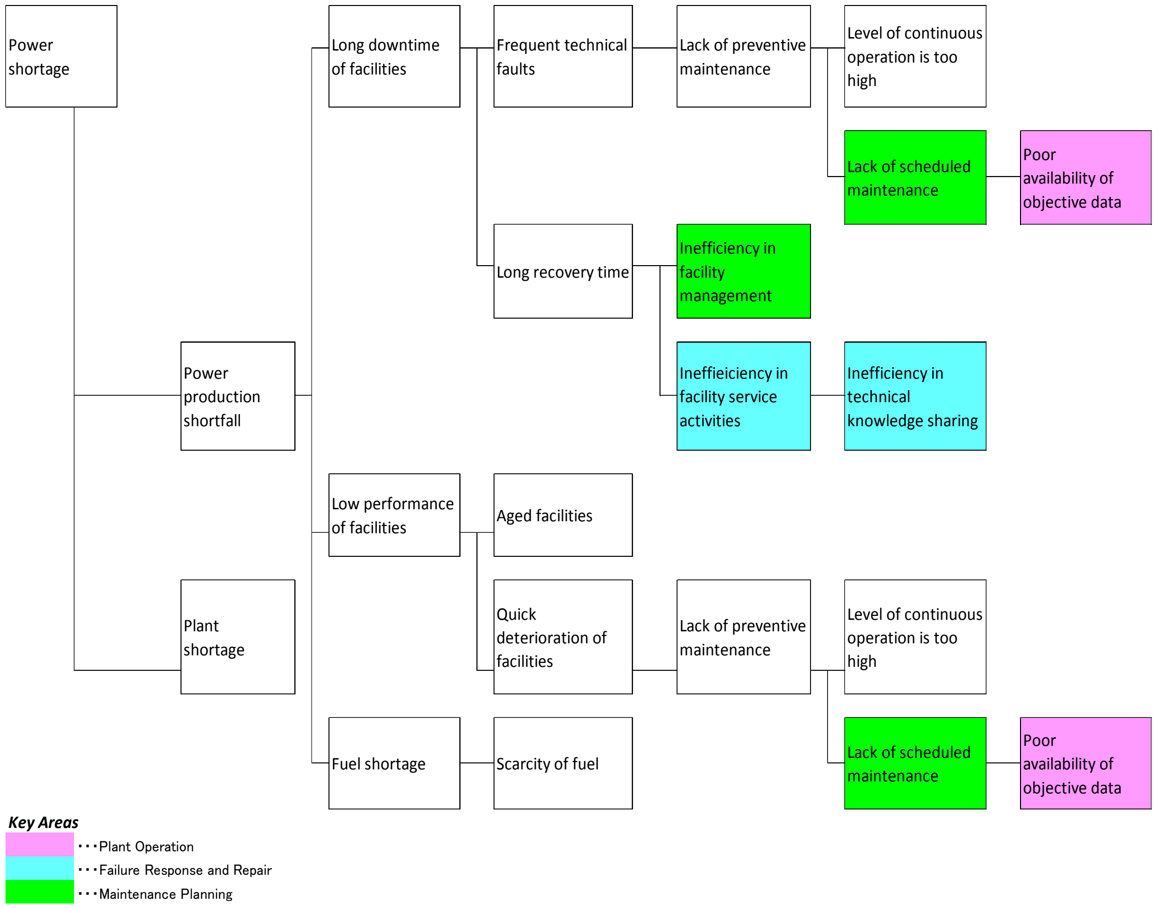
(a) Set a framework for effective information management for business efficiency
(b) Enforce information management strategy throughout the organization to strengthen organizational capacity
(c) Enforce improvement cycle by monitoring and measuring results

(2) Rationale
In general, commercial entities engaging in business process improvement set a performance framework in which efficiency and productivity are continuously monitored and analyzed. The survey results indicate that effective use of operation data can be the key to successful plant management in terms of reliability and economic efficiency. It appears that, at least in some power plants, paper based document handling is replaced by computer file operations and email systems. However, all the processes are managed in isolation and the information is not shared with other business units and power plants across the organization. For example, in one of the power plants, computers are used to write monthly reports for the management team. It takes about a month to complete a report because the information sources are dispersed through various processes and their timings are different. Another example is a disruption between the planning phase and field activities. Most of the power plants answer positively to a question about the significance of scheduled maintenance while many of them keep failing to actually implement it.
Typically, organizations have a hierarchical structure with multiple divisions, each of which is responsible for a specific activity such as plant operation, maintenance, procurement, administration or planning. Analytical use of accumulated information from daily and monthly reports enables the planning division to estimate future costs for maintenance of and repairs to the facilities which can be more accurately budgeted, while condition based maintenance enables scheduled shutdown for maintenance. Scheduled maintenance also contributes to procurement efficiency. The results of improvements should be observed as changes in various performance indicators.
As mentioned above, replacing paper documents with computer files only makes limited improvements in business efficiency. It is necessary to build a platform for information management integrated across the organization, from field activities to corporate management, from procurement to production, so that making efficient and effective use of information can be achieved.
Competitive business practices often demonstrate how they enforce the improvement cycle, a series of continual steps of Plan, Do, Check, Act. In order to achieve the goal, the business objectives must be aligned with the organizational strategy for information management. In implementation of the cycle, the Plan phase defines key performance indicators and sets baselines as measurable achievements. In the Do phase, performances are measured throughout the organization. The Check phase is for evaluation of the results. If there is any difference between the expected results and the actual results from the activities, corrective actions are taken in the Act phase. Information management strategy depicts the ‘what’, ‘when’, ‘where’, ‘who’, ‘how’ and most importantly ‘why’ of information handling

through the cycle. Some of the ‘whys’ are answered in the problem analysis as shown below.

(3) Challenges

Based on the survey results, a problem tree analysis was performed in order to find the key problems which have caused the current situation. The main problems the country faces today are broken down into manageable factors. The key problems fall into three areas from the viewpoint of business processes: Maintenance Planning, Plant Operation, and Failure Response and Repair.



Source: JICA PSMP2015

Figure 18-36 Problem Tree Analysis and Key Problems

The biggest problem the country faces today is power shortage, which is presumably caused by:

(a) The number of power plants is too small, or the total capacity of the plants is too little.
(b) The production level of each power plant is not sufficient.

The former is a factor for which we can expect solutions out of the scope of information management. The latter is caused by:

(a) The facilities are not fully operating.
(b) Performance of the facilities is low.
(c) Fuel shortage hinders power plants from achieving maximum performance capacity.

The first one is caused by long downtime. The second one is perhaps caused by aged facilities. However, some of the factors can be improved by the application of proper maintenance. The problem of fuel shortage is not within the scope of information management. However, if the fuel sources change in the future, efficiency in procurement and inventory control can be improved by implementing information management.

As for maintenance, which appears three times in the breakdown, we focus on the significance of preventive maintenance, which requires effective handling of data and documents, knowledge and planning skills. Failure response plays a large role in the downtime of a power plant. By organizing historical data which contains a lot of lessons to learn, the crew can take appropriate actions quickly.

The findings from the tree analysis are meaningful leads to envisage higher efficiency in the activity areas. For example, most of the power plants have difficulty applying preventive maintenance because facility data is not effectively collected. Although preventive maintenance needs a large amount of data for the physical state assessment of facilities, most of the power plants do not have an elaborate information platform to handle a wide variety of types of data which keeps growing.

Another example of a finding is process disruption. In failure response, looking up failure history is a common practice. However, the case records are stored in a software application in an isolated manner. Maintenance and repair activities involve various administrative tasks such as staffing, scheduling, purchasing and hiring contractors. At some power plants, it takes a long time for approval when a procurement request is filed. In this case, the obstacle between maintenance and procurement is the lack of plan and budget.

The three activity areas are actually the core processes of the power generating business and do not operate independently. Therefore, it is pointless to single out a problem from the activity areas and try to fix it. Poor information management and process disruption are the obstructive factors in many cases observed in the organization.

The table shows the obstructive factors found from the survey results. Efficiency is measured by the performance indicators commonly used by many companies. The organization perceives the performance of the processes through its key performance indicators which are, from an enterprise perspective, aligned with the organization's resources. This means that improvements in the activities' performances are measureable and quantitatively assessable.

Table 18-21 Obstructive Factors Found in the Survey

	Enterprise Resources		
	Human Asset	Facility	Finance
Obstructive Factors Found from Survey	Inefficient use of historical data Poor communication between business units	Heavy dependence on manual handling, paper based handling of data Weak interaction between engineering and administrative fields, or business units in the organization Poor management of process cycle	Weak awareness of cost due to lack of up-to-date supporting data Traditional governance on expenditure due to lack of forecast
Performance Factors Possibly Affected	Failure Responsiveness Employees skills	Performance Indicators in Power Generation (Reliability, Availability) Facility Lifecycle	Financial Indicators (ROE, ROI)

Source: JICA PSMP2015

Although, from the managerial point of view, the primary objective of indicators is to have a clear view of the operational performance and set standards for the organization, it is not realistic to cover all the performance factors across the power plants. It also requires the management team to set a framework to define meaningful indicators and keep tracking them. While most of the power generation companies focus on reliability, availability, safety and efficiency, other areas such as environmental impact should be considered in compliance with government regulatory changes. In the implementation effort on information management and sharing, designing a flexible system is crucial to embrace such changes in the business environment.

(4) Conclusion
Survey results indicate that there are some problems in the three core activities of the power generation business: plant operation, failure response, and maintenance planning. The problems are mainly caused by the absence of sufficient information and process disruption. Regardless of the level of management, activities need objective data to support improvement efforts.
The management team and the business units of the organization can achieve their improvement goals by carefully choosing meaningful performance indicators from a wide variety of types of information. Therefore, an integrated strategy for information management through the organization is necessary. This can be implemented by setting a framework for data acquisition and sharing, and interaction between business processes. Once the processes are established and the information for sharing is defined, it is very easy for the activities to make a plan, take an action, measure the efficiency and apply the results in decision making. This improvement cycle should be enforced across the organization so that the processes of the activities can work together by sharing information, which will bring higher efficiency in the overall activity of the organization. And then, the achievement will be perceived as the effective use of enterprise resources such as human assets, facilities and money.

18.8.4 Integration of information management strategy

(1) Key Processes
The key problems (factors) identified and categorized in the tree analysis affect the performance of the organization as a whole. The table below shows how the problems are connected with the organizational performance from the point of view of enterprise resources. The activities in the colored cells of the table correspond to the colored boxes in the problem tree.

Table 18-22 Key Problems in the Three Key Activity Areas

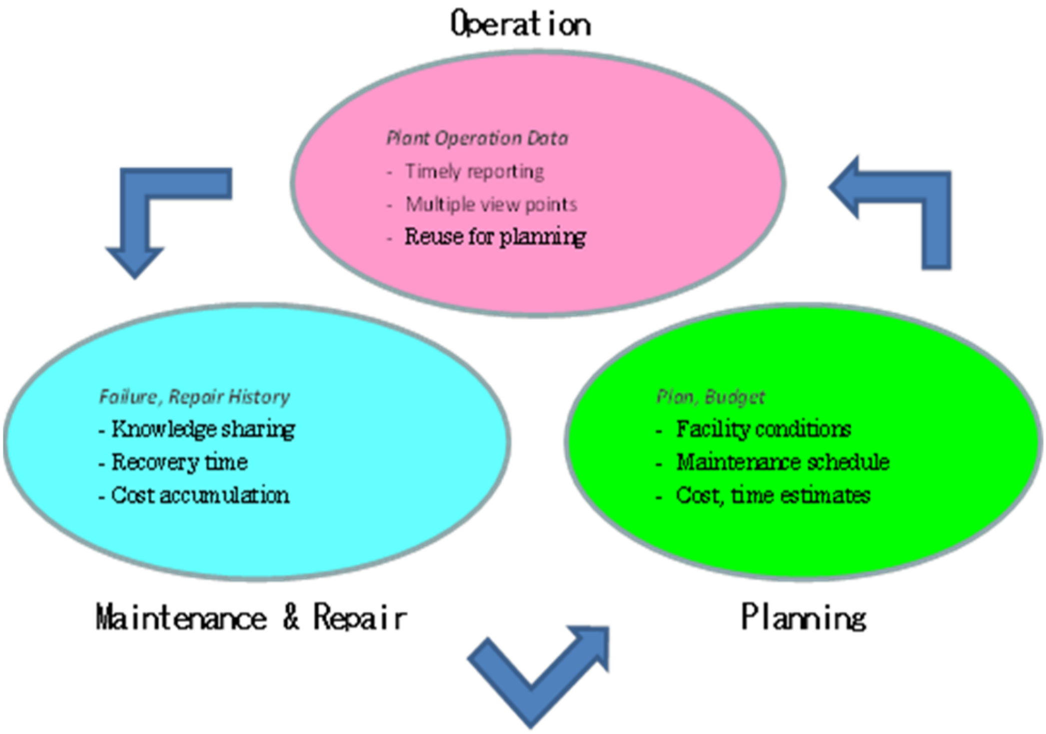
Activity/Resource	Human Asset	Facility	Finance
Plant Operation	—	Data loggers and information networks do not exist at some power plants.	—
Maintenance Planning	There is some need for technological enhancement.	Generally, facilities often keep performing until a forced outage occurs. Spare parts' inventory control is respectively implemented at power plants.	Budgeting and procurement planning processes are complicated. Maintenance plans often fail.
Failure Response and Repair	Although failure records are available, knowledge and know-how is not available to share.	Activities are not linked with facility conditions. Activities are not linked with procurement.	Total cost of owning the failed equipment is not managed. Past repair costs are not traced.

Source: JICA PSMP2015

(2) Process Cycle and Data
The three activity areas are the key processes (or core processes) of the power generation business,

which typically has a business process cycle as below.

Maintenance Planning	→	Operation	→	Maintenance and Repair



Source: JICA PSMP2015

Figure 18-37 Business Process Cycle in the Power Generating Business

The cycle has a fixed time period and occurs at different levels of management. Its focuses are broken down into detailed parameters and shared across the power plants and other business units. The frequency of monitoring and controlling varies depending on the level of management. Monthly reporting to the head office creates a control point at plant level while daily walkthrough reports are firstly delivered to the relevant manager who has span of control in the engineering field. The most important point is that those business process cycles across the hierarchy and structure of the organization are synchronized. Our objective is to set a framework for information management integrated through the organization, so that the management team and all of the business units can achieve their performance goals, which are measured by key performance indicators regardless of the level of management or the profession.
In order for the cycle to keep moving towards improvements, selection of appropriate data (parameters) is the key. The following are the data areas corresponding to the business process and the challenges the processes have followed by improvement ideas for the data areas.

(a) Plant Operation Data
Inefficient reporting processes often hinder quick managerial analysis and decision making, which is caused by the fact that information management relies heavily on manual handling. Timely reporting and analytical re-use of plant operation data lead to the efficient management of a modern power sector.
Switching from paper based reporting to information systems, aiming for:

- Timely, accurate, analytical, visualized presentation of plant performance
- Re-use of data for planning and budgeting

(b) Failure, Repair History

Although a software application is used for failure management at some power plants, it is not integrated with other systems. The management process is isolated and also handled manually. It is not easy to allocate optimal resources to the failure response team. History data, accumulation of know-how and lessons learned should be organized and shared by the field crew and transferred to other business units such as the procurement division for other purposes. For example, collectively controlling spare inventory across power plants, parts sharing and having an internal purchase program can contribute to a reduction of procurement overheads. Also, assessment of failure impacts improves the readiness for possible failures.

Knowledge sharing, aiming for:

- Accumulation of knowledge to help crew solve impending problems
- Reduction of response time, recovery time
- Improvement in activity efficiency based on lessons learned from history
- Learning opportunities for field engineers
- Case studies for other plants which own similar equipment.

Integration between failure trends, activities, procurement and budget, aiming for:

- Smooth procurement of spare parts and optimum replacement
- Spare inventory optimization
- Control of Total Ownership Cost

(c) Plan, Budget

A number of research studies and analysis results suggest that corrective maintenance costs more than preventive maintenance. Although it usually takes time to recognize the effects of preventive maintenance, sufficient data will be acquired to support rationalization of planned shutdown instead of forced shutdown in response to facility failures. It is also expected that implementing scheduled maintenance and procurement contributes to financial efficiency by optimizing inventory level and budget.

Creation of feasible maintenance plan, aiming for:

- Improved readiness for possible malfunction by predicting based on facility condition
- Accurate time and cost estimates
- Budget control, optimal procurement plan and spare inventory
- Grasp of facility lifecycle cost, investment decisions
- Facility life extension by performing proper maintenance

Implementing scheduled shutdown, aiming for:

- Mitigation of impact on the grid
- Reduction of opportunity cost and start-up/shut-down cost

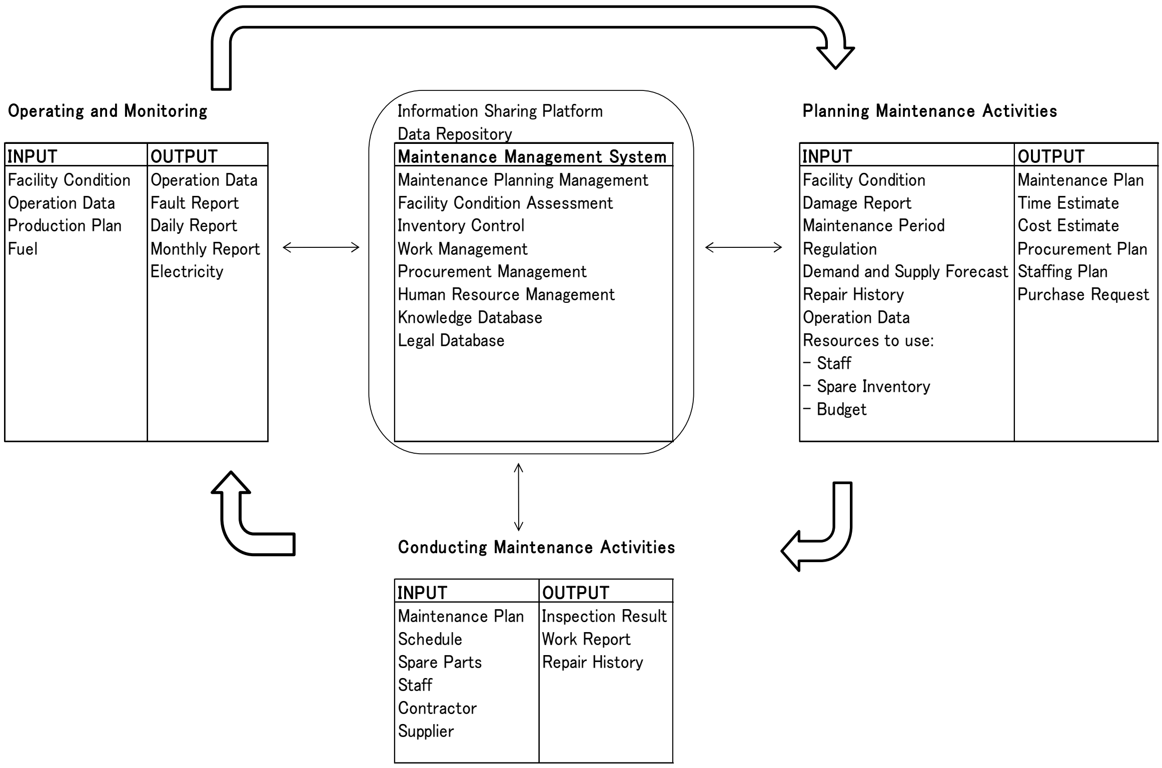
18.8.5 Implementation of information management system

(1) Information Sharing Platform

The three core activity areas and data areas in the cycle have various work which is performed by either people or computers. For example, data collection can be done by receiving paper documents or computer files. Maintenance plans are created primarily based on the physical state of the facility. Requirements from laws and regulations and manufacturers' recommended maintenance periods are taken into account as well. Maintenance managers also have to care about blackout schedules, staffing and procurement. Thus, data collection involves a lot of manual work and document handling. An information sharing platform allows all business units to access the necessary data to complete their work. Procurement managers can update purchase plans upon request from maintenance managers. The benefits of the use of an information sharing platform are:

(a) Centralized information management mitigates problems arising from data proliferation.
(b) Business processes are easily controlled and interactions are facilitated.
(c) It can be flexible and scalable.

The figure shows an example of the implementation of the maintenance process cycle on the information sharing platform. Each phase has Input and Output, of which information comes in various ways such as paper documentation, verbal conversation, and email and computer files. Therefore, it is very important for the management team to set a framework for an organization-wide information management strategy. Once the data handling rules are decided, the data repository stores the various types of information in a uniform, structured manner.



Source: JICA PSMP2015

Figure 18-38 Information Sharing Framework for Maintenance Activities

Concerns in collecting data from day-to-day activities vary depending on the level of management. The information management framework defines a set of indicators aligned with the performance goals of the activities. By carefully choosing parameters and their delivery methods, effective data collection can be achieved.
The table shows an example of a set of performance factors and information sources required to measure or calculate the organizational performance on each level of management. Data acquisition and delivery methods influence how efficiently the information is collected. Manual meter reading and manual data entry into an application system can be replaced by automated data acquisition in order to reduce delays and errors in reporting processes.

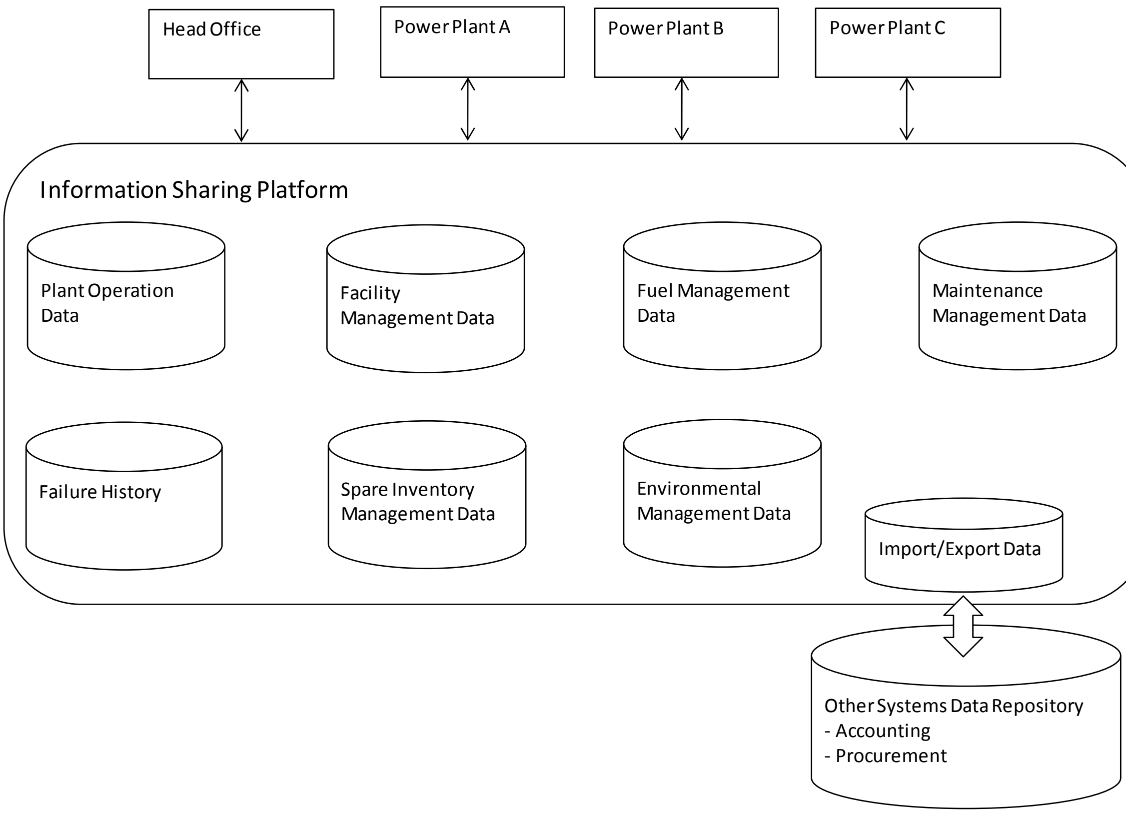
Table 18-23 Examples of Performance Indicators and Data Sources

		Performance Factor	Example of Information Source – Data Delivery Method	Data Acquisition Method
ENTERPRISE LEVEL	Financial Performance	Financial Performance Indicators	Accounting Data – Computer Files from Accounting System	Manual Data Entry
	Facility Condition	Reliability Availability Efficiency	Plant Operation Data – Computer Files from Data Loggers Damage Report – Paper Document Walkthrough Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing
	Human Asset	Number of Incidents Number of Qualified Employees Turnover	Human Recourse Data – Computer Files from HR Periodical Report – Paper Document from Power Plants	Manual Data Entry Manual Report Writing
PLANT LEVEL	Productivity	Production Consumption Thermal Efficiency	Plant Operation Data – Computer Files from Data Loggers Periodical Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing
	Maintenance Efficiency	Budget Balance Downtime	Activity / Procurement Plan – Paper Document Purchase History – Computer Files from Accounting System	Manual Data Entry
	Fault Management	Fault Responsiveness Downtime	Activity Report – Paper Document	Manual Data Entry
	Environmental Impact	Emission Effluent Discharge Disposal	Emission Data – Computer Files from Data Loggers Periodical Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing

Source: JICA Survey Team

The information sharing platform connects Head Office and other business units seamlessly. Information flows are orchestrated and reporting processes are simplified. Although there are some legacy systems being used in some business units, most application software products have functions to export and import data in standard formats which allow the systems to interact with the integrated information management system on the platform. This function can be extended to external organizations such as grid operators.

The figure below shows an example of a platform for information sharing. The platform provides the system users with data sharing functions through a range of user interfaces of application systems. The main functions are database access and file handling.



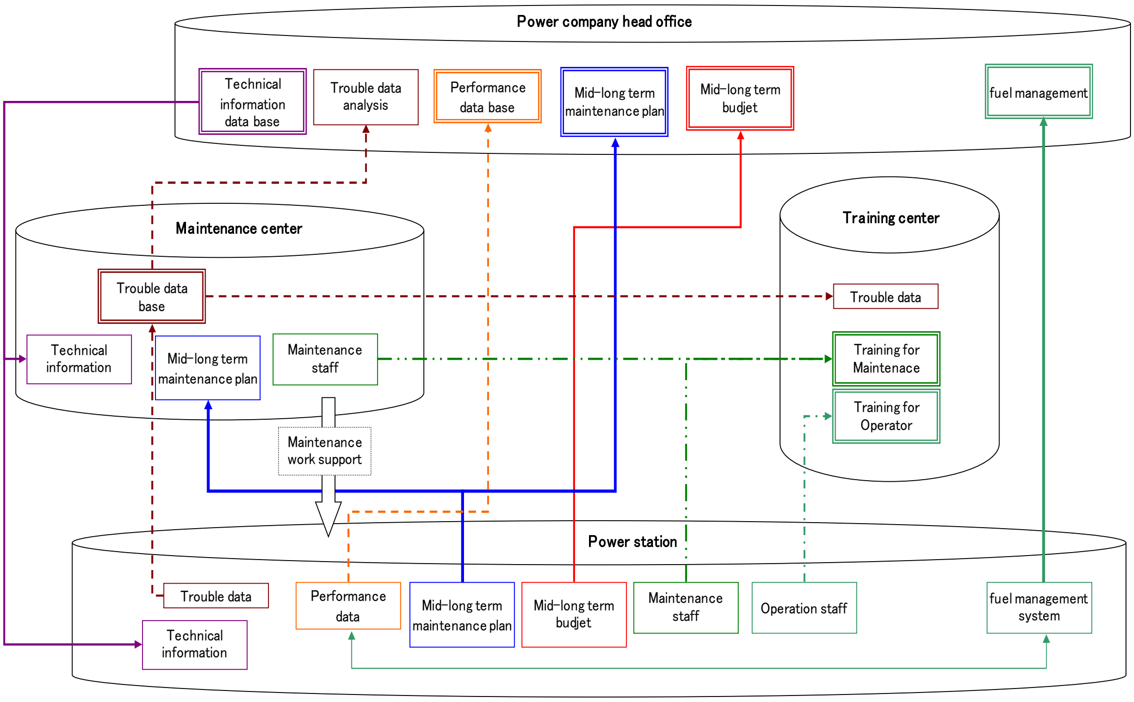
Source: JICA PSMP2015

Figure 18-39 Conceptual Model of the Information Sharing Platform

(2) Integrated Plant Operations Management System

According to the survey results, some power plants have application systems for the management of operational information which includes failure history. It is necessary to take into account such valuable information assets in the legacy systems when implementing a new system. Management of legacy data must be part of the organization-wide integration strategy for information management. ERP and EAM are examples of integrated application systems to provide data sharing functions in a uniform manner to various types of users who use the system for different purposes. One of the advantages of ERP or EAM is that data and business processes are structured based on the sector's standards. Configuration of the system includes templates for business processes and target data as well as report formats and data table formats which can be customized to meet the company's requirements. As mentioned before, the flexible and scalable platform allows the application system to embrace changes in organizational structure or policies. Interfaces with external organizations are usually available.

The figure shows a conceptual model of a Thermal Power Plant Operation Management System envisioning future implementation of information sharing among current business units and new agencies, Maintenance Center and Training Center. While maintenance activities and training activities are performed separately, the improvement cycle of facility operation and maintenance as a whole can be practiced effectively by controlling the data flows on the platform. The scope of the system covers maintenance knowledge, maintenance plans, activity results and failure information, which appear in the diagram as data flows between business units.



Source: JICA PSMP2015

Figure 18-40 System Functions and Data Flows for a Power Plant in Bangladesh

(3) Application Modules
The system consists of the three main components for business functions listed below. The users of the system can work concurrently through the information sharing platform by either accessing one of the modules or accessing the interface and files from other application systems which are integrated with the system.

(a) Production Management
(b) Maintenance Management
(c) Failure History Management

New modules can be added to the system for future extension. For example, if the government is going for new environmental regulations, an Environmental Management System can be introduced. Fuel Management may be added in the future if a new facility which uses coal as fuel is installed. The following explains the functions of each one of the main modules.

(a) Production Management
This module is equipped with presentation tools for visualization of plant performance. Data is mainly collected from the power generation facility. For some of the parameters used for calculation of plant performance indicators, data acquisition relies on manual entry. Key performance indicators vary depending on the level of management.

- Data acquisition frequency and report period settings
- Graphs and tables for analysis
- Data aggregation and comparison for multiple levels of management

(b) Maintenance Management
A project management tool to create plans and manage activities. By focusing on resources such as staff, materials and money, maintenance managers can monitor the efficiency of maintenance work

and budget balance.

- Schedules and work progress management
- Procurement plans and budget control
- Maintenance and repair history management

(c) Failure History Management
Case database linked with facility maintenance information. Information on the failed equipment and associated information is handled in a collective manner. Preventive maintenance requires historical data for the equipment, by reference of which a decision on further investment for the equipment can be made.

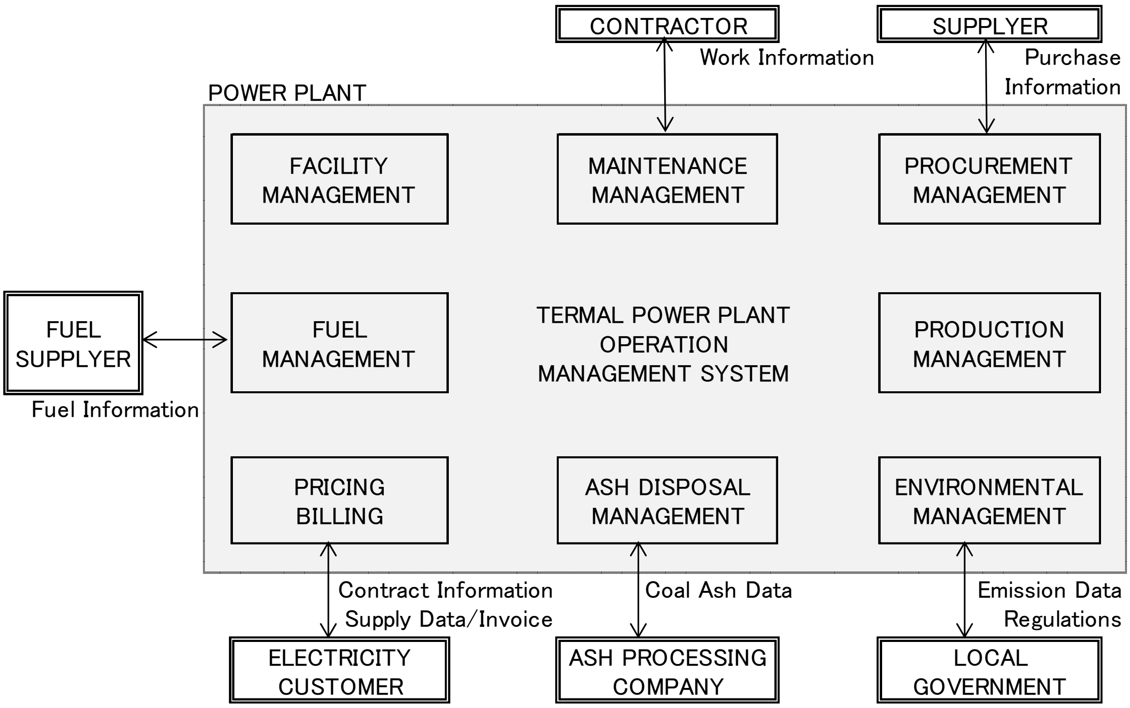
- Assistance to field crew to search similar cases
- Management of cost information along with technical information
- Organized data which is reusable for training purposes.

An additional module may be considered for the future installation of new facilities as the country's energy policy shifts from natural gas to coal.

(d) Fuel Management (For Future Plans)
The users of this module can keep track of the status of the fuel from procurement to delivery. The information contains the amount of fuel unloaded and its cost. Monthly report indicates the purchase trends, which can be useful information for procurement planning.

- Management of fuel transport, reception, inventory, delivery
- Management of fuel property and quality
- Management of fuel prices and associated cost

(4) Example for Further Enhancement
As shown above, the system will be enhanced in the future to suit the business growth and meet the requirements from the market in Bangladesh. As a further example of best practice for information management aimed at higher reliability and efficiency, an overview of the power plant information management system at one of the leading companies in Japan is shown in the figure below.



Source: JICA PSMP2015

Figure 18-41 Modern Information Management System in Japan

Over the past two decades, the company has injected efforts in information management as part of its achievements for maintaining reliability and efficiency. The challenge is to deal with the various types of facilities which are dispersed across more than 10 locations near the demand places in populated regions. On top of the inefficiency of paper based documentation, isolated systems on PCs limit the efficiency of data handling. One of the solutions to the challenge was to integrate the core business systems on an enterprise-wide network platform.

In Japan, power facilities are maintained with highly sophisticated information technology. The scope of information management includes environmental impact, safety, regulatory compliance, accountability to shareholders and social responsibility. The power sector is under severe watch by the government, and often in the center of public attention; therefore, the impact of information on its business is huge. Predictive maintenance technologies are also the key to successful operations of the high-performance large-capacity facilities. In consideration of future growth and market changes in Bangladesh, this implementation can be a good example of best practices in information management.

18.8.6 Implementation proposal

(1) Preparation for Successful Implementation

Strong leadership from top management is required for drawing up a plan for implementation of the integrated information management strategy. Relationships between business processes represent roles and objectives of the business units in the improvement cycle, which defines what information to share. While plant operators focus on maintaining production level, field engineers decide which piece of equipment needs to stop. Production planning and maintenance planning should be working concurrently by sharing schedules and facility condition data. The procurement manager needs to know when purchase requests will be filed from the maintenance manager because delays in supplier selection and financial arrangement lead to an overall delay in maintenance works, which may result in a longer downtime.

It might be a time consuming task to draw all the blueprints for information and process flows across the organization. Therefore, phased implementation is recommended. In a phased implementation

approach, implementation is done by gradually replacing conventional business processes and data handling with new systems based on the new information strategy. The management team is expected to prioritize the business objectives and carefully select performance indicators which are to be shared on the data sharing platform. As the platform is flexible and scalable, it is a feasible way to introduce new application systems step by step.
In the preparation for the implementation, there are many points which need to be considered. The priority processes must be examined to determine which tasks can be automated and which data can be accommodated in the data repository. Strategic ICT planning includes the following points, each of which must be addressed.

(a) ICT Infrastructure
- Data Acquisition from Power Generation Facility
- Plant LAN (Local Area Network)
- Data Repository (Data Center)
- Enterprise Network

(b) Management
- Business Process
- KPI (Key Performance Indicators)
- External Organizations (Suppliers, Contractors, etc.)
- Employee Training

(c) ICT System Operation
- Legacy Systems and Data Integration
- ICT Policies and Guidelines
- ICT Education

In order to address the points listed above, further survey is expected to be carried out as shown below.

Table 18-24 Items Expected to be Addressed in Further Survey

Category	Item	Details
ICT Infrastructure	Data acquisition from power generating facility	Connectivity between facility and data acquisition devices
		Data parameters, collection periods
	Plant LAN	Local Area Network availability in power plants
	Data repository (Data Center)	Data center location, storage capacity and scalability
	Enterprise network	Network availability, connectivity among business units and multiple locations, and its security, reliability and capacity.
Management	Business process	The three core business processes, tasks and their business requirements.
	KPI	Framework setting for KPIs and other indicators.
	External organizations	Interaction with stakeholders, data sharing scope and rules. Interaction with legal framework.
	Employee training	PC users and employees' computer literacy
ICT System Operation	Legacy systems and data integration	Legacy systems and legacy data.
	ICT policies and guidelines	ICT policy setting. Guidelines for operating and maintaining the information management system.
	ICT education	ICT staffing and the required skills.

Source: JICA PSMP2015

(2) Implementation Options
There might be some modifications needed to the current business processes. The organization must

respond to the requirements from the market, which rapidly keeps changing. The procurement policy may change to accept new suppliers or new energy sources, or to reflect new contract types of purchase or outsourcing of repair work. While the information management system can be flexible and scalable to embrace changes, conventional business processes may well remain unchanged due to the rigid structure of the organization based on roles and functions. In order for the process cycle to keep moving towards improvement, there are several options in which some part of the processes may be redesigned.

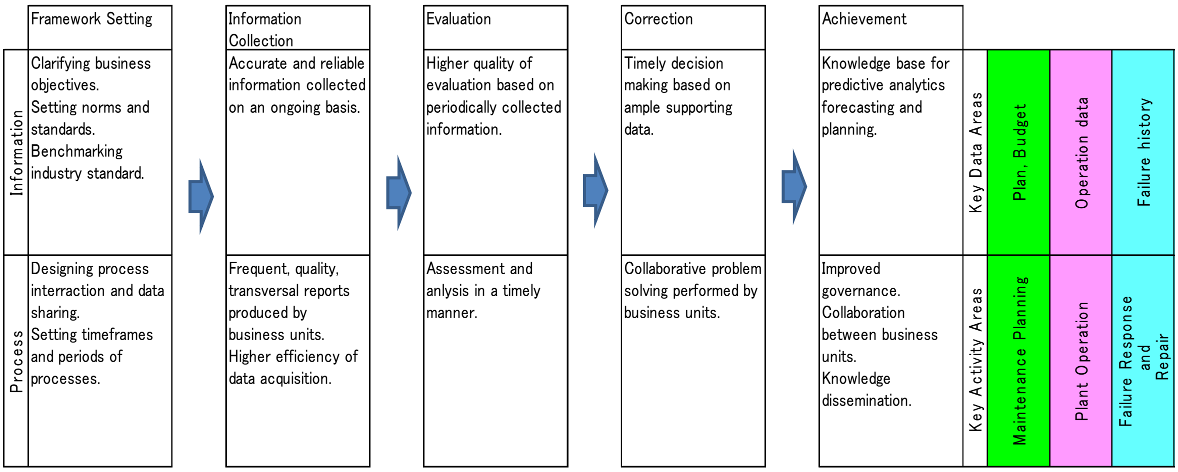
Table 18-25 Implementation Options and Process Modification Options

	Business Process Change		
System Implementation Options	No Process Change	Partial Modification	Process Reengineering
Configuration of Application System	Not realistic. Feasibility study is required to know if system best suits process. Legacy system is a burden.	Take advantage of business templates. Feasibility study is required to know which process to modify to suit the system. Data redundancy and duplication of work remain.	Take advantage of business templates. Quick implementation. Most economical but radical. Suitable for startups. Move from legacy system to new system.
Customization of Application System	Use business templates and out-of-box functions. Integrate with legacy system. Initial cost is relatively high.	Use business templates and out-of-box functions. Integrate with legacy system. Cost is relatively high.	Use business templates and out-of-box functions. Integrate with legacy system. Less expensive. Data redundancy and duplication of work remain.
Development of Tailored Application System	The processes do not need to change if they are performed through best practices. System may be inflexible and vulnerable to environmental change. Initial cost is high.	Carefully designed system can be flexible. Cost is high.	Develop system which best suits the organization. Align system to business strategy. Integration with legacy system is guaranteed. Long term ICT strategy is required.

Source: JICA PSMP2015

18.8.7 Expected results

By promoting certain practices such as process interaction and information sharing, positive results will be obtained in the key activity areas. The figure below shows the sequence of intended events by implementing the information management strategy in the power generating business.



Source: JICA PSMP2015

Figure 18-42 Improvement Cycle and Otcomes

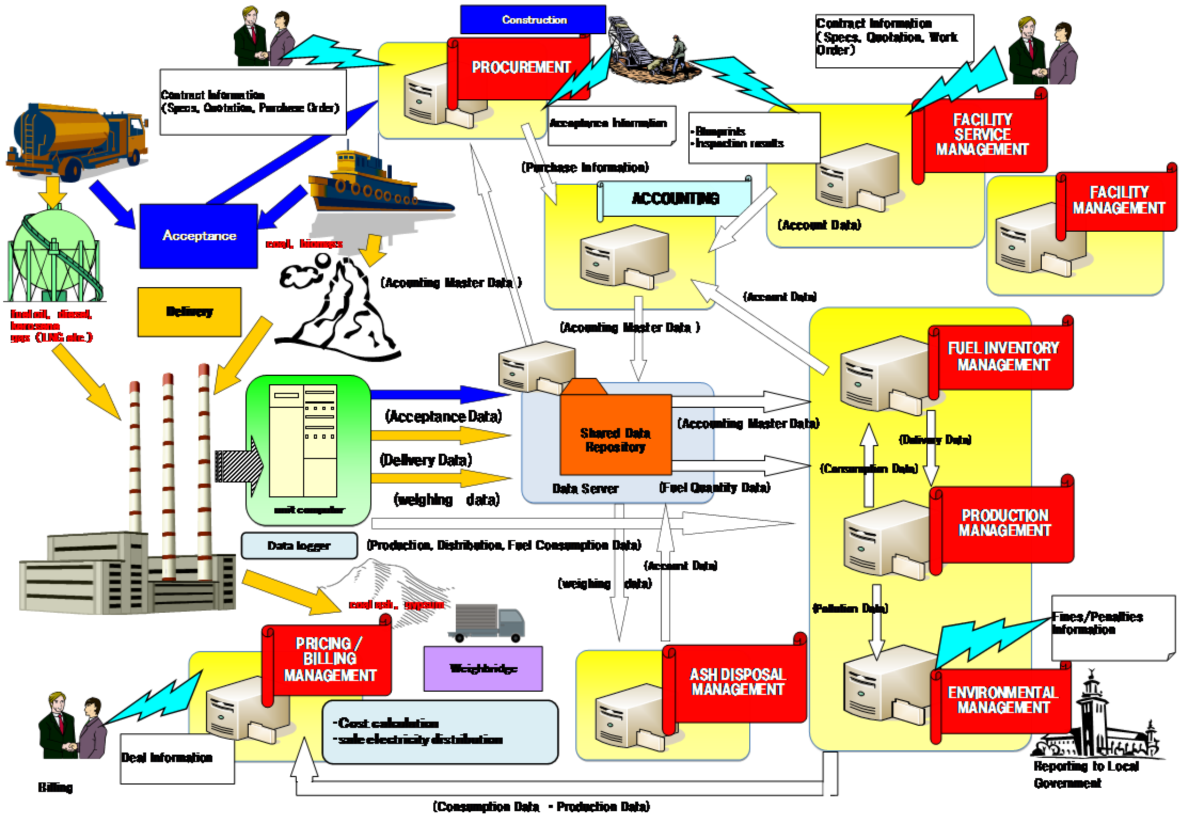
As a result, the following improvements in the three core activity areas will be expected.

(a) Maintenance Planning
- ➢ Accurate time and cost estimate for maintenance enables precise budget control, and optimization of procurement and spare inventory.
- ➢ Ascertainment of facility lifecycle cost and optimum investment decisions brings financial efficiency.
- ➢ Facility life extension by applying proper maintenance reduces total ownership cost.
- ➢ Implementing planned shutdown mitigates impact on the grid, and reduces opportunity cost and start-up/shut-down cost.

(b) Plant Operation
- ➢ Timely collected, accurate and reliable data improves the quality of evaluation and decision making, which contributes to facility assessment and maintenance planning.
- ➢ A wide variety of types of data, which is structured and assorted in a uniform manner, facilitates process interaction for problem solving and improvement.

(c) Failure Response and Repair
- ➢ Knowledge base helps field crew solve impending problems and reduce recovery times in the case of failure.
- ➢ Improvement in activity efficiency based on lessons learned from history will be achieved.
- ➢ Process interaction and data sharing with procurement leads to a reduction of total ownership cost and inventory cost.

The figure below depicts an overview of the power plant information management system which is envisioned for future implementation.



Source: JICA PSMP2015

Figure 18-43 Future of the Power Plant Information Management System

18.9 Training Center

18.9.1 Necessity of training center

To improve Bangladesh's O&M skills, the most necessary thing is construction of the training organization. As mentioned in 11.3.2 Summary of actual O&M situation, Bangladesh does not have an efficient training center. Therefore, it needs to have an effective training center and curriculum and also to develop instructors.
In reference to training facilities and training courses in Japan, the JICA survey team explains what is necessary for Bangladesh, as follows.

18.9.2 Training course

In Japan, to develop staff, several courses are prepared for them according to their skill level, and their knowledge level is confirmed.

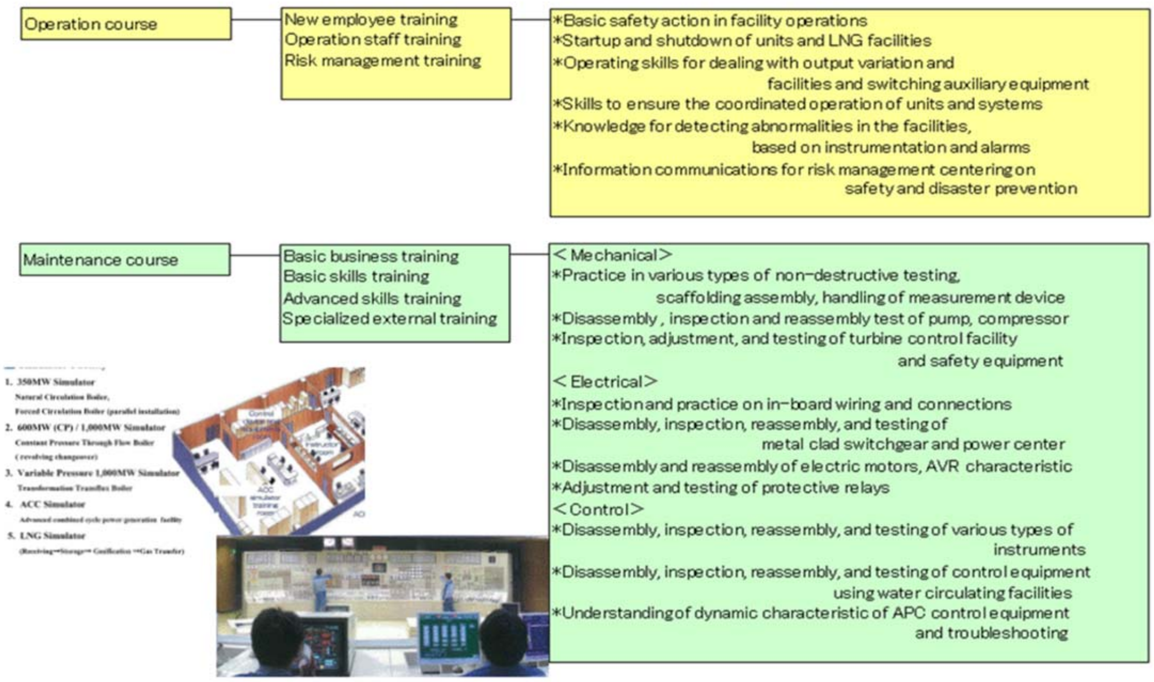
"Sample of operator training course"

(a) Training course for new employee
(b) Operator training course
(c) Risk management training course (Guide class, practitioner class, manager class)
(d) Chemical treatment, water treatment, drainage treatment training course

“Sample of maintenance course”

(e) Basic training course
(f) Applied training course (boiler, turbine, electrical, control)
(g) Special training course by manufacturer

The above courses are separated into several, more detailed courses.
And operator and maintenance staff need to be checked and authorized according to their years of experience.



Source: JICA PSMP2015

Figure 18-44 Sample of Training Curriculum

18.9.3 Instructors

Instructors need a high level of skill and knowledge, and they also get a high level of education and training. Because every instructor is also an operator or maintenance staff, they also have personnel rotation between the training center and power station, getting site knowledge and feeding this back into the training content. The most important thing is to keep instructors' skill and knowledge levels high, by gathering people of ability from every power station, performing periodic personnel rotation between the training center and power station and ensuring that instructors do not forget the feeling of working at a site.

18.9.4 Training facility (simulator)

A training simulator is very useful for a training facility.
The simulator has to satisfy the following functions.

Functions for instructor

(1) Simulator execute, stop and snapshot function
(2) Initial condition setting function
(3) Variable speed control function
(4) Back track, reappearance function
(5) Malfunction
(6) Change operation condition function

Functions for trainee

Graphic screen has to show the same level screen as an operator console, and be able to operate the same as an operator console. It must also be able to show a control logic, trend graph and alarm screen.

Functions for simulator

The simulator has to simulate the following systems.

(1) Plant automatic start up and shut down control system
(2) Usual operation control system
(3) Burner control system
(4) Boiler sequence control system
(5) Turbine sequence control system
(6) Other sequence control system
(7) Plant operation simulation system after parameter tuning

Except for main facilities like boiler, turbine and generator, other facilities like a coal handling system, steam turbine, water analysis system, fire extinguishing system and so on vary with manufacturer, so the need for their inclusion in the simulator should be judged in consultation with the owner.
Of course, control logic and parameters need to be equal to a real unit control system, so that the plant simulator becomes a more realistic simulation.

18.9.5 Training facility (maintenance)

During training, maintenance staff learn how to re-assemble, adjust, fix and assemble several facilities. Therefore, when selecting a training facility, one which is the same as the facility in Bangladesh is suitable and effective.
The following facilities are those basically needed.

(1) A motor and pump
(2) Turbine feed water pump
(3) Control valve and actuator
(4) Pressure transmitter and flow transmitter
(5) A control system that has a control valve, pump and water tank in one loop
(6) A centrifugal fan or axial flow fan
(7) Non Destructive Inspection (PT, MT, UT) training facilities
(8) Rotary apparatus balance adjustment training facilities using a vibration analysis device

This is an example, and it is desirable to have the necessary facilities in the training center.

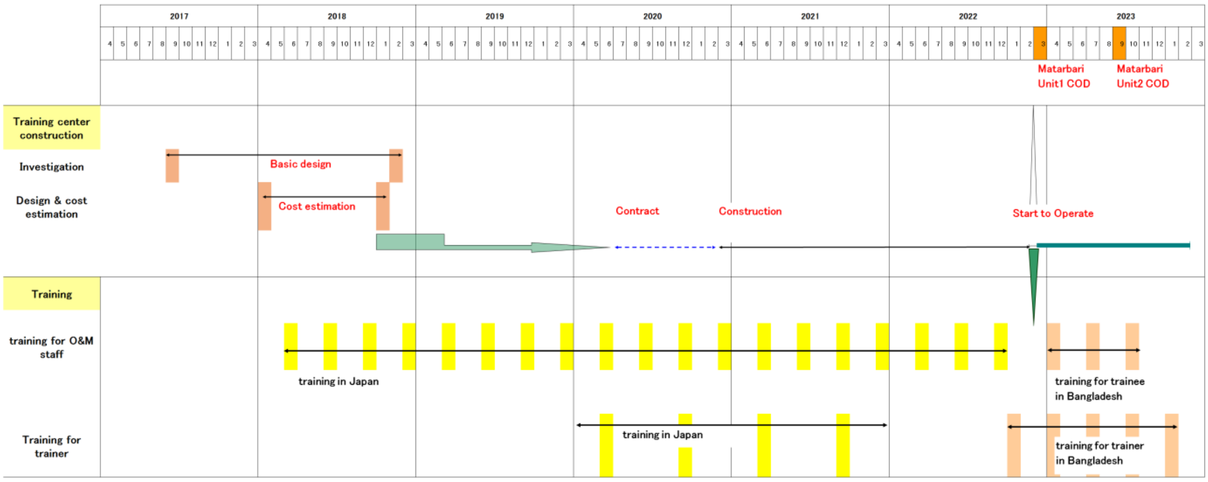
18.9.6 Important points for training center

It is important that the training center satisfies the following

(1) Curriculum from new employee to veteran
(2) Lecturer development, personnel interchange
(3) Most suitable training facility

18.9.7 Schedule for training center construction

Below is the schedule plan for O&M personnel development training center establishment when the target is the commercial operation date for Matarbari.



Source: JICA PSMP2015

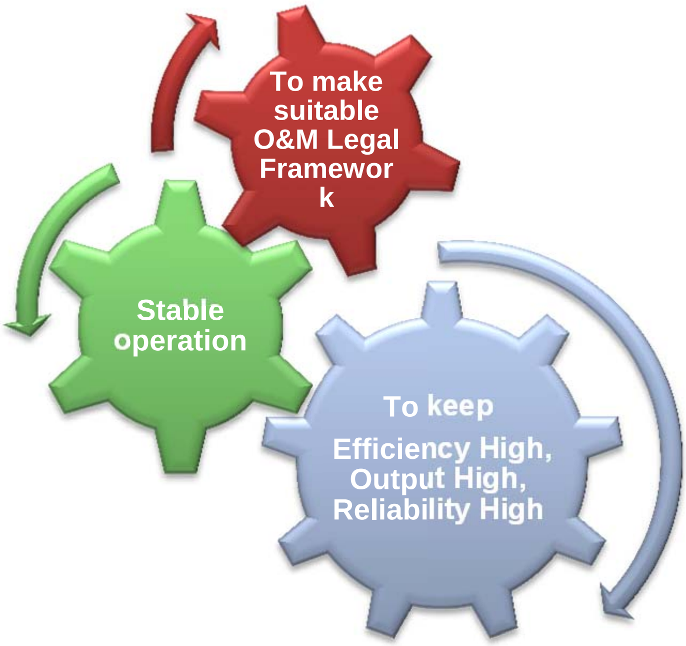
Figure 18-45 Training Center Construction Schedule Image

Chapter 19 Study for O&M Legal Framework

19.1 Introduction

19.1.1 Purpose of this study

The purpose of this study is to suggest the establishment of the suitable legal framework for Bangladesh.

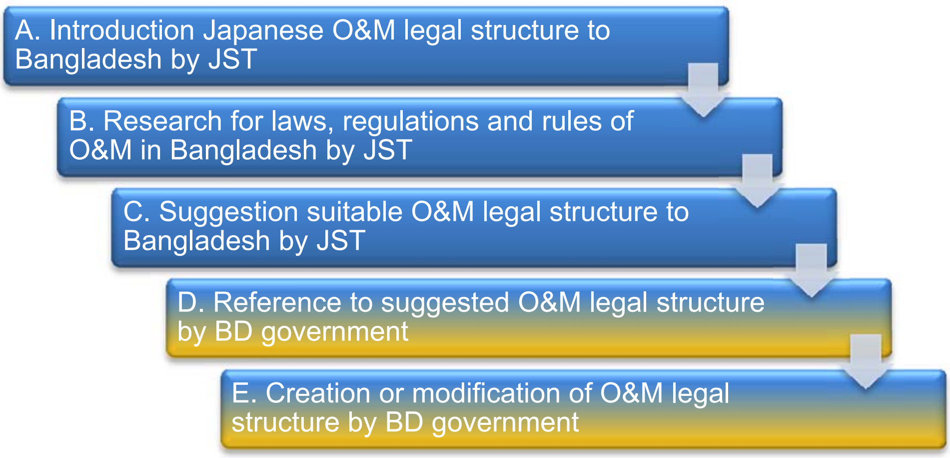


Source: JICA Survey Team

Figure 19-1 Purpose of O&M Legal Framework

19.1.2 Solutions procedure

This solutions procedure is as follows. A, B and C are done by WG, and D and E are done by the Bangladesh government. JST means JICA Survey Team.

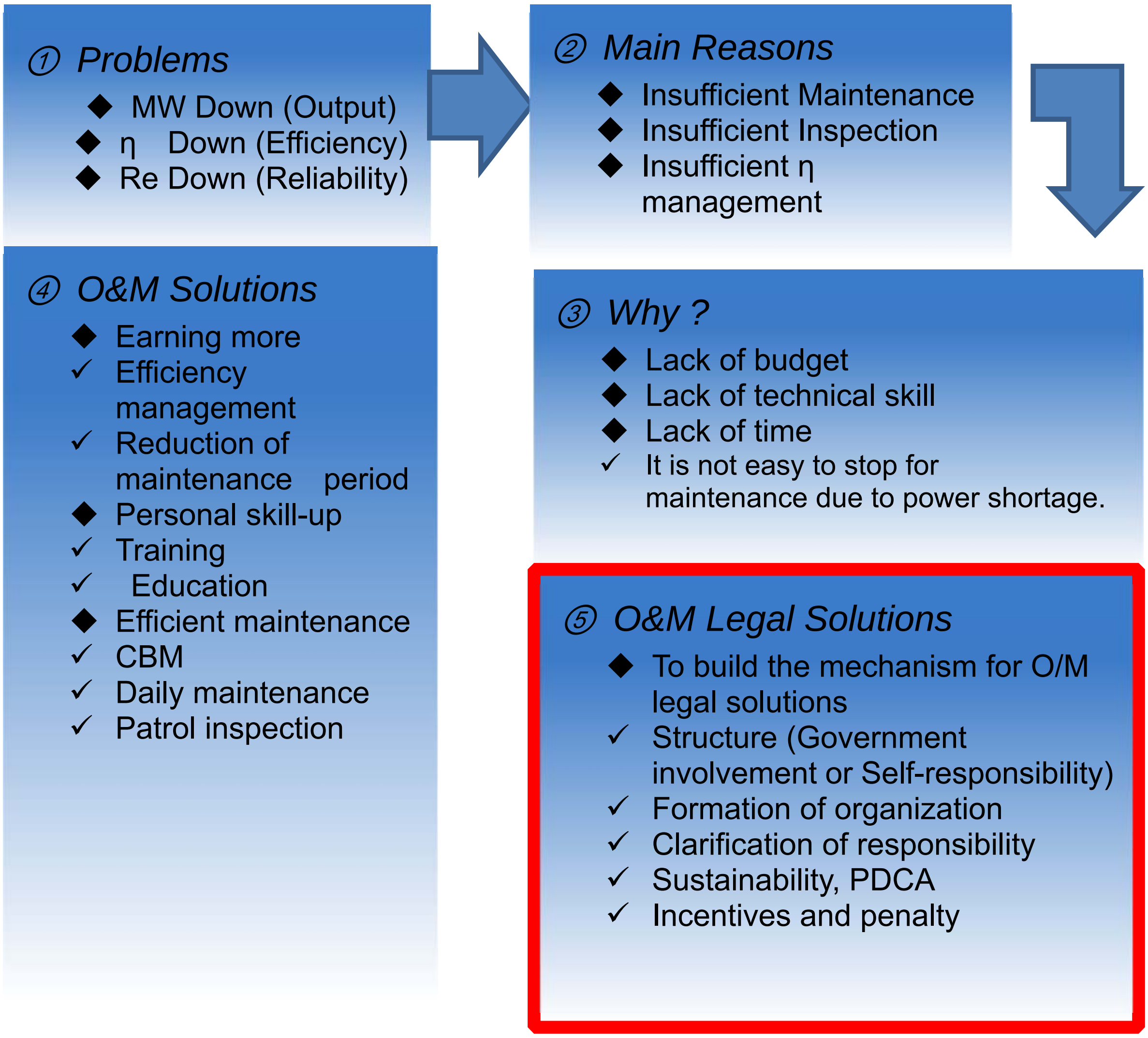


Source: JICA Survey Team

Figure 19-2 O&M Legal Solutions Procedure

19.1.3 Cause and effect diagram

Cause and effect diagram for Bangladesh is as below. The red square is this study's solutions for suitable O&M in Bangladesh.



Source: JICA Survey Team

Figure 19-3 Problems and O&M Legal Solutions

19.1.4 Scheme of O&M legal framework

The O&M Legal Framework contains 2 kinds of schemes. One is concrete measures and the other is philosophical approaches.
There are a lot of measures for stable operation, as per the below figure, and many approaches should be considered by the legal framework.

Source: JICA Survey Team

Figure 19-4 Concrete Measures

Source: JICA Survey Team

Figure 19-5 Philosophical Approach

19.1.5 Key factors for stable operation

The O&M Legal Framework should support key factors for stable operation.
The key factors for O&M are these three measures:

- MAINTENANCE
- ORGANIZATION
- PERSONAL SKILL

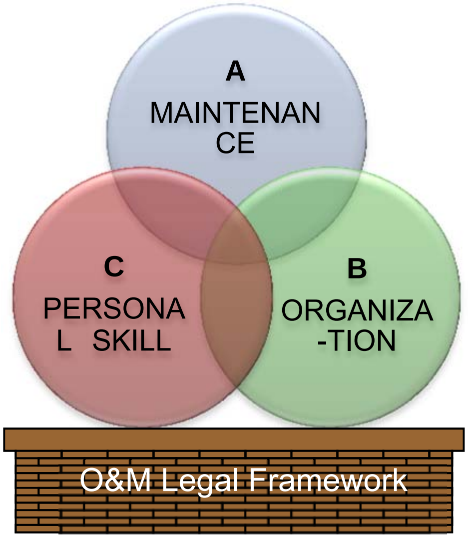


Figure 19-6 Key Factors for O&M

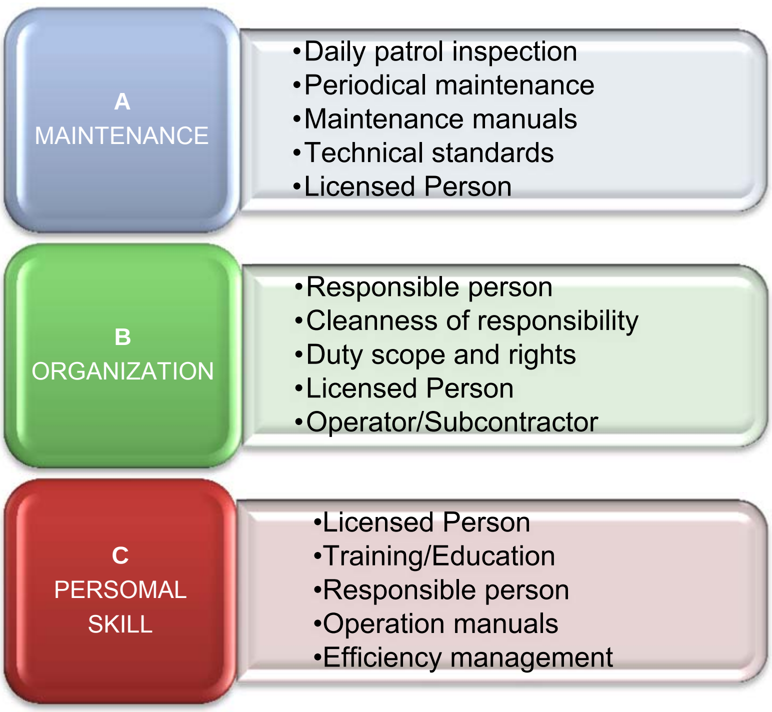
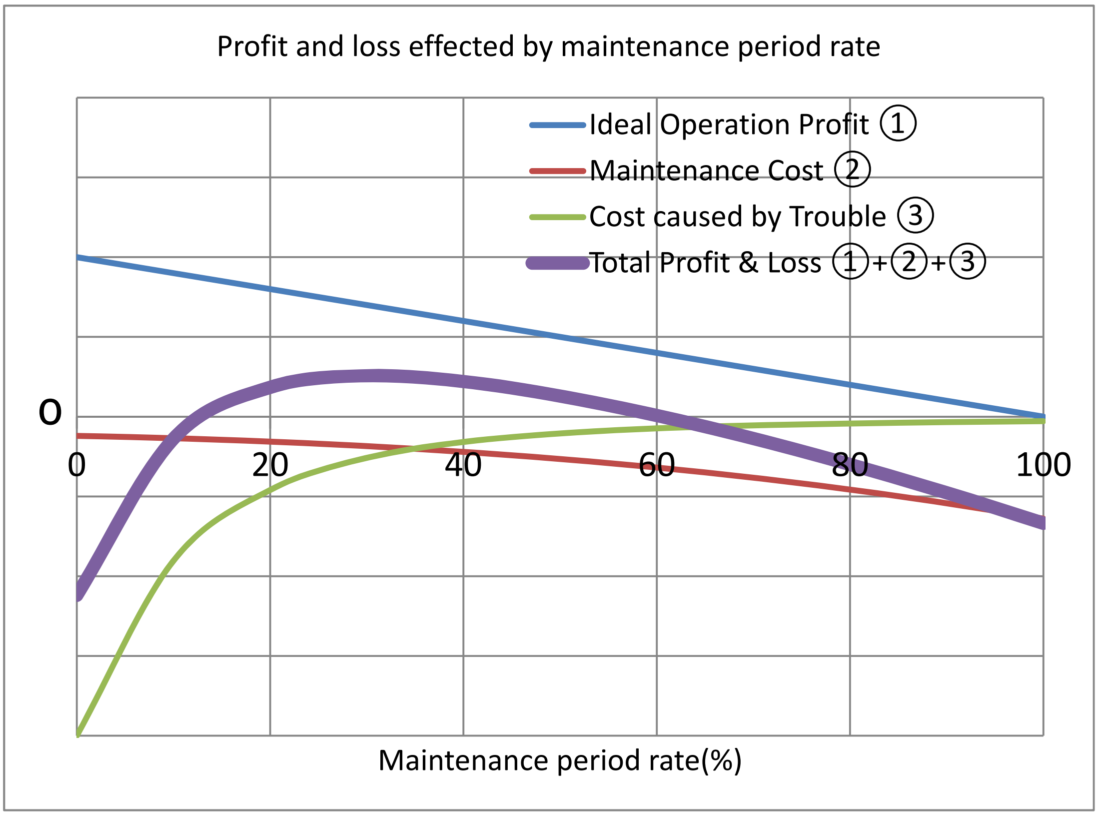


Figure 19-7 Details of Key Factors for O&M

19.1.6 General economic concept of O&M

(1) Maintenance period rate

Suitable maintenance will enable stable operation and stable operation will produce economic benefit. Maintenance Period Rate explains operational benefit easily.
**Maintenance Period Rate (%) = Maintenance days/All days
MPR 0% = No maintenance, Operation always if no trouble
MPR 100% = Maintenance always. NO operation
The following figure shows operational profit/loss against maintenance period rate. It is easy to understand that suitable maintenance produces economic benefit for P/P.



Source: JICA Survey Team

Figure 19-8 Profit and Loss Affected by Maintenance Period Rate

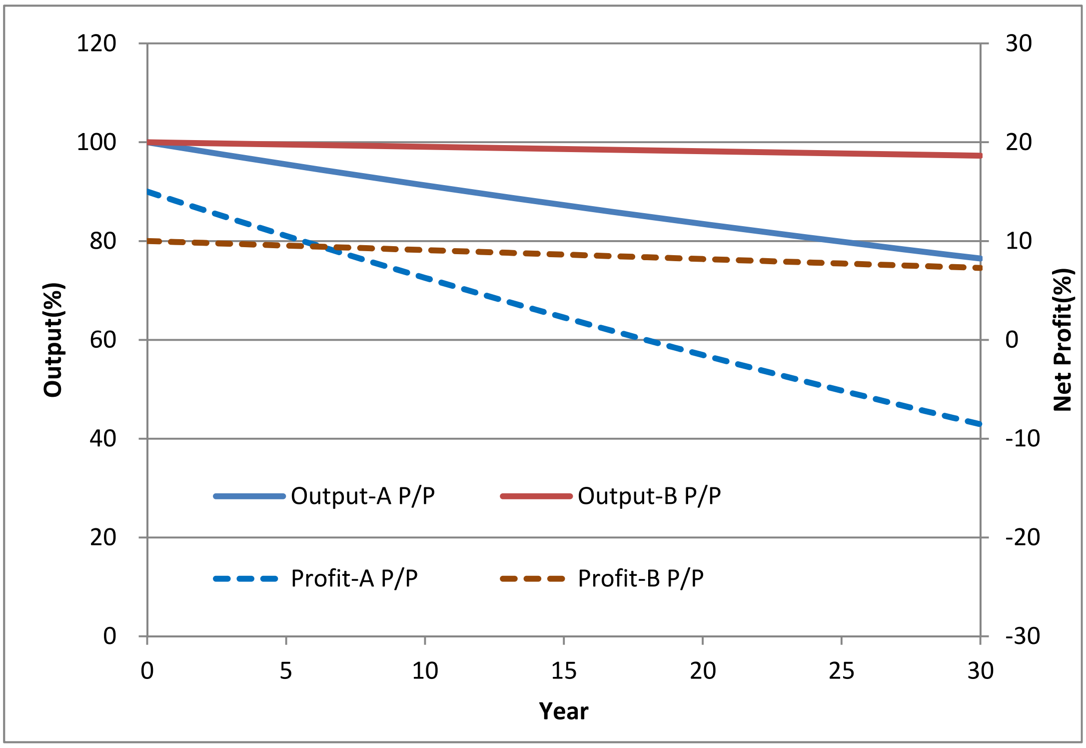
- Too low an MPR produces a big loss
  - Long unplanned stop, with no earnings
  - Huge cost for repair needed
- O&M legal solutions should be built to encourage suitable maintenance opportunities

(2) Output and Profit

The maintenance/inspection cost is much cheaper than operational gross profit but insufficient maintenance causes output-decrease and efficiency-decrease. The output-decrease and efficiency-decrease influence gross profit directly and cause a huge negative impact.
Two P/P, A and B, are assumed as insufficient maintenance and sufficient maintenance with some conditions. The following figure shows operational profit/loss against operation years. It is easy to understand that suitable maintenance produces economic benefit for P/P.

Table 19-1 Conditions

	A P/P	B P/P
Output(MW)	100% at COD to 77% at 30y	100% at COD to 97% at 30y
Gross Profit①	100% at COD to 77% at 30y	100% at COD to 97% at 30y
Fuel Cost②	70% at COD to 70% at 30y	70% at COD to 70% at 30y
Fixed cost③	10% at COD to 10% at 30y	10% at COD to 10% at 30y
Maintenance Cost④	5% at COD to 5% at 30y	10% at COD to 10% at 30y
Net Profit①-②-③-④	Calculated	Calculated



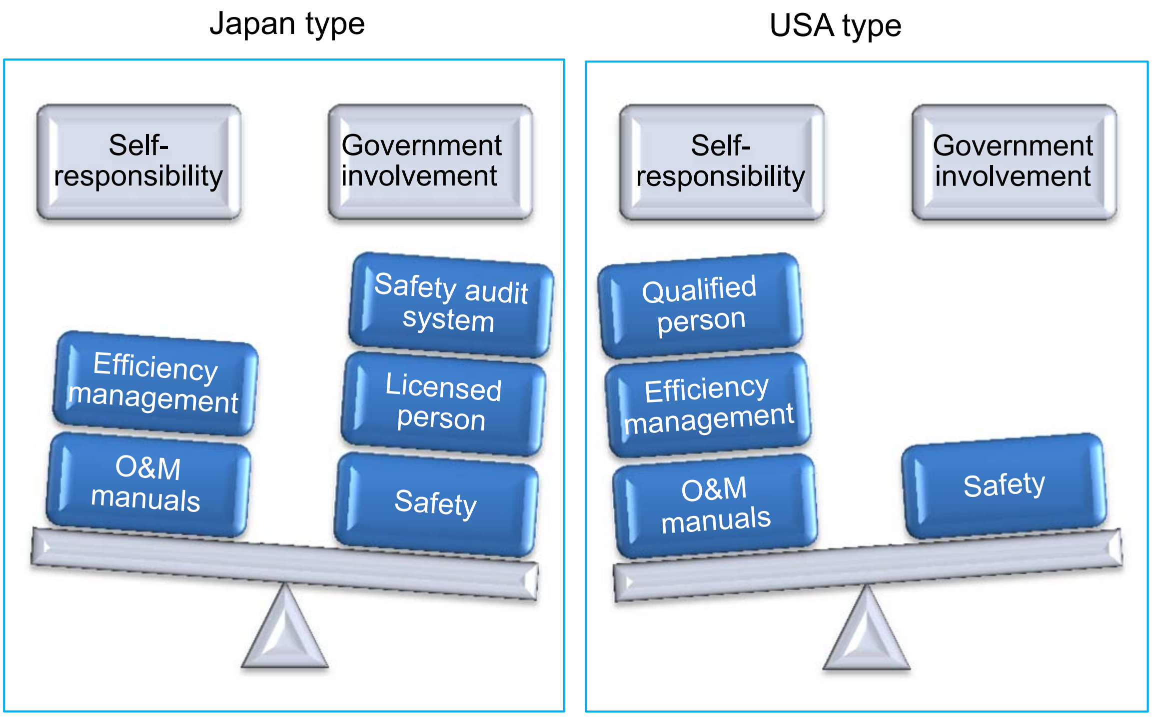
Source: JICA Survey Team

Figure 19-9 Output and Profit

19.2 Japanese O&M Legal Framework

19.2.1 General concept for regulations of O&M

The government should take into consideration how much government involvement is suitable to regulate the power sector. Too much regulation will make private sector vitality decrease and too little regulation will make the private sector uncontrollable. Japan is famous for strict government involvement in the private sector and the trend of current regulation is deregulation, but government involvement still remains.



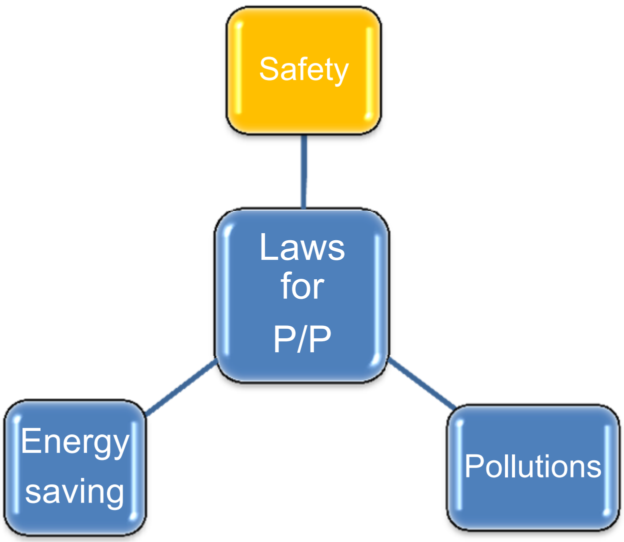
Source: JICA Survey Team

Figure 19-10 Government Involvement or Self-responsibility

19.2.2 Japanese government's main requirements for P/P

The main concepts of the Japanese O&M legal framework are as follows:

- Self-responsibility controlled by government
  - Minimum government involvement
- To meet with government requirements
  - Government regulates
    - Safety (technical standards, etc.)
    - Energy saving
    - Pollutions
  - Government doesn't regulate
    - Output (MW)
    - Efficiency (%)
- To meet with manuals decided by P/P
  - P/P makes manuals and follows the manuals
    - Maintenance manual
    - Patrol inspection manual



Source: JICA Survey Team

Figure 19-11 Legal Framework in Japan

19.2.3 Main regulations for P/P

The regulations for Japanese P/P can be divided three categories such as safety, Energy saving and Pollution. The details of regulations are as follows.

- Safety
  - Electricity Business Act Act No. 170 of July 11, 1964
    The purpose of this Act is to protect the interests of electricity users and achieve the sound development of Electricity Businesses by realizing appropriate and reasonable management of Electricity Businesses, and to assure public safety and promote environmental preservation by regulating the construction, maintenance and operation of Electric Facilities.

  - Electricians Act Act No. 139 of 1960

  - High Pressure Gas Safety Act Act No. 204 of June 7, 1951
    The purpose of this Act is to regulate the production, storage, sale, transportation and other matters related to the handling of high pressure gases, their consumption as well as the manufacture and handling of their containers and to encourage voluntary activities by private businesses and the High Pressure Gas Safety Institute of Japan for the safety of high pressure gases with the aim of securing public safety by preventing accidents and disasters caused by high pressure gases.

  - Electrical Appliances and Materials Safety Act (Tentative translation) Act No. 234 of November 16, 1961
    The purpose of this Act is to regulate the manufacture, sale, etc. of Electrical Appliances and Materials and to foster voluntary activities by private businesses to ensure the safety of Electrical Appliances and Materials, so as to prevent hazards and damages resulting therefrom.

  - Industrial Safety and Health Act Act No. 57 of June 8, 1972
    The purpose of this Act is to secure, in conjunction with the Labor Standards Act (Act No. 49 of 1947), the safety and health of workers in workplaces, as well as to facilitate the establishment of a comfortable working environment, by promoting comprehensive and systematic countermeasures concerning the prevention of industrial accidents, such as taking measures for the establishment of standards for hazard prevention, clarifying the safety and health management responsibility and the promotion of voluntary activities with a view to preventing industrial accidents

  - Act on Ensuring Fair Electric Business Practices Act No. 96 of May 23, 1970

  - Fire Service Act Act No. 186 of July 24, 1948
    The purpose of this Act is to prevent, guard against, and suppress fires in order to protect the lives, bodies and property of citizens from fires, and to reduce the damage arising from fires or disasters such as earthquakes, thereby maintaining peace and order and contributing to the promotion of social and public welfare.
    Chapter III Hazardous Materials
    Hazardous materials of the designated quantity or a larger quantity shall not be stored at facilities other than a storage facility (including a storage facility for storing or handling hazardous materials by means of a tank mounted on a vehicle (hereinafter referred to as a "mobile tank storage facility"); the same shall apply hereinafter), nor shall they be handled at facilities other than a manufacturing facility, storage facility and handling facility; provided, however, that this shall not apply where the designated quantity or a larger quantity of hazardous materials are stored or handled temporarily for not more than ten days with the

approval of the competent fire chief or fire station chief.

- Energy saving
  - Act on the Rational Use of Energy Act No. 49 of June 22, 1979
    The purpose of this Act is, with the aim to contribute to securing the effective utilization of fuel resources according to the economic and social environment concerning energy in and outside Japan, to take the measures required for the rational use of energy with regard to factories, etc., transportation, buildings, and machinery and equipment as well as other necessary measures, etc. for comprehensively promoting the rational use of energy, thereby contributing to the sound development of the national economy.

- Pollution
  - Basic Environment Law Act No. 91 of Nov. 10, 1993
    The purpose of this law is to comprehensively and systematically promote policies for environmental conservation to ensure healthy and cultured living for both the present and future generations of the nation as well as to contribute to the welfare of mankind, through articulating the basic principles, clarifying the responsibilities of the State, local governments, corporations and citizens, and prescribing the basic policy considerations for environmental conservation.

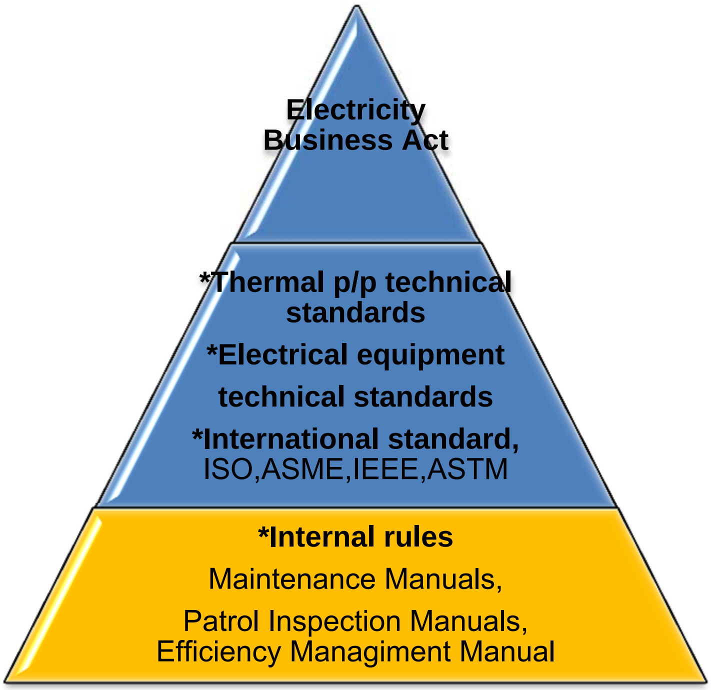
  - Air Pollution Control Act Act No. 97 of June 10, 1968
    The purposes of this Act are to protect the health of citizens and to protect the living environment from air pollution by, among other things, controlling emissions, etc. of Soot and Smoke, Volatile Organic Compounds, and Particulates associated with the business activities of factories and workplaces and with the demolition, etc. of buildings, etc., by promoting the implementation of measures against hazardous air pollutants and by setting maximum permissible limits for automobile exhaust; and to protect victims where air pollution has caused harm to human health by providing for the liability of business operators for damages.

  - Water Pollution Control Act Act No. 138 of 1970

  - Noise Regulation Act Act No. 98 of 1968

19.2.4 Laws, regulations and rules concerning inspection & maintenance

The Japanese O&M legal framework is like a pyramid, as per the below figure. The blue portion is defined by the government or public organizations and the yellow portion is defined by P/P.
The Electricity Business Act contains two major parts, 1) Business and 2) Safety. The safety laws are the minimum requirement for safety but they are very strict. Therefore, P/P maintains a high quality of operation.
The Japanese government requests that P/P define the safety regulations, which consist of many manuals, by themselves and that P/P should observe the safety regulations.



Source: JICA Survey Team

Figure 19-12 O&M Legal Framework in Japan

The below table shows the individual regulations described in pyramid but the international rules are excluded.

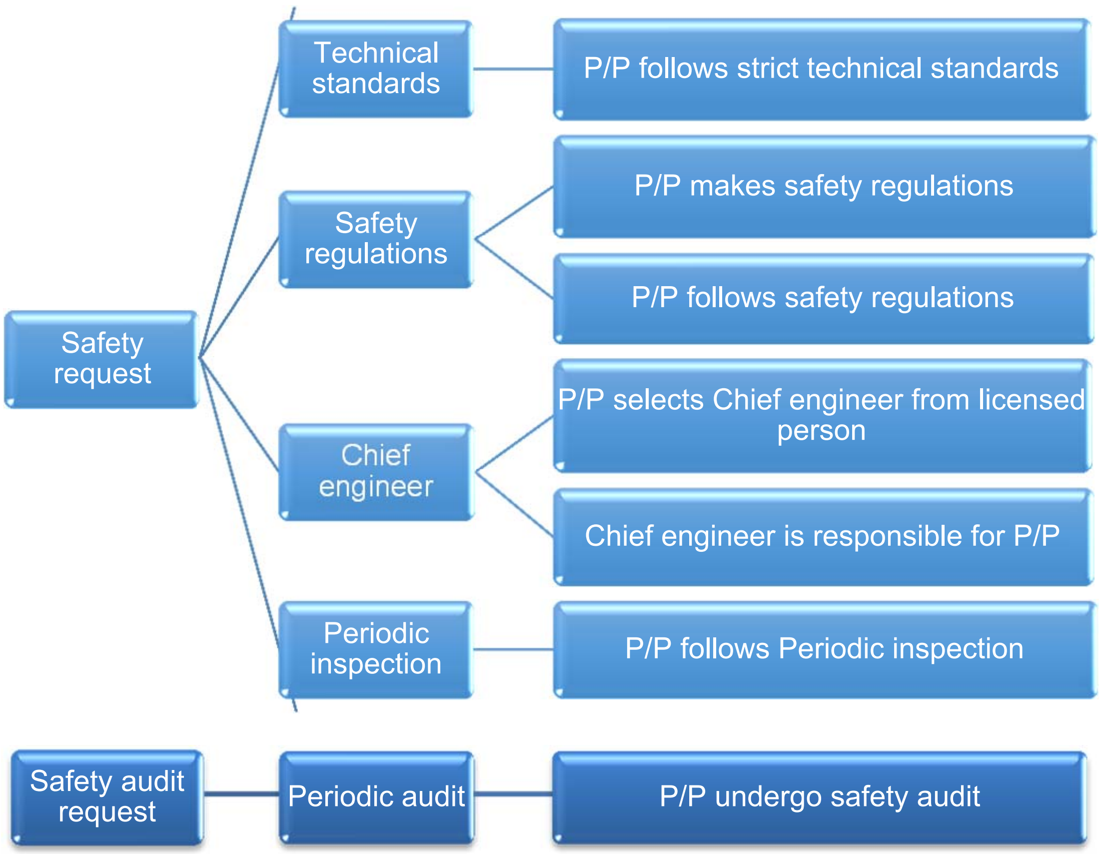
Table 19-2 Safety Rules Related Electricity Business Act

Law	*Electricity Business Act
Cabinet order	*Electricity Business Act Enforcement Order
Ordinance	*Ministerial Ordinance for the Enforcement of the Electricity Business Act Electrical reporting rules
Ministerial ordinance	*Ministerial Ordinance for Establishing Technical Standards for Thermal Power Generation Equipment: *Ministerial Ordinance for Establishing Technical Standards for Electrical Equipment: Ordinance on the qualifications of the chief engineer based on provisions of the Electricity Business Act
Notice	*Interpretation of technical standards for Thermal Power Generation Equipment *Notice defining the details of the technical standards for Thermal Power Generation Equipment *Interpretation of technical standards for Electrical Equipment *Technical elements required to meet the technical standards ordinance based on Electricity Business Act *Q & A relates to chief engineer system *Interpretation of welding inspection in thermal power plant based on the Electricity Business Act Enforcement Regulations etc.

19.2.5 Safety requirements in Electricity Business Act

Safety requirements in the Electricity Business Act number five items, as per the below figures.

Figure 19-13 Government Safety Requirements for P/P (1)



Source: JICA Survey Team

Figure 19-14 Government Safety Requirements for P/P (2)

19.2.6 Details of safety requirements in Electricity Business Act

The actual text regarding safety requirements in the Electricity Business Act is as follows.

- (Technical Standards)

Article 39 (1) A person who installs Electric Facilities shall maintain the Electric Facilities to ensure that they conform to the technical standards established by an Ordinance of the Competent Ministry.

- (Safety Regulations)

Article 42 (1) A person who installs Electric Facilities shall, in order to ensure safety of the construction, maintenance and operation of the Electric Facilities, pursuant to the provision of an Ordinance of the Competent Ministry, establish safety regulations for each organization in charge of the Electric Facilities, the safety of which should be secured uniformly, and notify the Competent Minister of the regulations before the commencement of the use of the Electric Facilities by the organization (in the case of facilities requiring self-inspection set forth in Article 51, paragraph (1) or operator's inspection set forth in Article 52, paragraph (1), before the commencement of the construction of the facilities).

- (Chief Engineer)

Article 43 (1) A person who installs Electric Facilities shall, pursuant to the provision of an Ordinance of the Competent Ministry, appoint one or more chief engineers from among persons who have a chief engineer's license in order to cause him/her to supervise the safety of the construction, maintenance, and operation of the facilities.

- (Periodic Safety Management Inspection)

Article 55 (1) A person who installs Specific Electric Facilities (which means boilers, turbines and other Electric Facilities for electricity generation, which are specified by an Ordinance of the Competent Ministry and have some parts under a pressure higher than that specified under the preceding Article, as well as nuclear reactors for electricity generation and auxiliary equipment thereof, which are specified by an Ordinance of the Competent Ministry; hereinafter the same shall apply) shall, pursuant to the provision of an Ordinance of the Competent Ministry, conduct an operator's inspection of the Specific Electric Facilities at periodic intervals, record the inspection results, and preserve such records.

- (Safety Audit)

Article 55 (4) A person who installs Specific Electric Facilities subject to a Periodic Operator's Inspection shall, within the period specified by an Ordinance of the Ministry of Economy, Trade and Industry, submit the system for conducting a Periodic Operator's Inspection to undergo examination by the Minister of Economy, Trade and Industry in the case of other persons.

19.2.7 Safety regulations content defined in the Electricity Business Act

The Japanese Electricity Act imposes upon P/P the making of safety regulations, and the content defined by the government is as follows.

① *Safety structure*
② *Duty and organization*
③ *Duty scope and rights of Chief Engineer*
④ *Safety education*
⑤ *Safety PDCA*
⑥ *Writing, modification and preserving of Documents*
⑦ *Documents status for safety regulations*
⑧ *Record*
⑨ *Patrol, check and inspection*
⑩ *Operation*
⑪ *Management for items and service*
⑫ *Safety for long no-operation*
⑬ *Measures for Disaster*
⑭ *Regular improvement for safety regulations*
⑮ *Important items for safety*

Every P/P decides the original safety regulation, submits the safety regulation to the government, and follows the safety regulation.
The above content involves not only O&M legal solutions but also O&M solutions as described in 19.1.3 , as per the below figure; therefore, this safety regulation is a key point of the O&M legal framework in Japan.

④ O&M Solutions

- ◆ Earning more
  - ✓ Efficiency management
  - ✓ Reduction of maintenance period
- ◆ Personal skill-up
  - ✓ Training
  - ✓ Education
- ◆ Efficient maintenance
  - ✓ CBM
  - ✓ Daily maintenance
  - ✓ Patrol inspection

⑤ O&M Legal Solutions

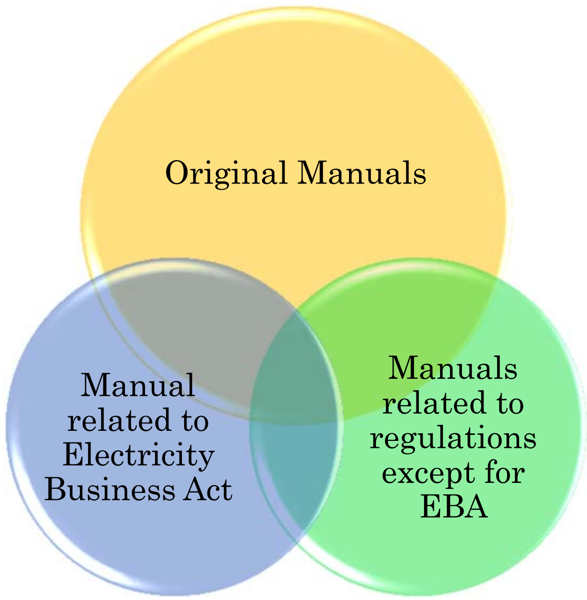
- ◆ To build the mechanism for O/M legal solutions
  - ✓ Structure (Government involvement or Self-responsibility)
  - ✓ Formation of organization
  - ✓ Clarification of responsibility
  - ✓ Sustainability, PDCA
  - ✓ Incentives and penalty

Source: JICA Survey Team

Figure 19-15 Problems and O&M Legal Solutions (excerpt)

19.2.8 Internal rules

Every P/P makes many internal manuals for O&M to achieve stable operation. The internal rules can divided three categories, such as 1) related to Electricy Business Act, 2) related to regulations which is except for Electricy Business Act, and 3) original manuals. Most of internal manuals consist of original manuals in general.



Source: JICA Study Team

Figure 19-16 Internal Manuals in P/P

Typical original manuals in p/p are as follows.

- Inspection Manuals
  - Boiler
  - Turbine
  - Electrical
  - I&C
    - Interval (1 year, 2 years, 4 years, 8 years)
    - Inspection items

- Daily Patrol Inspection Manual
  - Patrol Route
  - Inspection items
  - Points of check (Vibration, Temperature, Pressure, Level, Noise, etc.)

- Operation Manual
  - Emergency
  - Operation against Trouble manual
    - Boiler
    - Turbine
    - Electrical
    - I&C

- Efficiency Management Manual
  - Method of Efficiency calculation
    - Gas firing P/P

- Coal firing P/P
- Management against Efficiency down

- Education and Training Manual
  - Safety
  - Operation
    - Emergency
    - Continuous monitoring
  - Maintenance
    - Boiler
    - Turbine
    - Electrical
    - I&C
  - Original license system

19.2.9 Licensed and qualified persons in power plant

Japanese has a license system, defined by laws, which makes the quality of work high.

- Power plant
  - Boiler &Turbine supervisor (Boiler &Turbine chief engineer)
  - Electrical supervisor (Electrical chief engineer)
  - Energy saving supervisor (Energy Management Control Officer)
  - High pressure tank supervisor
  - Pollution prevention supervisor
  - Dangerous materials supervisor
  - etc.
- Subcontractors
  - Welder
  - Electrical technician
  - Scaffolding worker
  - Slinging worker
  - etc.

The method of license acquisition depends on each license system, as an example, the following is the Chief Engineering License.

(Chief Engineering License)
Article 44 (1) The types of chief engineering license are as follows.
(i) First-Class Chief Electricity Engineering License;
(ii) Second-Class Chief Electricity Engineering License;
(iii) Third-Class Chief Electricity Engineering License;
(vi) First-Class Chief Boiler/Turbine Engineering License;
(vii) Second-Class Chief Boiler/Turbine Engineering License.
(2) A chief engineering license is granted by the Minister of Economy, Trade and Industry to persons who fall under any of the following:
(i) a person who holds the academic record or qualification and work experience specified by Ordinance of the Ministry of Economy, Trade and Industry for each type of chief engineering license;
(ii) with respect to the types of chief engineering licenses listed in items (i) to (iii) of the preceding paragraph, a person who has passed an examination for a chief electricity engineering license.

19.2.10 Notification and reports system

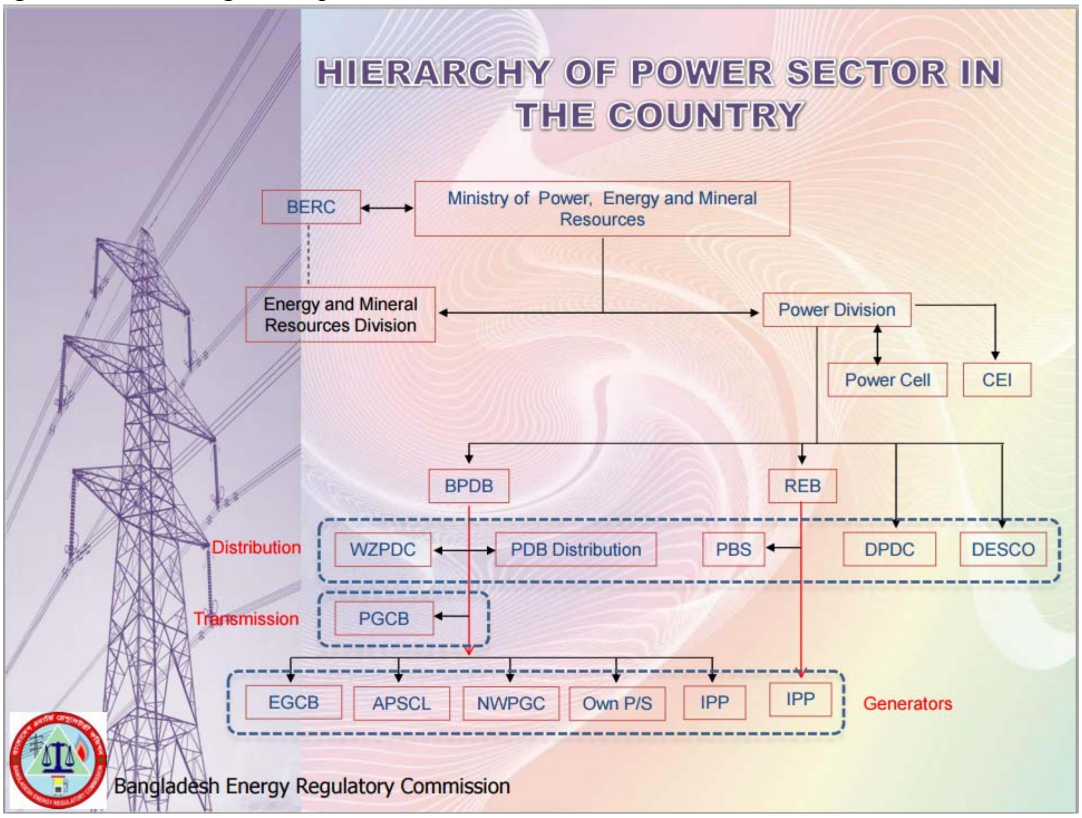
The Japanese Electricity Act has notification and reports system about O&M as below.

- Changes of Electric Facilities, etc.
- Safety Regulations
- Chief Engineer
- Plan of the construction project
- Collection of Reports
  - Periodic report
  - Report on accident
    - Fatal accident
    - Electrical fire accident
    - Accident to the public
    - Disruptive accident
    - Power supply trouble due to the accident
    - Secondary accident to the other company
  - Pollution prevention

19.3 Bangladesh O&M Legal Framework

19.3.1 Hierarchy of power sector

The organization of Bangladesh power sector is as follows.



Source:
http://www.sari-energy.org/PageFiles/What_We_Do/activities/Cross_Border_Energy_Trade_Feb_2013/Presentations/Bangladesh.pdf
Accessed: 9/6/2015

Figure 19-17 Hierarchy of Power Section in Bangladesh

19.3.2 Laws and Acts in Bangladesh

There are some laws and acts regarding the power sector in Bangladesh, two of them as Electricity Act 1910 and Bangladesh Energy Regulatory Commission Act, 2003 are most important regulations about O&M in P/P.

19.3.3 Electricity Act 1910

Table 19-3 Electricity Act 1910

PART I PRELIMINARY
1. Short title, extent and commencement
2. Definitions
PART II SUPPLY OF ENERGY
Licenses
3. Grant of Licenses
4. Revocation or amendment of licenses
5. Provisions where license of licensee, not being a local authority, is revoked
6. Provisions where license of local authority is revoked
7. Purchase of undertaking
8. Provisions where no purchase and license revoked with consent of licensee
9. Licensee not to purchase, or associate himself with other licensed undertakings or transfer his undertakings
10. General power for Government to vary terms of purchase
11. Annual accounts of licensee
Works
12. Provisions as to the opening and breaking up of streets, railways and tramways
13. Notice of new works
14. Alteration of pipes or wires
15. Laying of electric supply-lines or other works near sewers, pipes or other electric supply-lines or works
16. Streets, railways, tramways, sewers, drains or tunnels broken up to be reinstated without delay
17. Notice to telegraph authority
18. Aerial lines
19. Compensation for damage
Supply
19A. Point where supply is delivered
20. Power for licensee to enter premises and to remove fittings or other apparatus of licensee
21. Restrictions on licensee's controlling or interfering with use of energy

PART III
SUPPLY, TRANSMISSION AND USE OF ENERGY BY NON-LICENSEES

PART IV
GENERAL

Protective Clauses

Administration and Rules

Criminal Offences and Procedure

44A. Penalty for abettors in certain offences

45. Penalty for extinguishing public lamps

46. Penalty for negligently wasting energy or injuring works

47. Penalty for offences not otherwise provided for

48. Penalties not to affect other liabilities

49. Penalties where works belong to Government

49A. Offences by companies

50. Institution of prosecutions

50A. Power of Magistrate to pass sentence, impose fine

Supplementary

51. Exercise in certain cases of powers of telegraph-authority

52. Arbitration

52A. Bar to jurisdiction of Civil Courts

53. Service of notices, orders or documents

54. Recovery of sums recoverable under certain provisions of Act

54A. Charges for supply of energy recoverable as arrears of land revenues

54B. Requisition of police assistance

54C. Bar of Jurisdiction

55. Delegation of certain functions of Government to Electric Inspectors

56. Protection for acts done in good faith

57. [Omitted]

58. [Omitted]

SCHEDULE

Source: http://bdlaws.minlaw.gov.bd/pdf_part.php?id=93
Accessed: 9/6/2015

19.3.4 Bangladesh Energy Regulatory Commission Act 2003

Bangladesh Gazette, Extraordinary, July 24, 2003

BANGLADESH GAZETTE

Extraordinary
Published by the Authority

Published: Thursday, July 24, 2003
Amended: Thursday, February 17, 2005

S.R.O.No- 228/Law/2003— The Government, in exercise of the powers conferred by section 65 of the Bangladesh Energy Regulatory Commission Act, 2003, is pleased to publish the following English translation of the Act, to be called the Authentic English Text of the Act, and it shall be effective from the date on which the Act comes into force under sub-section (2) of section 1 of the Act.

Act No 13 of 2003
An Act to make provisions for the establishment of an independent and impartial regulatory commission for the energy sector

WHEREAS it is expedient to make provisions for the establishment of an independent and impartial regulatory commission to create an atmosphere conducive to private investment in the generation of electricity, and transmission, transportation and marketing of gas resources and petroleum products, to ensure transparency in the management, operation and tariff determination in these sectors; to protect consumers' interest and to promote the creation of a competitive market;

It is hereby enacted as follows —

CHAPTER - 1
Preliminary

1. Short title and commencement—

(1) This Act shall be called the Bangladesh Energy Regulatory Commission Act, 2003.

(2) It shall come into force on such date as the Government may, by Gazette notification, appoint.

Figure 19-18 Bangladesh Energy Regulatory Commission Act 2003 (Front)

Source: http://www.berc.org.bd/images/stories/pdf/law/berc_act_2003_English.pdf
Accessed: 9/6/2015

19.3.5 Bangladesh Energy Regulatory Commission Act, 2003.(excerpt)

- *CHAPTER – 1 Preliminary*
- *CHAPTER – 2 Establishment of the Commission*
- *CHAPTER – 3 Financial matters of the Commission*
- *CHAPTER – 4 Functions, Powers and Proceedings of the Commission*
  - *22. Functions of the Commission—*

    (a) to determine efficiency and standard of the machinery and appliances of the institutions using energy and to ensure through energy audit the verification, monitoring and analysis of the energyand the economy use and enhancement of the efficiency of the use of energy;

    (b) to ensure efficient use, quality services, determine tariff and safety enhancements of electricity generation and transmission marketing, supply, storage and distribution of energy;

    (c) to issue, cancel, amend and determine conditions of licences, exemption of licences and to determine the conditions to be followed by such exempted persons;

    (d) to approve schemes on the basis of overall program of the licencee and to take decision in this regard taking into consideration the load forecast and financial status;

    (e) to collect, review, maintain and publish statistics of energy;

    (f) to frame codes and standards and make enforcement of those compulsory with a view to ensuring quality of service;

    (g) to develop uniform methods of accounting for all licencees;

    (h) to encourage the creation of a congenial atmosphere to promote competition amongst the licencees;

    (i) to extend co-operation and advice to the Government, if necessary, regarding electricity generation, transmission, marketing, supply distribution and storage of energy;

    (j) to resolve disputes between the licencees, and between licencees and consumers, and refer those to arbitration if considered necessary;

    (k) to ensure appropriate remedy for consumer disputes, dishonest business practices or monopoly;

    (l) to ensure control of environmental standards of energy under existing laws; and

    (m)to perform any incidental functions if considered appropriate by the Commission for the fulfillment of the objectives of this Act for electricity generation and energy transmission, marketing, supply, storage, efficient use, quality of services, tariff fixation and safety improvement.
  - *23. Investigation power—*

    (1) Commission shall have all those powers for the purposes of an investigation or proceedings, which are exercised by a Civil Court at the time of trial under the Code of Civil Procedure, such as: –

    (a) to summon a witness and ensure his presence and examination of the witness on oath;

    (b) to detect and present any important document which may be submitted as a document or evidence;

    (c) to collect evidence through an affidavit;

    (d) to call for public record from any court or office;

    (e) to adjourn hearing;

    (f) to ensure presence and absence of the parties; and

    (g) to review the Commission's decisions, directives or orders.
- *CHAPTER – 5 Relationship between the Government and the Commission*
- *CHAPTER – 6 License*
  - *27. Licence—*
  - *28. Issuance of licence by the Commission—*
  - *31. General duties and powers of the licencee.*

    (1) Every licencee shall make arrangement for the efficient, co-ordinated, cost-effective production, transmission and supply of energy.

(2) Every licencee shall maintain international standards and working methods at the time of discharging his duties relating to energy operation, maintenance and safety.

- CHAPTER – 7 Tariff
- CHAPTER – 8 Commission's power to issue order and implement its decision
- CHAPTER – 9 Flow of Information
- CHAPTER – 10 Arbitration - Settlement and Appeal
- CHAPTER – 11 Offence and Penalty
- CHAPTER – 12 Receipt of Complaint of Consumer and disposal
- CHAPTER – 13 Miscellaneous
- CHAPTER – 14 Transitional Provision

19.4 Comparison between Bangladesh and Japan

Next table shows that comparison between Bangladesh and Japan about main provisions of O&M regulations.

Table 19-4 Comparison between Bangladesh and Japan

	JAPAN	Bangladesh
Business Licenses	*Electricity Business Act* ***(Business Licenses)*** *Article 3 (1) A person who intends to conduct Electricity Business (excluding Specified-Scale Electricity Business; hereinafter the same applies in this Chapter (except for Article 5, item (vii) and Article 17, paragraph (1))) must obtain a license from the Minister of Economy, Trade and Industry.* *(2) The license set forth in the preceding paragraph is granted by business category, for each of General Electricity Business, Wholesale Electricity Business, or Specified Electricity Business respectively.* ***(Application for a License)*** *Article 4 (1) A person who intends to obtain a license under paragraph (1) of the preceding Article must submit a written application to the Minister of Economy, Trade and Industry, stating:* *(i) the name and address of the applicant, as well as the name of the representative if the applicant is a corporation;* *(ii) the service area, the General Electricity Utilities to which electricity is to be supplied or the service points;* *(iii) the following particulars concerning the Electric Facilities to be used for Electricity Business;* *(a) regarding Electric Facilities for the generation of electricity, the site*	*Electricity Act 1910* ***Grant of Licenses*** *3. (1) The Government may, on application made in the prescribed form and on payment of the prescribed fee (if any), grant to any person a license to supply energy in any specified area, and also to lay down or place electric supply-lines for the conveyance and transmission of energy,-* *(a) where the energy to be supplied is to be generated out-side such area from a generating station situated outside such area to the boundary of such area, or* *(b) where energy is to be conveyed or transmitted from any place in such area to any other place therein, across an intervening area not included therein, across such area.* *BERC Act 2003* *CHAPTER – 6* ***Licence*** *27. Licence—* *(1) No person shall engage himself in the following business unless he is empowered by a licence or exempted from having it under this Act or any other Act, such as:-* *(a) power generation;* *(b) energy transmission;* *(c) energy distribution and marketing;*

	where they are to be installed, the type of motive power, frequency, and output capacity; *(b) regarding Electric Facilities for the transformation of electricity, the site where they are to be installed, frequency, and output capacity;* *(c) regarding Electric Facilities for the transmission of electricity, the site where they are to be installed, the electric system, installation means, number of circuits, frequency, and voltage;* *(d) regarding Electric Facilities for the distribution of electricity, the electric system, frequency, and voltage.* *(2) The written application set forth in the preceding paragraph must be accompanied by a business plan, estimate of business income and expenditure, and other documents specified by Ordinance of the Ministry of Economy, Trade and Industry.*	*(d) energy supply; and* *(e) energy storage.* *28. Issuance of licence by the Commission—* *Licence may be issued to any person for the following purposes in a procedure prescribed by the Commission, such as:-* *(a) for power generation;* *(b) for energy transmission;* *(c) for distribution and marketing of energy;* *(d) for supply of energy; and* *(e) for storage of energy.*

	JAPAN	Bangladesh
Supervision for Safety	*Electricity Business Act* ***(Purpose)*** *Article 1 The purpose of this Act is to protect the interests of electricity users and achieve the sound development of Electricity Businesses by realizing appropriate and reasonable management of Electricity Businesses, and to assure public safety and promote environmental preservation by regulating the construction, maintenance and operation of Electric Facilities.* ***(Order for Improvement of Operational Procedure)*** *Article 30 The Minister of Economy, Trade and Industry may, when a General Electricity Utility or Specified Electricity Utility fails to make the necessary repairs or take other measures immediately to eliminate any stoppage to the*	*Electricity Act 1910* ***Prohibition of connection with earth, and power for Government to interfere in certain cases of default*** *34. (1) No person shall, in the generation, transmission, supply or use of energy, permit any part of his electric supply-lines to be connected with earth except so far as may be prescribed in this behalf or may be specially sanctioned by the Government.* *(2) If at any time it is established to the satisfaction of the Government-* *(a) that any part of an electric supply-line is connected with earth contrary to the provisions of sub-section (1), or* *(b) that any electric supply-lines or other works for the generation, transmission, supply or use of energy are attended with danger to the public safety or to human life or injuriously affect any telegraph-line, or* *(c) that any electric supply-lines or*

	electricity supply arising from an accident or he/she finds that the interest of electricity users is adversely affected because the General Electricity Utility's or Specified Electricity Utility's operational procedure for supplying electricity is inappropriate, order the General Electricity Utility or Specified Electricity Utility to improve the operational procedure.	*other works are defective so as not to be in accordance with the provisions of this Act or of any rule thereunder,* *the Government may, by order in writing, specify the matter complained of and require the owner or user of such electric supply-lines or other works to remedy it in such manner as shall be specified in the order, and may also in like manner forbid the use of any electric supply-line or works until the order is complied with or for such time as is specified in the order.*

	JAPAN	Bangladesh
On-site Inspections	*Electricity Business Act* ***(On-site Inspections)*** *Article 107 (2) In addition to the on-site inspection prescribed in the preceding paragraph, the Minister of Economy, Trade and Industry may, to the extent necessary for the enforcement of this Act, have officials of the Ministry of Economy, Trade and Industry enter the business office or other office or other workplace of an Electricity Utility, and inspect the status of the services or accounting or the Electric Facilities, books, documents, and any other articles of the Electricity Utility.*	*BERC Act 2013* ***23. Investigation power—*** *(1) Commission shall have all those powers for the purposes of an investigation or proceedings, which are exercised by a Civil Court at the time of trial under the Code of Civil Procedure, such as: –* *(a) to summon a witness and ensure his presence and examination of the witness on oath;* *(b) to detect and present any important document which may be submitted as a document or evidence;* *(c) to collect evidence through an affidavit;* *(d) to call for public record from any court or office;* *(e) to adjourn hearing;* *(f) to ensure presence and absence of the parties; and* *(g) to review the Commission's decisions, directives or orders.*

	JAPAN	Bangladesh
Technical Standards	*Electricity Business Act* ***Conformity with Technical Standards*** *Article 39 (1) A person equipped with Electric Facilities for Business Use must*	***There is no technical standard established by government agencies.***

	maintain the Electric Facilities for Business Use to ensure that they conform to the technical standards established by Ordinance of the Competent Ministry. *(2) The Ordinance of the Competent Ministry set forth in the preceding paragraph must be formulated in accordance with the following:* *(i) Electric Facilities for Business Use do not cause bodily harm nor cause damage to objects;* *(ii) Electric Facilities for Business Use do not cause electric nor magnetic interference with the functioning of other electric equipment or objects;* *(iii) damage to Electric Facilities for Business Use does not significantly hinder the supply of electricity by a General Electric Utility;* *(iv) if Electric Facilities for Business Use are used for General Electricity Business, damage to the Electric Facilities for Business Use does not significantly hinder the supply of electricity pertaining to General Electricity Business.* ***Order for Conformity with Technical Standards*** *Article 40 The competent minister may, when finding that Electric Facilities for Business Use do not conform to the technical standards established by Ordinance of the Competent Ministry under paragraph (1) of the preceding Article, order the person equipped with the Electric Facilities for Business Use to repair or alter the Electric Facilities for Business Use to ensure conformity to the technical standards, or order the person to relocate the facilities or suspend the use of them, or restrict the person from using the facilities.*	*Bangladesh Gazette, Extraordinary, July 24, 2003* ***31. General duties and powers of the licensee. –*** *(2)Every licensee shall maintain international standards and working methods at the time of discharging his duties relating to energy operation, maintenance and safety.*

	JAPAN	Bangladesh
Safety Regulations	*Electricity Business Act* ***Independent Safety Measures*** *(Safety Regulations)* *Article 42 (1) A person equipped with Electric Facilities for Business Use must, in order to ensure*	***There is no safety regulation.***

	safety of the construction, maintenance and operation of the Electric Facilities for Business Use, pursuant to the provisions of Ordinance of the Competent Ministry, establish safety regulations for each organization in charge of the Electric Facilities for Business Use, the safety of which should be secured uniformly, and notify the competent minister of the regulations before commencement of the use of the Electric Facilities for Business Use by the organization (in the case of facilities requiring self-inspection set forth in Article 51, paragraph (1) or operator's inspection set forth in Article 52, paragraph (1), before the commencement of the construction of the facilities). *(2) A person equipped with Electric Facilities for Business Use must, when having revised the safety regulations, notify the competent minister of the revised particulars without delay.* *(3) The competent minister may, when finding it necessary in order to ensure safety of the construction, maintenance, and operation of Electric Facilities for Business Use, order the person equipped with the Electric Facilities for Business Use to revise the safety regulations.* *(4) A person equipped with Electric Facilities for Business Use and employees thereof must observe the safety regulations.*	

	JAPAN	Bangladesh
Chief Engineer	*Electricity Business Act* ***Independent Safety Measures*** ***(Chief Engineer)*** *Article 43 (1) A person equipped with Electric Facilities for Business Use must, pursuant to the provisions of Ordinance of the Competent Ministry, appoint one or more chief engineers from among persons who have a chief engineering license in order to have said chief engineer supervise the safety of the construction, maintenance, and operation of the facilities.* *(2) Notwithstanding the provisions of the preceding*	***There is no obligation to appoint chief engineers.***

	paragraph, a person equipped with Electric Facilities for Private Use may, when permitted by the competent minister, appoint a person who does not have a chief engineering license as a chief engineer. *(3) A person equipped with Electric Facilities for Business Use must, when having appointed a chief engineer (excluding, however, cases of an appointment permitted under the preceding paragraph), notify the competent minister to that effect without delay. The same applies when such person has dismissed the chief engineer.* *(4) The chief engineer must perform the duty of supervising the safety of the construction, maintenance, and operation of Electric Facilities for Business Use in good faith.* *(5) People who are engaged in the construction, maintenance or operation of Electric Facilities for Business Use must follow the instructions given by the chief engineer to ensure the safety thereof.*	

	JAPAN	Bangladesh
Chief Engineering License	*Electricity Business Act* ***Independent Safety Measures*** ***(Chief Engineering License)*** *Article 44 (1) The types of chief engineering license are as follows.* *(i) First-Class Chief Electricity Engineering License;* *(ii) Second-Class Chief Electricity Engineering License;* *(iii) Third-Class Chief Electricity Engineering License;* *(iv) First-Class Chief Dam/Waterway Engineering License;* *(v) Second-Class Chief Dam/Waterway Engineering License;* *(vi) First-Class Chief Boiler/Turbine Engineering License;* *(vii) Second-Class Chief Boiler/Turbine Engineering License.* *(2) A chief engineering license is granted by the Minister of Economy, Trade and Industry to persons who fall under any of the following:* *(i) a person who holds the academic record or qualification and work experience specified by Ordinance of the Ministry of*	***There is no chief engineering license system.***

	Economy, Trade and Industry for each type of chief engineering license; *(ii) with respect to the types of chief engineering licenses listed in items (i) to (iii) of the preceding paragraph, a person who has passed an examination for a chief electricity engineering license.* *(3) The Minister of Economy, Trade and Industry may choose not to grant a chief engineering license to persons who fall under any of the following:* *(i) a person who was ordered to return their chief engineering license pursuant to the following paragraph, before the elapsing of a period of one year since the person was thus ordered;* *(ii) a person who was sentenced to a fine or more severe punishment for violation of this Act or any order issued under this Act, before the elapsing of a period of two years since the person served out the sentence or ceased to be subject to the sentence.* *(4) If a person who has a chief engineering license has violated this Act or any order issued under this Act, the Minister of Economy, Trade and Industry may order that person to return their chief engineering license.* *(5) The scope of the construction, maintenance and operation of the Electric Facilities for Business Use for which a person who has a chief engineering license is in charge of safety supervision as well as the procedural particulars concerning the grant of a chief engineering license are specified by Ordinance of the Ministry of Economy, Trade and Industry.*	

	JAPAN	Bangladesh
Periodic inspection	*Electricity Business Act* ***(Periodic Safety Management Inspections)*** *Article 55 (1) A person equipped with Specific Electric Facilities (which means boilers, turbines and other Electric Facilities for electricity generation, which are specified by Ordinance of the Competent Ministry and have some parts exposed to pressures higher than those specified under the preceding Article, as well as nuclear reactors for electricity generation and auxiliary equipment thereof, which are specified by Ordinance of the Competent Ministry; hereinafter the same applies) must, pursuant to the provisions of Ordinance of the Competent Ministry, conduct an operator's inspection of the Specific Electric Facilities at periodic intervals, record the inspection results, and keep such records on file.* *(2) In the inspection set forth in the preceding paragraph (hereinafter referred to as a "Periodic Operator's Inspection"), it is necessary to confirm that the Specific Electric Facilities*	***There is no obligation of Periodic Inspection.***

	conform to the technical standards established by Ordinance of the Competent Ministry under Article 39, paragraph (1).	

	JAPAN	Bangladesh
Safety audit	*Electricity Business Act* *Article 55 (4) A person equipped with Specific Electric Facilities subject to a Periodic Operator's Inspection must, within the period specified by Ordinance of the Competent Ministry (if notification has been given under Article 51, paragraph (7) as applied mutatis mutandis pursuant to paragraph (6), the period specified by Ordinance of the Competent Ministry depending on the past evaluation of the Periodic Operator's Inspection to which the notification pertained), submit the system for conducting a Periodic Operator's Inspection to undergo examination by a person registered by the Minister of Economy, Trade and Industry if that person installs Specific Electric Facilities other than Specific Electric Facilities for electricity generation by means of nuclear power, which are specified by Ordinance of the Ministry of Economy, Trade and Industry, or examination by the Minister of Economy, Trade and Industry in the case of other persons.* *(5) The examination set forth in the preceding paragraph is conducted, in accordance with the principle of ensuring safety management for Specific Electric Facilities, with respect to the organization in charge of a Periodic Operator's Inspection, inspection means, process control, and other particulars specified by Ordinance of the Competent Ministry.*	***There is no safety audit system***

Source: JICA Survey Team

19.5 Suggestions

The JICA Survey Team suggests that the Bangladesh government take into consideration the following items in their regulations.

19.5.1 Review of research

This chapter consists from physical matters to philosophical matters, it is not easy to understand the flow of research method. Therefore the research items are reviewed again as follows.

- Introduction
  - Purpose of this study
  - Solutions procedure
  - Cause and effect diagram
  - Scheme of O&M legal framework
  - Key factors for stable operation
  - General economic concept of O&M

- Japanese O&M Legal Framework
  - General concept for regulations of O&M
  - Japanese government's main requirements for P/P
  - Main regulations for P/P
  - Laws, regulations and rules concerning inspection & maintenance
  - Safety requirements in Electricity Business Act
  - Details of safety requirements in Electricity Business Act
  - Safety regulations content defined in the Electricity Business Act
  - Internal rules
  - Licensed and qualified persons in power plant
  - Notification and reports system

- Bangladesh O&M Legal Framework
  - Hierarchy of power sector
  - Laws and Acts in Bangladesh
  - Electricity Act 1910
  - Bangladesh Energy Regulatory Commission Act 2003

- Comparison between Bangladesh and Japan

19.5.2 Suggested O&M legal items

According to our research, five items of safety requirements in Japanese Electricity Business Act have not been implemented in Bangladesh and these items are modified a bit to suitable for Bangladesh situations.

- Periodic inspection
  - Purpose
    - To avoid a situation in which to postpone the inspection because of the budget shortages and tight supply and demand, etc. by implementation of periodic inspection.
    - To prevent the occurrence of a serious accident by conducting the periodic inspection.
  - Action
    - Authorities decide the intervals and inspection items of periodic inspection.
    - Generators have to conduct the periodic inspection.

- Safety audit
  - Purpose
    - To investigate the situation of periodic inspection whether inspection are implemented properly or not.
    - If there is a defect in the periodic inspection, auditors instruct the correct way.
  - Action
    - Authorities decides items of safety audit
    - Generators undergo safety audit by authority periodically

- Chief engineer
  - Purpose
    - To clarify the responsibility of the technical matters.
    - To carry out the technical management by the structure under top of chief engineer.
  - Action
    - Authorities order generators selects the chief engineers
    - Generators selects chief engineer among licensed person

- Safety regulations
  - Purpose
    - To establish self-management system by making safety regulations
    - To establish PDCA cycle of operation independently
  - Action
    - Authorities order generators to make original safety regulations
    - Generators follows the original safety regulations

- Technical standards
  - Purpose
    - To prevent from accident and disasters caused by technical issues
    - To reduce the forced maintenance occasions
  - Action
    - Authorities makes national technical standards
    - Generators follows the national technical standards

19.5.3 Recommended schedule of regulations

Suggested O&M legal items mentioned above can be divided into three classes as mentioned below, and these classes are recommended to achieve step by step.

1) Strengthening of control by government
   - ✓ Periodic inspection
   - ✓ Safety audit

2) Self-management by Generators
   - ✓ Chief engineer
   - ✓ Safety regulations

3) Enhancement of technical aspects
   - ✓ Technical standards

When the preparation time until implementation of regulation is set to 2 years and start time of every class has 1 year difference, the schedule becomes as follows. Because this recommended schedule is just a sample, Bangladesh government is expected to set up a reasonable schedule for the authorities and generators in consideration of power sector’s situation.

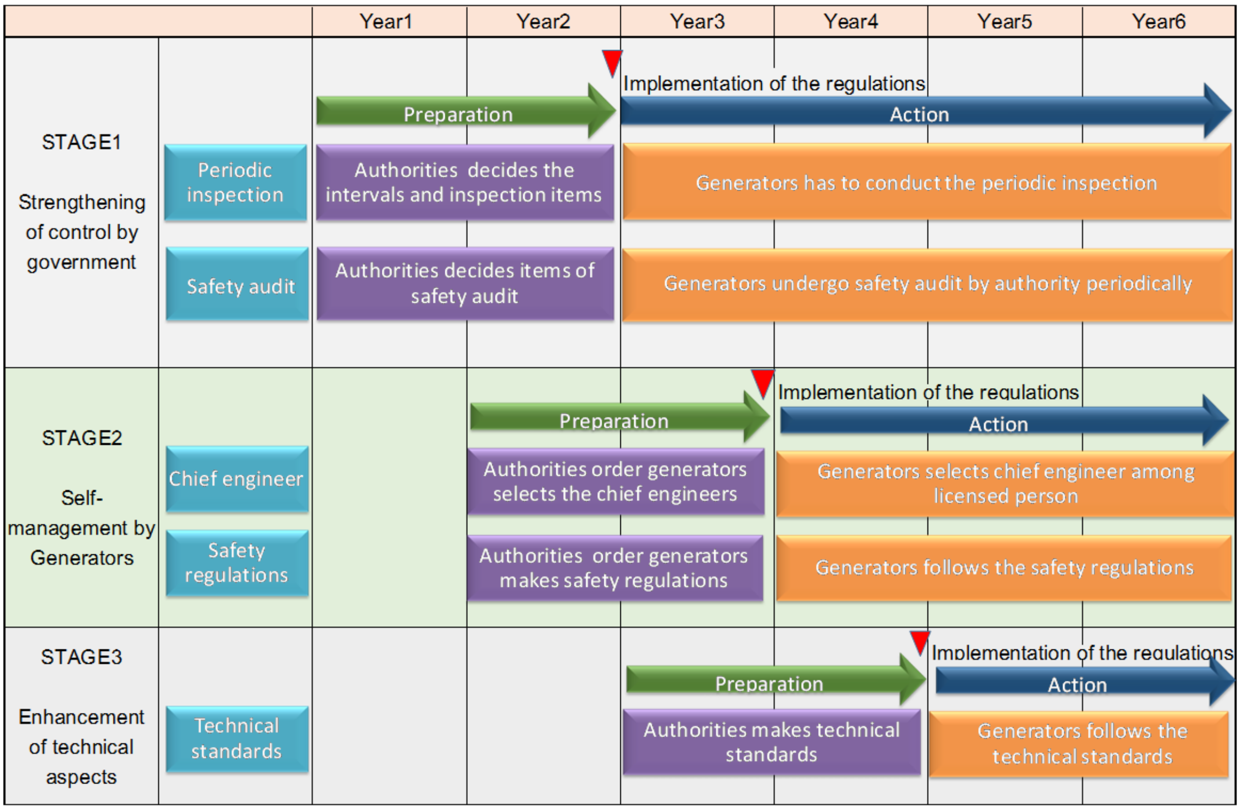


Figure 19-19 Recommended Schedule

PART V ENERGY COST AND TARIFF BALANCE

Chapter 20 Current Status of Energy Tariff and Financial Performance of the Power Sector

20.1 Electricity Tariff

20.1.1 Overview of Electricity Tariff in Bangladesh

The first Electricity Act was established in 1910, followed by the Electricity Rules in 1937. However, from 2003, the Bangladesh Energy Regulatory Act has taken over a number of provisions from the Electricity Act, including Tariff Setting as well as License to Generators, Transmitters and Distributors (public & private) and Purchase of undertakings by the Licensee.
The organization that is responsible for Bangladesh's tariff policy is Bangladesh Energy Regulatory Commission, or BERC. Its major tariff policies are the Power Pricing Framework (2004), the Vision 2020 - Tariff guidance, and the BERC Electricity Tariff Regulations: Generation: BST - Bulk Supply Tariff, Transmission: Wheeling Charge, Distribution: Retail Distribution Tariff.

Table 20-1 Major Tariff Policies

■ Power Pricing Framework (2004)
■ Vision 2020 - Tariff guidance
■ BERC Electricity Tariff Regulations: Generation : BST - Bulk Supply Tariff Transmission : Wheeling Charge Distribution : Retail Distribution Tariff

Source: South Asia Regional Initiative for Energy Integration (SARI/EI)

Principles and methodologies for tariff fixation are set in BERC's Tariff Regulations. Principles are fixed, but may be adjusted if necessary. In case of dispute, the Bangladesh Energy Regulatory Commission will come up with a resolution.
BERC's interaction with the government is defined in Article 22(i) of BERC Act 2003 as to extend co-operation and advice to the Government, if necessary, regarding electricity generation, transmission, marketing, supply distribution and storage of energy.
Some highlights of the Power Pricing Framework (2004) and the Vision 2020 are as follows.
According to the Power Pricing Framework (2004), the average end-user electricity tariff for each customer class will be set to fully cover reasonable costs of supplying electricity. On the other hand, the Government also decides to subsidize from the budget. It also differentiates rates for cases of Peak and off-peak, Capacity Cost and variable Cost.
The Vision 2020 progressively reflects the cost of supply of Tariff guidance electricity. It emphasizes the importance of efficiency, economical use of the resources, good performance and optimum investment; the need to safeguard the interests of the consumers. The Vision also states that Generation, transmission, distribution and supply are conducted on commercial principles. Differential tariff will be set related to time of the day to facilitate efficient demand side management.

Table 20-2 Tariff Policy

Act/ Policy	Highlights
Power Pricing Framework, 2004	• The electricity tariff to cover costs of supplying electricity. • Government subsidy • Differentiated rates for certain cases : Peak and off-peak Capacity Cost and variable Cost
Vision 2020	• Progressively reflect the cost of supply of Tariff guidance electricity • Efficiency, economical use of the resources, good

	performance and optimum investment are important ・ Interests of the consumers ・ Generation, transmission, distribution and supply on commercial principles ・ Time-related tariff to facilitate efficient demand side management

Source: South Asia Regional Initiative for Energy Integration (SARI/EI)

Electricity tariff set by BERC as of 2015 are as follows. Tariff for electricity used for agriculture pumping, non-residential, and part of small industry and commercial category are set as flat rate. On the other hand, electricity tariff for the remaining categories, including domestic use, are set proportional to the usage.

Table 20-3 Electricity Retail Tariff Structures in Bangladesh (as of 2015)

	Consumer Category			Energy Charge (BDT/kWh)	Service Charge (BDT/month)	Demand Charge (BDT/kW/month)
1	**Category A: Residential**				1-Phase: 10.00 3-Phase: 30.00	15
	Life Line: 1-50 Units			3.33		
		a	First Step: From 00 to 75 units	3.80		
		b	Second Step: From 76 to 200 units	5.14		
		c	Third Step: From 201 to 300 units	5.36		
		d	Fourth Step: From 301 to 400 units	5.63		
		e	Fifth Step: From 401 to 600 units	8.70		
		f	Sixth Step: From 601 to above	9.98		
2	**Category B: Agricultural pumping**			3.82	30	40 (Applicable for approved demand more than 30 kWh)
3	**Category C: Small Industries**				70	40 (Applicable for approved demand more than 30 kWh)
		a	Flat Rate	7.66		
		b	Off-Peak Time	6.90		
		c	Peak Time	9.24		
4	**Category D: Non-Residential (Light & Power)**			5.22	1-Phase: 10.00 3-Phase: 30.00	20
5	**Category E: Commercial & Office**				1-Phase: 10.00 3-Phase: 30.00	25
		a	Flat Rate	9.80		
		b	Off-Peak Time	8.45		
		c	Peak Time	11.98		
6	**Category F: Medium Voltage, General Purpose (11 KV)**				400	45 (For Maximum Demand)
		a	Flat Rate	7.57		
		b	Off-Peak Time	6.88		
		c	Peak Time	9.57		
7	**Category G-2: Extra High Voltage, General Purpose (132 KV)**				500	40 (For Maximum Demand)
		a	Flat Rate	7.35		
		b	Off-Peak Time	6.74		
		c	Peak Time	9.47		
8	**Category H: High Voltage, General Purpose (33 KV)**				450	40 (For Maximum Demand)
		a	Flat Rate	7.49		
		b	Off-Peak Time	6.82		
		c	Peak Time	9.52		
9	**Category J: Street Light and Water Pumps**			7.17	1-Phase: 10.00 3-Phase: 30.00	20

Source: Bangladesh Energy Regulatory Commission (BERC)

Note) “Non-residential category” includes public services such as street lighting and non-residential use such as water pumps.

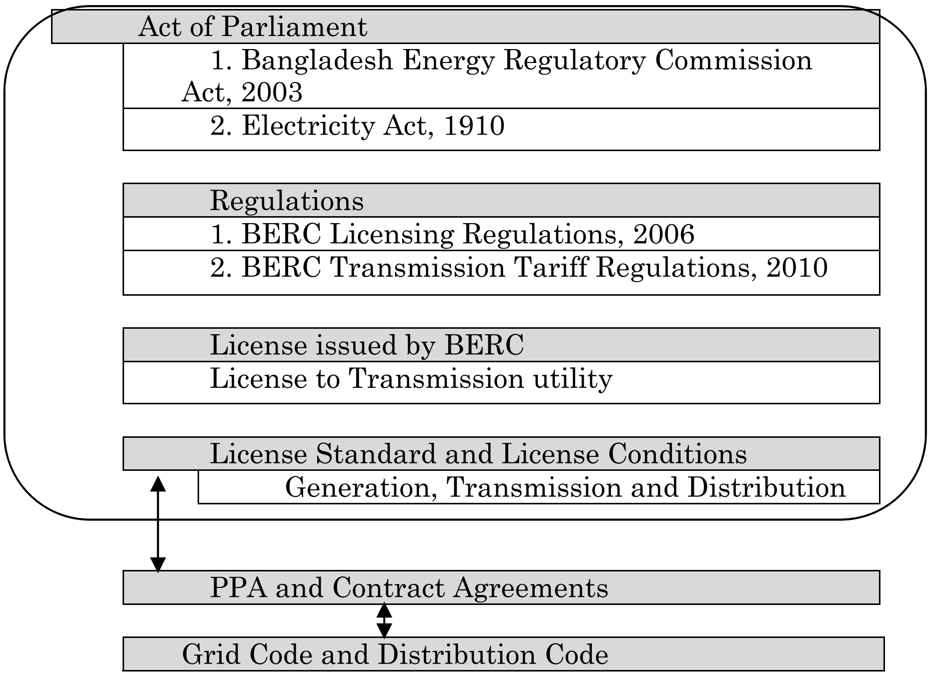
In addition, the BERC Act 2003 determines the tariff issues, dispute resolutions and relationship with the government as follows:

Table 20-4 Tariff Policy

Act/ Policy	Highlights
BERC Act 2003 Tariff Issues	Article 22 : (b) to ensure efficient use, quality services, determine tariff and safety enhancement of electricity generation and transmission, marketing, supply, storage and distribution of energy; BERC Electricity Tariff Regulations
BERC Act 2003 Dispute Resolutions	Article 22 : (j) to resolve disputes between the licensees, and between licensees and consumers, and refer those to arbitration if considered necessary (k) to ensure appropriate remedy for consumer disputes, dishonest business practices or monopoly
BERC Act 2003 Relationship with Government	Article 34 : BERC determines tariff in accordance with government Policies. BERC consults with Government in preparing the Tariff methodologies only.

Source: South Asia Regional Initiative for Energy Integration (SARI/EI)

BERC is also involved in setting the policies for transmission, by licensing to transmission utilities, including PPA and contract agreements. At the parliament level, the Bangladesh Energy Regulatory Commission Act (2003) and the Electricity Act (first established in 1910) are the 2 main acts. At BERC level, the BERC Licensing Regulations (2006) and the BERC Transmission Tariff Regulations (2010) are the 2 major regulations.



Source: South Asia Regional Initiative for Energy Integration (SARI/EI)

Figure 20-1 Hierarchy of Governance for Transmission

20.2 Natural Gas

20.2.1 Natural Gas tariff

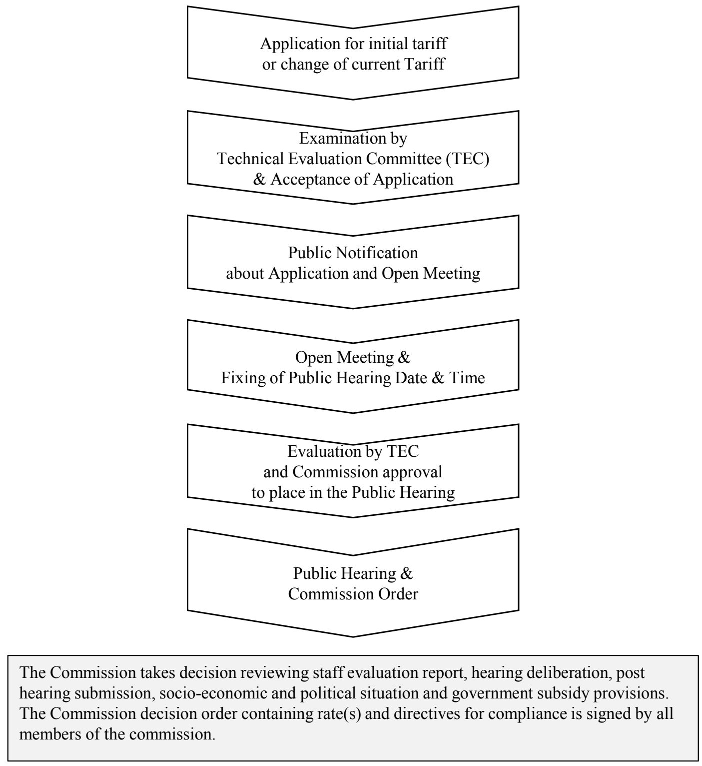
BERC (Bangladesh Energy Regulatory Commission Act), which was established following the Bangladesh Energy Regulatory Commission Act, 2003 is authorized to regulate not only nation-wide electricity, but also natural gas and petroleum products. “Transparency in tariff determination and economic efficiency” is clearly defined as one of the key pillars of BERC’s missions.

Table 20-5 Commission’s missions

· Enforcement of fiscal discipline of the energy sector
· Introduction of performance targets and incentive-based regulation
· Introduction of uniform operational standards and quality of supply
· Transparency in tariff determination and economic efficiency
· Increased opportunities for development of competitive markets
· Increased opportunities for efficiency and economic growth
· Public involvement into the energy sector

Source: BERC website

BERC has prepared two regulations regarding the gas sector, i.e. the gas transmission tariff regulation 2010 and the gas distribution tariff regulation 2010. These regulations are formulated in consideration of the participation of private entities and include the following procedures to approve the gas tariff in the gas transmission and distribution: Procedure of submitting the application for gas tariff by a Licensee, Procedure of reviewing the application for gas tariff, Procedure of issuing the approval for applied gas tariff.
Both regulations specify in detail the standard methodology to calcurate various rates included in tariff calculations. Figure below shows the outline of the process to determine the gas tariff.



Source: “Data Collection Survey on Bangladesh Natural Gas Sector - Final report” (JICA, 2012)

Figure 20-2 Bangladesh’s tariff decision process

Table 20-6 Natural gas tariff trend from 1969

(Unit: Tk/mcf)

Effective from	Power	Fertilizer	Industry	Commercial	Tea estate	Cap. Power	CNG Feed gas	Brick field (seasonal)	Domestic		
									Metered	Single Burner	Double burner
28.06.1969	1.60	1.60	2.92	6.40	-	-	-	-	6.40	6.30	10.50
19.06.1974	3.72	3.72	7.20	12.00	-	-	-	-	12.00	15.00	28.00
01.12.1977	5.00	5.00	9.00	13.00	-	-	-	-	13.00	16.00	30.00
02.06.1979	6.25	6.25	16.00	17.00	-	-	-	-	16.00	20.00	36.00
07.06.1980	7.75	7.75	18.00	19.00	-	-	-	-	18.00	22.00	40.00
07.06.1981	9.30	9.30	27.75	28.00	-	-	-	-	20.00	25.00	45.00
01.07.1982	10.50	10.50	31.00	31.00	-	-	-	-	27.00	35.00	65.00
30.06.1983	11.50	11.50	36.00	36.00	-	-	-	-	34.00	45.00	80.00
27.06.1984	13.05	13.05	36.00	45.20	-	-	-	51.00	34.00	45.00	80.00
30.06.1985	15.66	15.66	43.20	54.24	-	-	-	61.20	40.80	60.00	100.00
28.06.1986	19.09	19.09	52.14	65.39	-	-	-	78.30	44.88	66.00	110.00
18.06.1987	24.82	24.82	52.14	85.00	72.30	-	-	78.30	56.10	80.00	130.00
01.07.1988	28.54	28.54	59.96	97.75	83.15	-	-	90.05	56.10	92.00	150.00
01.07.1989	33.00	28.54	70.00	110.00	83.15	-	-	-	65.00	100.00	170.00
01.07.1990	37.95	32.82	80.42	126.50	95.62	-	-	-	74.75	115.00	195.00
01.07.1991	39.08	33.98	85.23	134.22	100.62	-	-	106.19	74.75	115.00	195.00
01.05.1992	43.05	37.39	93.74	134.22	110.16	-	43.05	116.67	82.12	126.00	215.00
01.03.1994	47.57	41.34	103.07	147.53	113.26	-	-	128.28	82.12	160.00	250.00
01.12.1998	54.65	47.57	118.93	169.90	130.26	86.37	-	147.25	94.86	185.00	290.00
01.09.2000	62.86	54.65	136.77	195.39	149.80	99.11	-	169.33	109.02	210.00	330.00
01.01.2002	65.98	57.48	143.57	205.30	157.16	104.21	-	177.83	114.40	275.00	350.00
01.09.2002	70.00	60.00	140.00	220.00	140.00	100.00	-	220.00	120.00	325.00	375.00
15.02.2003	-	-	-	-	-	-	70.00	-	-	-	-
01.07.2004	72.45	62.15	145.20	228.50	145.20	-	-	228.50	126.10	340.00	390.00
01.09.2004	-	-	-	-	-	103.50	-	-	-	-	-
01.01.2005	73.91	63.41	148.13	233.12	148.13	105.59	-	233.00	130.00	350.00	400.00
25.04.2008							282.30	-	-	-	-
01.08.2009	79.82	72.92	165.91	268.09	165.91	118.26	-	-	146.25	400.00	450.00
12.05.2009							509.70		-	-	-
19.09.2011							651.29		-	-	-
01.09.2015									-	600.00	650.00

Source: PetroBangla Annual Report 2014, No. BERC/Tariff/Gas-12/Transmission & Distribution/3056

According to gas sales regulation, prices can be revised once a year. However, although BERC is authorized to revise the prices, there have been cases where the regulations are revised on short notice due to strong requests from the central government.

The latest price of gas became effective since 1st September, 2015. BERC declared the price hike in a press briefing at BERC office on 27th August, 2015. According to No. BERC/Tariff/Gas-12/Transmission & Distribution/3056, the revised tariff was Tk 600 and Tk 650 for single and double burners, up from Tk 400 and Tk 450 respectively.

20.2.2 Comparison of Bangladesh Gas tariff with other countries

Bangladesh's natural gas retail tariff as of 2011 are compared with a number of countries in Asia, including those in its immediate neighboring area, i.e. Pakistan and India. The table below illustrates that Bangladesh's retail Gas tariffs are significantly cheaper. For electric power production Gas tariffs in Bangladesh are barely two fifths of the price in Pakistan and are less than 10% of the price in Singapore. Only CNG price in Bangladesh comes close to prices slightly above the price in Pakistan, but even then they are only approximately half the price in India.

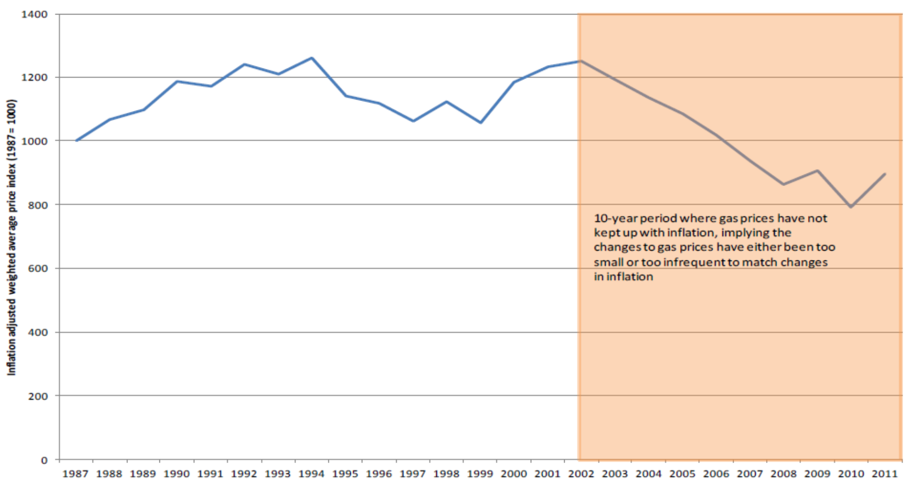
Table 20-7 Gas tariffs of Bangladesh and other Asian countries

(Unit: USD/mcf)

Country Effective Date of Tariff	Bangladesh 19/09/2011	Pakistan 7/08/2011	India 1/12/2011	Malaysia 1/06/2011	Thailand 1/06/2011	Indonesia 1/06/2011	Singapore 1/06/2011
Consumer Category							
Power	1.05	5.14	5.06	4.36	5.81	6.7	13.79
IPP	1.05	4.34					
Fertilizer							
Feed Stock	0.96	1.17	5.06				
Power	1.56	4.99					
Industry	2.19	4.99	18.19	5.12	6.2	5.97	35.21
Cement		7					
Ice Factory		6.05					
Captive Power	1.56	4.99					
CNG	8.6	6.57	16.17				
Large Commercial	3.54	6.05	18.19	5.12			
Small Commercial	3.54	6.05	23.51	5.12			
Domestic	1.93	1.24	12.27				
Tea Estate	2.19						

Source: "Bangladesh: Tariff Reform and Inter-sectoral Allocation of Natural Gas" (ADB, 2013)

In addition, figure below shows that since 2002, despite a number tariff increases, the real price of gas couldn't match changes in inflation. The reason was because those increases were either too small or too infrequent.

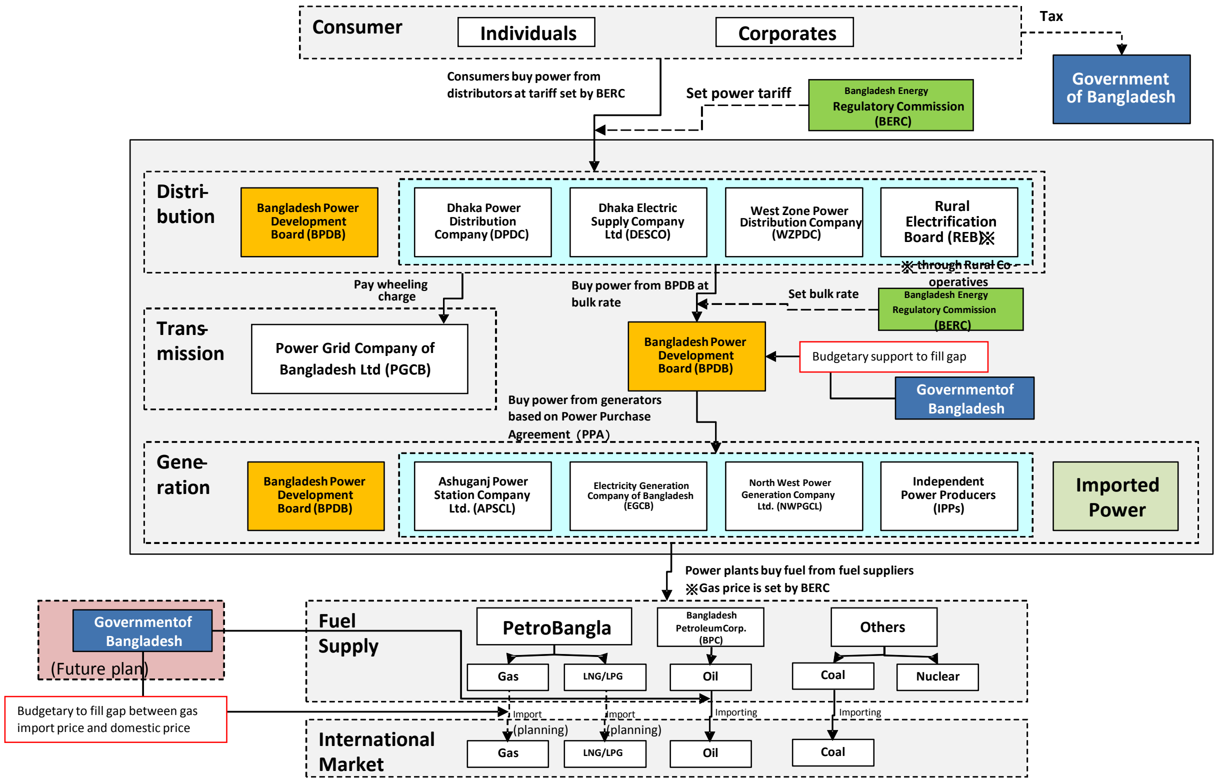


Source: "Bangladesh: Tariff Reform and Inter-sectoral Allocation of Natural Gas" (ADB, 2013)

Figure 20-3 Inflation adjusted average gas price index of Bangladesh

20.3 Overview of Flows of Funds Related to the Power Sector

In order to establish Finance Projection Model, main relevant institutions of power sector are identified and their cash flows among these institutions are investigated. In this process, the operation phase and the capital investment phase are investigated separately (see Figure 20-4 and Figure 20-5).

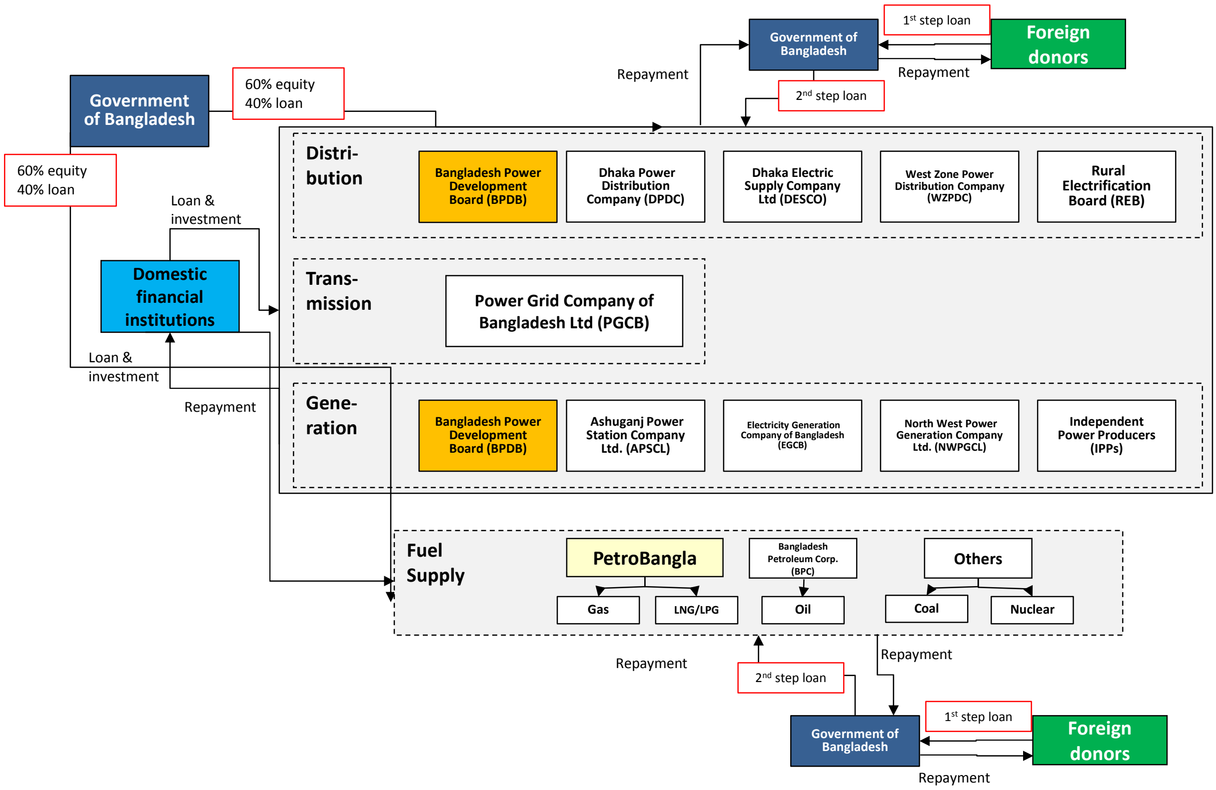


Source: JICA Survey Team

Figure 20-4 Cash Flow of Bangladesh Power Sector for Operation Phase

In the operation phase, the cash flows from consumers, i.e. both individuals and corporates, to distributing entities (BPDB, DPDC, DESCO, WZPDC and REB) using the power tariff set by BERC. These distributing entities buy power from BPDB at bulk rate which is also determined by BERC. The distribution entities pay wheeling charge to PGCB, the only entity responsible for power transmission in Bangladesh. In addition to transmission charge, BPDB as the single power buyer also purchases power from generation entities based on individual Power Purchase Agreement (PPA) between BPDB and each company. These generation entities purchase fuel (gas, oil, coal, etc.), which are required for power generation, from primary energy suppliers. In cases where the fuel needs to be procured from abroad, these primary energy suppliers purchase fuel from oversea markets.

In the capital investment phase, businesses in the power sector (including power generation, transmission and distribution) borrow from the government of Bangladesh (GOB) as well as financial institutions (including international donors, i.e. World Bank, Asia Development Bank, JICA, and local commercial banks). In case of international donors, loan is injected into projects in a 2-step manner. At step 1, the GOB signs a loan agreement and borrows from international donors using concessional loan from these donors. In step 2, the GOB provides loans in BDT to businesses with their own conditions. Details of these loan conditions are given in 20.5.2 .



Source: JICA Survey Team

Figure 20-5 Cash Flow of Bangladesh Power Sector for Capital Investment

20.4 Financial Performance of Main Players in the Power Sector

Regarding the financing environment and cash flows of businesses in the power sector, its generation sector, transmission sector, and distribution sector were investigated. In general, the transmission and distribution sectors (excluding BPDB) have been able to achieve appropriate profit to sustain their operations, although in some years distribution entities have recorded a small amount of loss from their operations. On the other hand, both BPDB’s generation and distribution sectors have been continuously recording loss from their operations. BPDB as the single power buyer is the one entity that absorbs the entire imbalance between power generation and sales. This finding indicated that by looking at the imbalance in the cash flow of BPDB, one could basically evaluate the soundness of the finance state of the whole power sector of Bangladesh. This point is described in details in the description of the analytical model.

20.4.1 Overview

The structure of the power sector and its current situation of financial deficit is illustrated in Figure 20-8. Its generation sector consists of generation entities such as IPP’s, SIPP’s, public plants, and BPDB’s generation sector. All of the generated electricity from these plants is first bought by BPDB’s generation sector as the single buyer. BPDB sells the purchased electricity to distribution entities such as WZPDCL, REB, DESCO, DPDC, and its own distribution sector. Each distribution entity pays wheeling charges to PGCB for using its transmission facilities. The distribution entities finally sell their electricity to the consumers. From the annual reports of the aforementioned power sector entities, it was concluded that both generation and distribution sectors of BPDB are in a financial deficit, as shown in Figure 20-6.

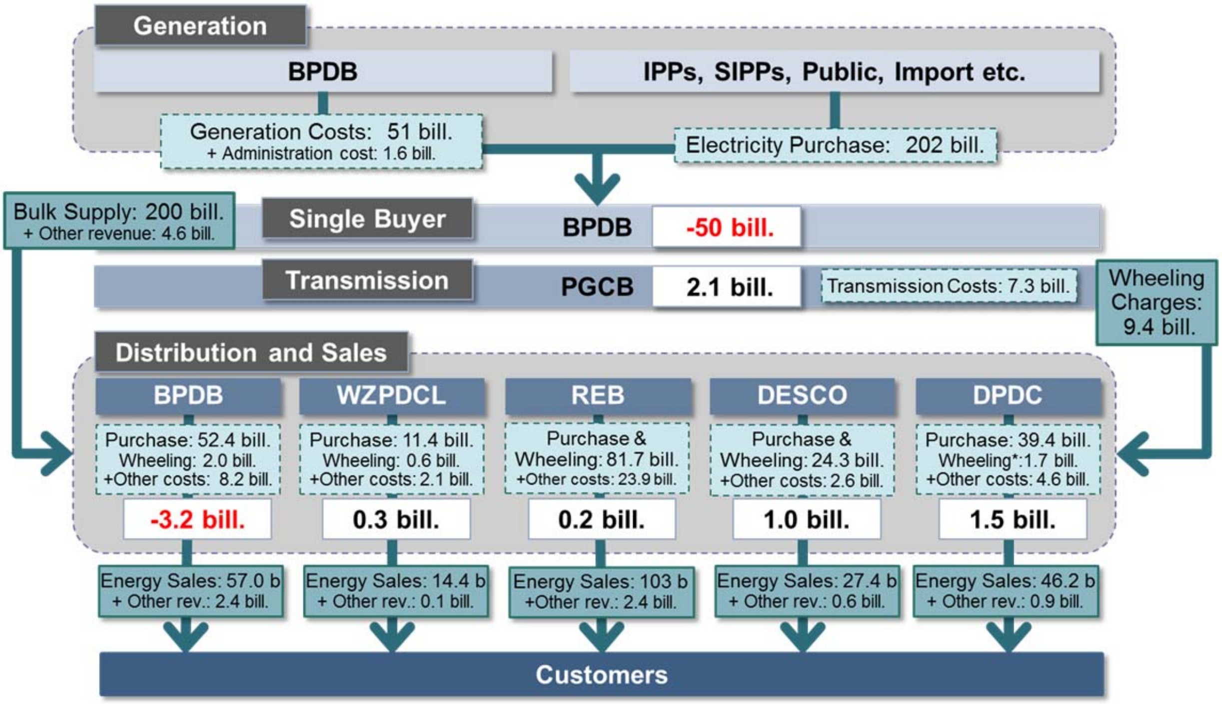


Figure 20-6 Structure of Financial Deficit in Bangladesh Power Sector

For FY2014-2015, distribution entities sold approximately 248 billion BDT worth of power to both individual and corporate consumers. In the same fiscal year, BPDB's distribution sector paid PGCB 2.0 billion BDT for wheeling charge. BPDB purchases power from generation entities based on individual Power Purchase Agreement (PPA) between BPDB and each company at a price that reflect the actual generation costs. In FY2014-2015, it purchased 202 billion BDT worth of power from IPP's, SIPP's, Public, rental, and import. BPDB, as single buyer, sold the electricity for a total of 200 billion BDT to distribution entities. As a result, a total loss of 53.2 billion BDT was incurred in BPDB.

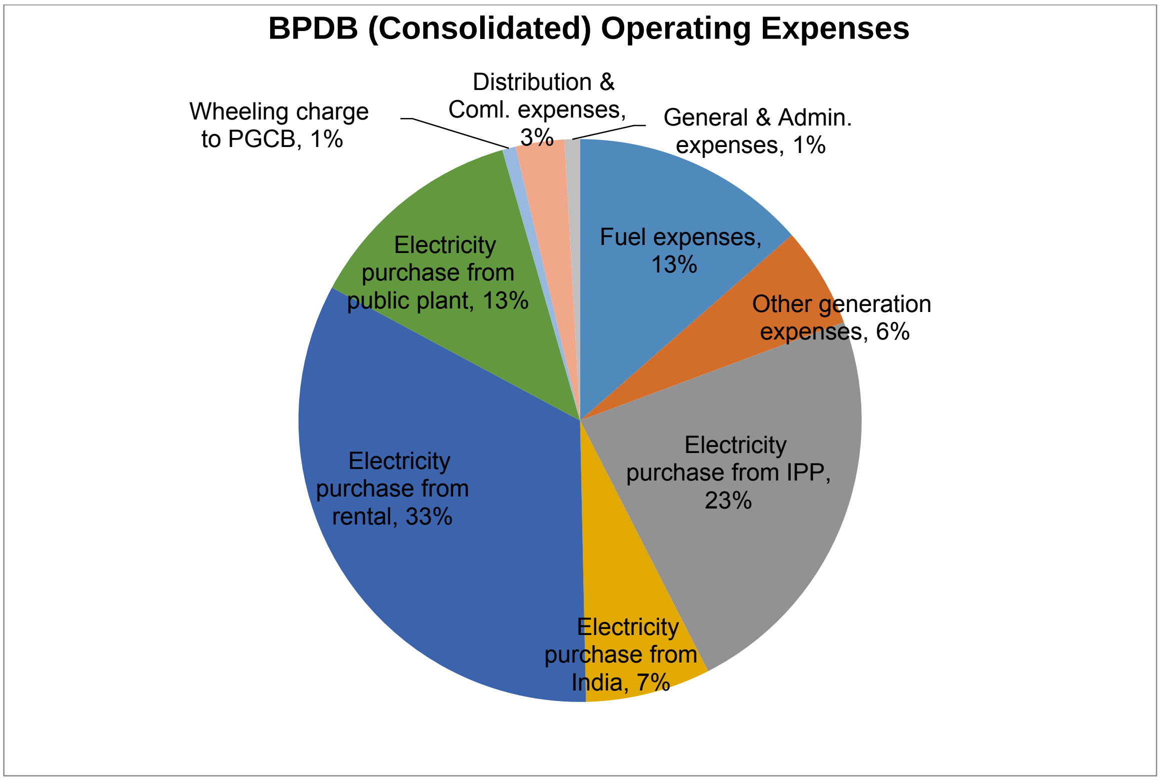
As stated above, both BPDB's generation and distribution sectors are in a financial deficit. Therefore, BPDB's consolidated operating revenue and expenses are analyzed. In FY2014-2015, apart from BPDB own generation (around 35.9 billion BDT in fuel cost and 15.2 billion BDT of other generation expenses, or around 20% of its operating expenses), most of its operating expenses was payment to rental/quick-rental plants (33%, or 87.7 billion BDT). Other main components of BPDB'S operating expenses were payment to IPPs (23% or 61.3 billion BDT) and to public plants (13%, or 33.7 billion BDT).

Table 20-8 Operating Revenue and Operating Expenses of BPDB (Consolidated) (million BDT)

Head of accounts	FY2013-14	FY2014-15
1. Operating Revenue	**194,288**	**211,876**
Energy Sales (Bulk)	186,371	204,921
Other operating income	7,917	6,955
2. Operating Expenses	**206,789**	**264,624**
Fuel expenses	41,927	35,869
Other generation expenses	15,824	15,248
Electricity purchase from IPP	44,634	61,313
Electricity purchase from India	11,457	19,003
Electricity purchase from rental	97,503	87,748
Electricity purchase from public plant	22,724	33,656
Wheeling charge to PGCB	1,849	2,018
Distribution & Coml. expenses	6,970	7,451

General & Admin. expenses	1,901	2,318
3. Operating (Loss)/Profit	**-50,501**	**-52,748**

Source: BPDB Annual Report 2014-2015



Source: BPDP Annual Report 2014-2015

Figure 20-7 Operating Income and Operating Expenses of BPDB as the Single Power Buyer

Financial deficit in BPDB mainly comes from differences in net supply cost and bulk supply rate. BPDB purchases power from generation entities based on individual Power Purchase Agreement (PPA) between BPDB and each company at a price that reflect the actual generation costs. In FY2014-2015, it purchased power from generators at average net supply cost of 5.94 BDT/kWh, and sold to distribution entities at average bulk rate of 4.69 BDT/kWh. The distribution entities sold power to consumers at tariff set by BERC, which was at an average 6.26 BDT/kWh. Due to the difference between bulk rate and supply cost, a deficit of around 50 billion was incurred at BPDB generation sector. The aforementioned supply cost, bulk rate, and retail tariff are described in Table 20-9 and Figure 20-8.

Table 20-9 Net Generation Cost, Supply Cost, and Bulk Rate

Particulars	Unit	FY2013-14	FY2014-15
Net Generation Cost before Budgetary Support	BDT/kWh	5.81	5.78
Net Supply Cost* before Budgetary Support	BDT/kWh	5.96	5.94
Bulk Rate	BDT/kWh	4.71	4.69
Difference between Net Supply Cost and Bulk Rate	BDT/kWh	1.25	1.25

*Note: Net Supply Cost is the Net Generation Cost factored in the transmission loss
Source: BPDB, PGCB, WZPDCL, DESCO, and DPDC Annual Reports

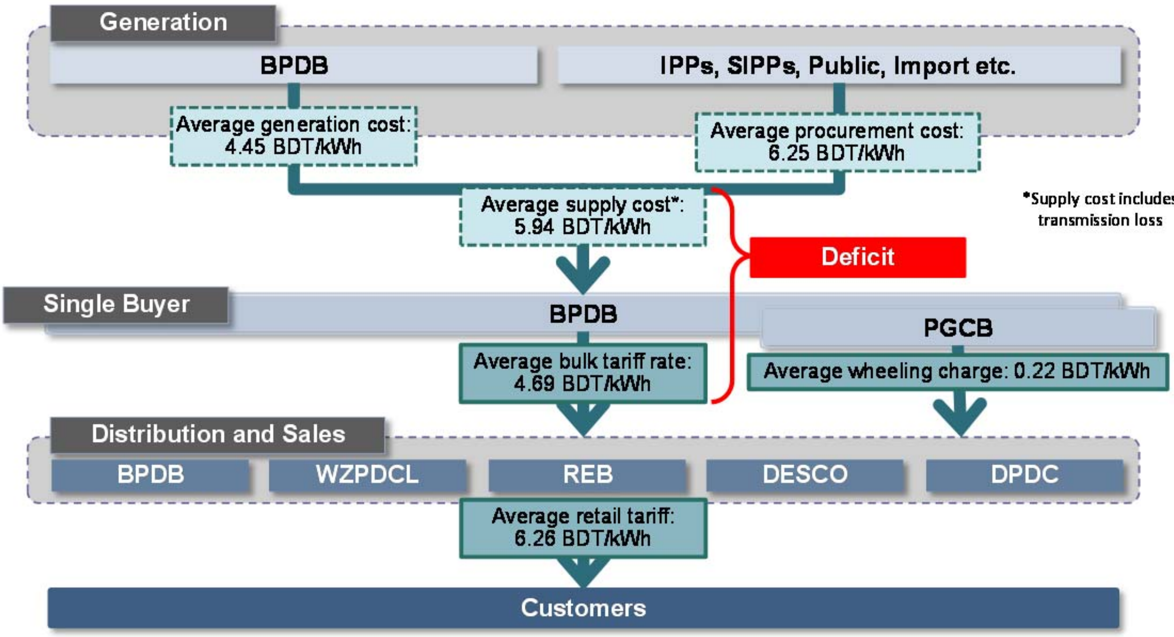


Figure 20-8 Supply Cost, Bulk Rate, and Retail Tariff of Electricity (FY2014-2015)

In order to sustain BPDB's operation, the Finance Ministry has been providing a budgetary support. This budgetary support is intended not only to offset BPDB's financial deficit, but also to support its funding management. Therefore, it is assumed that the amount of budgetary support is determined based on the situation of the balance sheet.

Table 20-10 Budgetary Support from the Government to BPDB (billion BDT)

Item	FY2010-2011	FY2011-2012	FY2012-2013	FY2013-2014	FY2014-15
Balance of budgetary support	69.005	132.572	176.634	236.363	328.215
Net increase of budgetary support	40.000	63.567	44.062	59.729	91.852

Source: BPDB Annual Report

Budgetary support from the government has been increasing annually; the balance, which was 69 billion BDT in 2011, increased to 328 billion BDT in 2015. Its net increase is in an increasing trend as well; net increase for 2015 was 92 billion BDT.

20.4.2 Generation Entities

Power generation entities, i.e. APSCL, EGCB, NWPGCL, IPPs and rental/quick-rentals, generate power and sell to BPDB, which is Bangladesh's single power buyer. BPDB purchases power from those entities based on individual Power Purchase Agreement (PPA) between BPDB and each company. Based on interviews with governmental entities, it was found that the PPAs take into account the actual generation costs and set at a level that ensures that the generation entities can receive appropriate profits to sustain their operations.
Power generation cost consists of 3 components, fuel cost, capital cost and fixed costs. Actual cost by fuel type from FY2007 to FY2012 is summarized in table below. This cost composition was considered when forecasting generation cost in the future.

Table 20-11 Fuel, Capital and Fixed Cost by Fuel Type for Power Generation (BDT/kWh)

FY	Fuel type plant	Fuel cost	Capital cost	Fixed cost	Total Generation cost
2007	Gas	0.76	0.11	0.86	1.74
	Coal	2.15	0.25	1.17	3.57
	Oil	8.67	0.82	2.16	11.65
2008	Gas	0.78	0.00	0.91	1.70
	Coal	2.55	0.14	1.19	3.88
	Oil	11.08	0.23	2.42	13.72
2009	Gas	0.86	0.09	0.98	1.93
	Coal	2.50	0.20	1.08	3.78
	Oil	10.49	0.25	3.29	14.02
2010	Gas	0.85	0.14	1.14	2.13
	Coal	2.91	0.27	2.36	5.54
	Oil	10.45	0.22	3.01	13.68
2011	Gas	0.81	0.14	1.59	2.54
	Coal	3.41	0.26	1.88	5.56
	Oil	12.84	0.25	3.03	16.11
2012	Gas	0.82	0.15	1.61	2.57
	Coal	4.70	0.28	1.84	6.81
	Oil	13.69	0.28	4.88	18.85

Source: Material provided by BERC

Regarding fuel procurement, in the case of public enterprises such as BPDB, the primary energy for electric power generation is basically provided by public corporations such as BPC. In this case, a unit price of the primary energy is set by BERC or the Government of Bangladesh. On the other hand, since the primary energy supplied to such as IPP, rentals/quick-rentals is not always through public enterprises such as BPC, it is not necessarily purchased at the price set by BERC or the Government of Bangladesh.

20.4.3 Transmission Entity

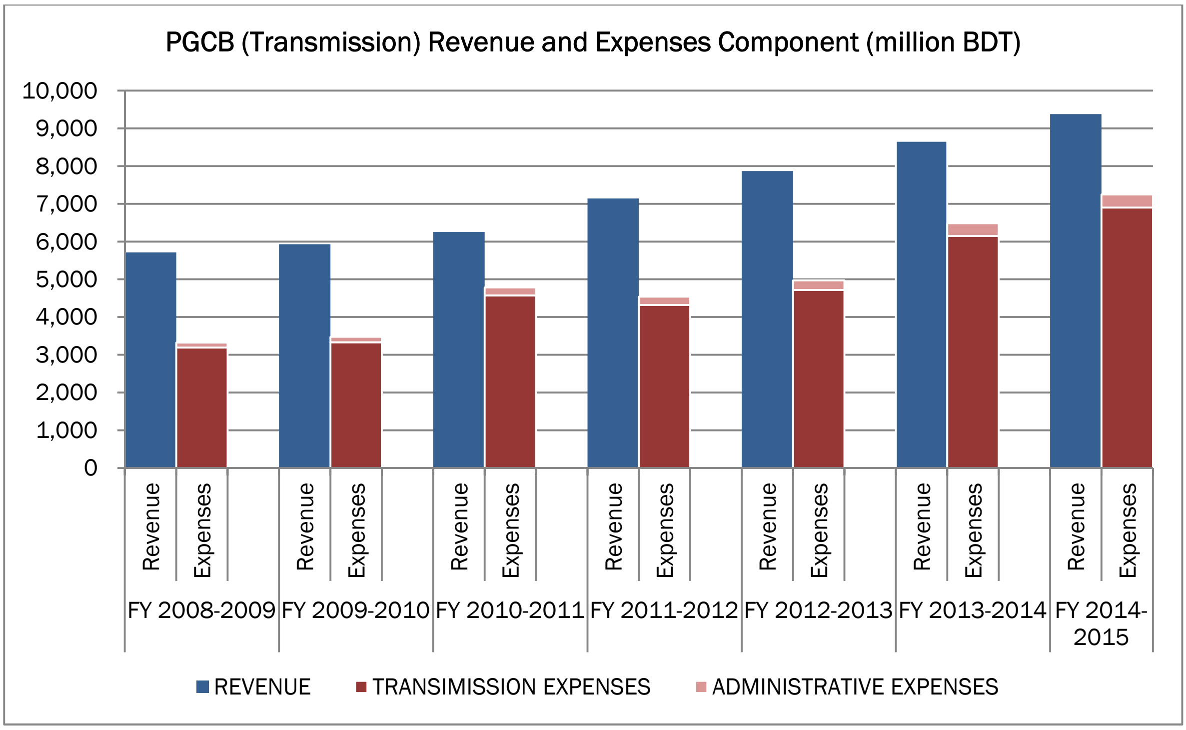
PGCB is the only system operator which conducts all electric power transmission operation in Bangladesh. Each distribution entity pays PGCB wheeling charge at a rate decided by BERC based on governmental ordinances. Based on interviews with governmental entities, it was found that BERC takes into account the operating cost of PGCB and set the wheeling charge rate at a level so that PGCB can receive appropriate profits to sustain its operations.
Regarding the wheeling charge rate, that of FY2006-2007 through FY2014-2015 was calculated to be 0.22 BDT/kWh based on data from PGCB’s annual report. Operating profit of FY2012-13, FY2013-14, and FY2014-15 was 2,897 million BDT, 2,185 million BDT, and 2,127 million BDT, respectively (Table 20-12).

Table 20-12 Operating Revenue and Expenses of PGCB

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Revenue	mil.BDT	7,870	8,672	9,378
Transmission volume	GWh	35,466	39,256	42,616
Transmission loss	%	2.78	2.58	2.57
Wheeling charge rate	BDT/kWh	0.22	0.22	0.22
Transmission expenses	mil.BDT	4,719	6,146	6,904
Administrative expenses	mil.BDT	255	341	348
Operating profit	mil.BDT	2,897	2,185	2,127

Source: PGCB's annual report

Based on the analysis of operating revenue and expenses of PGCB in the last several years, PGCB has continuously maintained higher revenue than expenses (Figure 20-9). However, its operating margins are in a decreasing trend for the past few years; such trend may have negative influence on its transmission investment plan.



Source: PGCB Annual Reports

Figure 20-9 PGCB Operating Revenue and Expenses

20.4.4 Distribution Entities

Distribution entities, i.e. BPDB's distribution division, DPDC, DESCO, WZPDC and REB, purchase power from BPDB at bulk rate and sell power to consumers (both individuals and corporate) at tariff rate. Both bulk rate and tariff rate are determined by BERC. Recent average bulk rate and average revenue rate (per kWh of retail electricity) are described in Table 20-13. As average revenue rate is kept at a higher level than bulk rate, those distribution entities are relatively able to achieve appropriate profits to sustain their operations, though there are some exceptions as explained below.

Table 20-13 Distribution Sales and Tariff Rates

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Sales from BPDB to distributors	mil. BDT	161,304	185,104	200,262
	GWh	35,466	39,256	42,616
Average Bulk Rate	BDT/kWh	4.55	4.71	4.70
Sales from distributors to consumers	mil. BDT	189,800	217,600	248,000
	GWh	32,740	36,233	39,625
Average Revenue Rate	BDT/kWh	5.80	6.01	6.26

Source: BPDB, WZPDCL, DESCO, DPDC Annual Reports

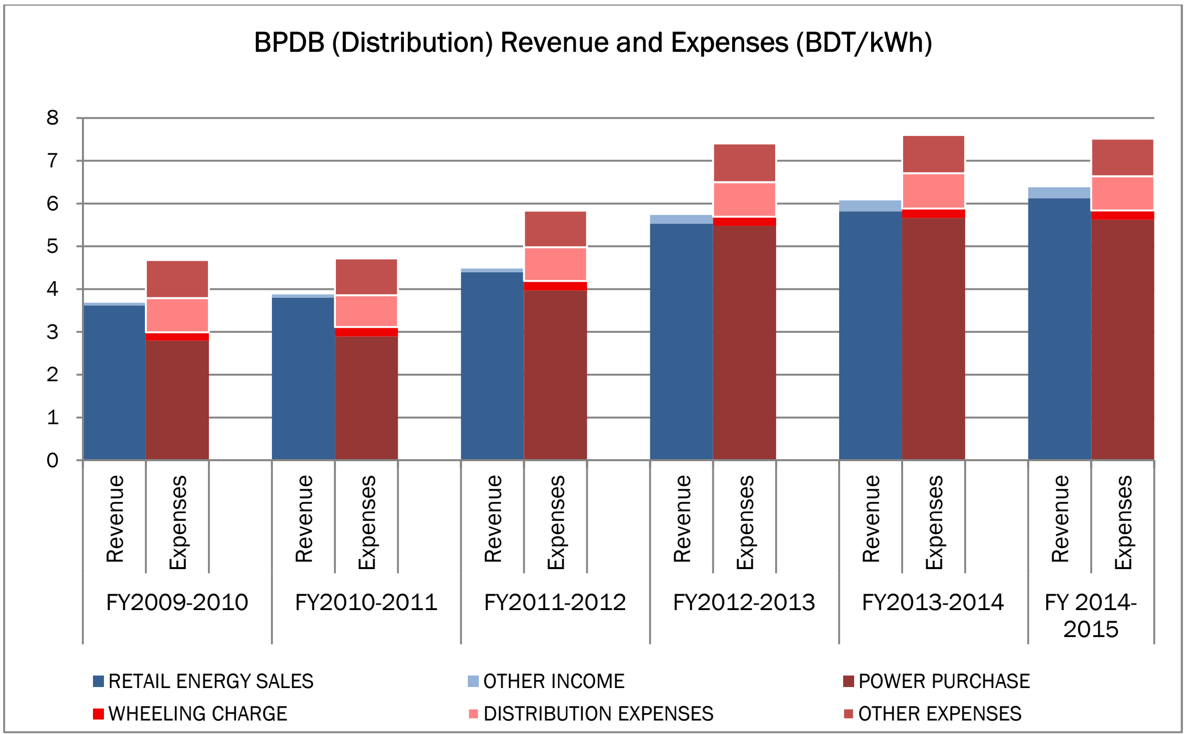
(1) BPDB Distribution Sector

Although BPDB's average revenue rate for the past few years has been higher than its average bulk rate, operating margins of BPDB have been in a deficit in the past several years (Table 20-14, Figure 20-10). In the past several years, there has been a larger increase in the amount of power purchase than retail energy sales; therefore expenses in BPDB's distribution sector have continuously exceeded its revenue.
Such financial situation in BPDB distribution sector may be due to its distribution expenses. Compared with other distribution companies analyzed in the following sections, BPDB's distribution sector has larger distribution expenses. Its rural distribution area may be one of the contributing factors, but its low operational efficiency could be one as well.

Table 20-14 BPDB (Distribution) Sales and Tariff Rates

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Sales from BPDB (single buyer)	mil. BDT	42,161	47,896	52,365
	GWh	8,737	9,597	10,486
Average Bulk Rate	BDT/kWh	4.83	4.99	4.99
Sales to consumers	mil. BDT	42,562	49,163	57,024
	GWh	7693	8456	9315
Average Revenue Rate	BDT/kWh	5.53	5.81	6.12

Source: BPDB Annual Report



*per kWh of retail sales
Source: BDPB Annual Reports

Figure 20-10 BPDB (Distribution) Operating Revenue and Expenses

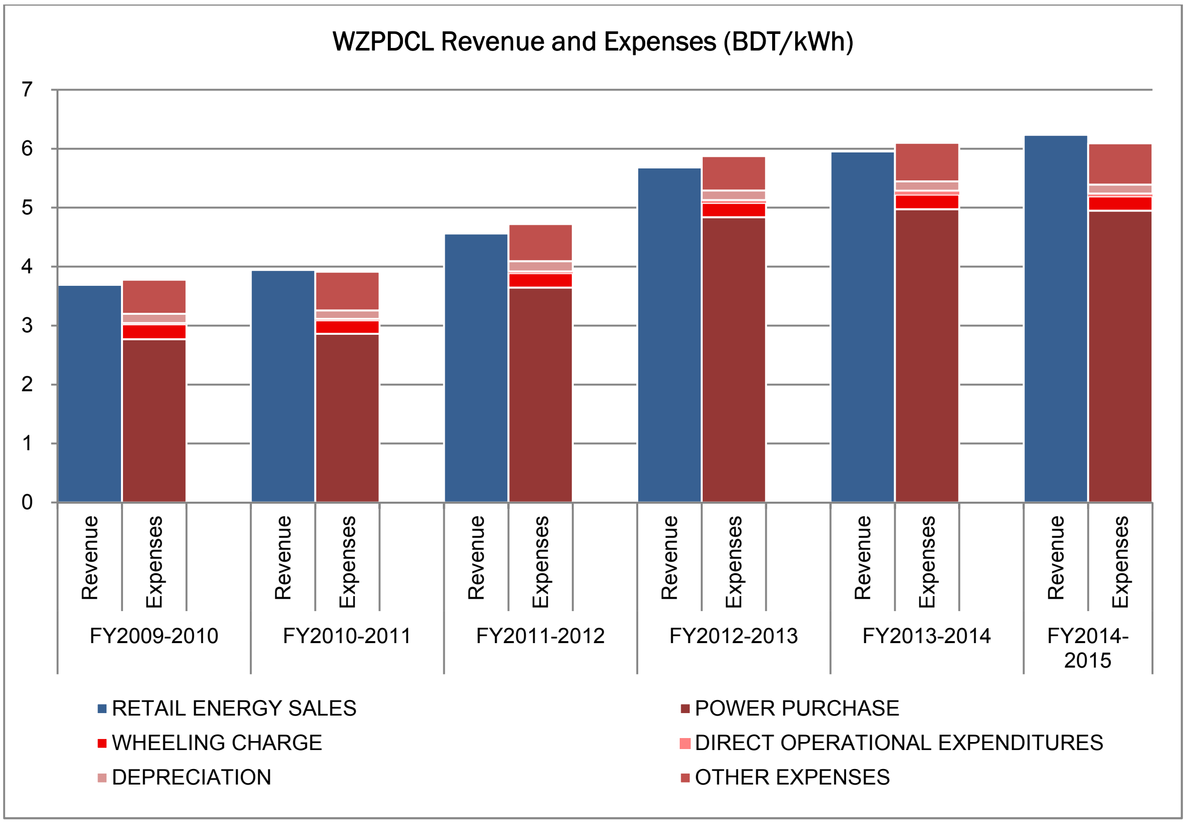
(2) WZPDCL

In general, WZPDCL has had balanced operating revenue and expenses for the past several years. In FY2013 and 2014, its operating margins were slightly in a deficit; however, it has regained positive operating margin in FY 2015. Both the average bulk rate and the average revenue rate have been increasing in the past few years, and its average revenue rate has been higher than its bulk rate. Table 20-15 and Figure 20-11 illustrate such situation.

Table 20-15 WZPDCL Sales and Tariff Rates

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Sales from BPDB (single buyer)	mil. BDT	9,379	10,606	13,430
	GWh	2,187	2,394	2,574
Average Bulk Rate	BDT/kWh	4.29	4.43	5.22
Sales to consumers	mil. BDT	11,019	12,693	14,402
	GWh	1,939	2,132	2,310
Average Revenue Rate	BDT/kWh	5.68	5.95	6.23

Source: WZPDCL Annual Report



*per kWh of retail sales
Source: WZPDCL Annual Reports

Figure 20-11 WZPDCL Operating Revenue and Expenses

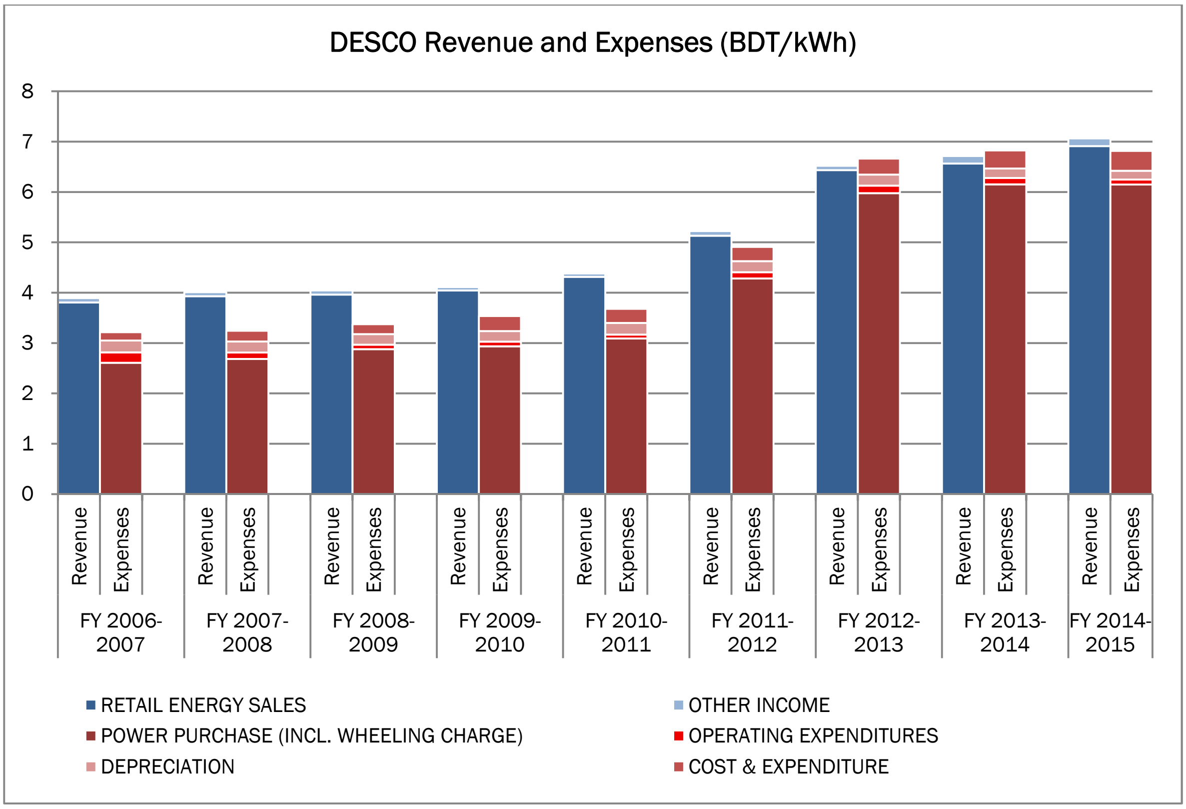
(3) DESCO

In general, DESCO has had balanced operating revenue and expenses for the past several years. In FY2013 and 2014, its operating margins were slightly in a deficit; however, it has regained positive operating margin in FY 2015. Its average bulk rate was not calculated since the amount of electricity purchase cost excluding wheeling charge was not described in its annual report. On the other hand, average revenue rate calculated from the annual reports shows an increasing trend for DESCO as well. Compared with the average revenue rate in WZPDCL, DESCO has higher average average revenue rate. Table 20-16 and Figure 20-12 illustrate such situation.

Table 20-16 DESCO Sales and Tariff Rates

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Sales from BPDB (single buyer)	GWh	3,726	4,067	4,320
Sales to consumers	mil. BDT	21,951	24,431	27,358
	GWh	3,412	3,722	3,959
Average Revenue Rate	BDT/kWh	6.43	6.56	6.91

*Electricity purchase shown in DESCO's annual report included wheeling charges as well; thus, average bulk rate is not included in this table.
Source: DESCO Annual Report



*per kWh of retail sales
Source: DESCO Annual Reports

Figure 20-12 DESCO Operating Revenue and Expenses

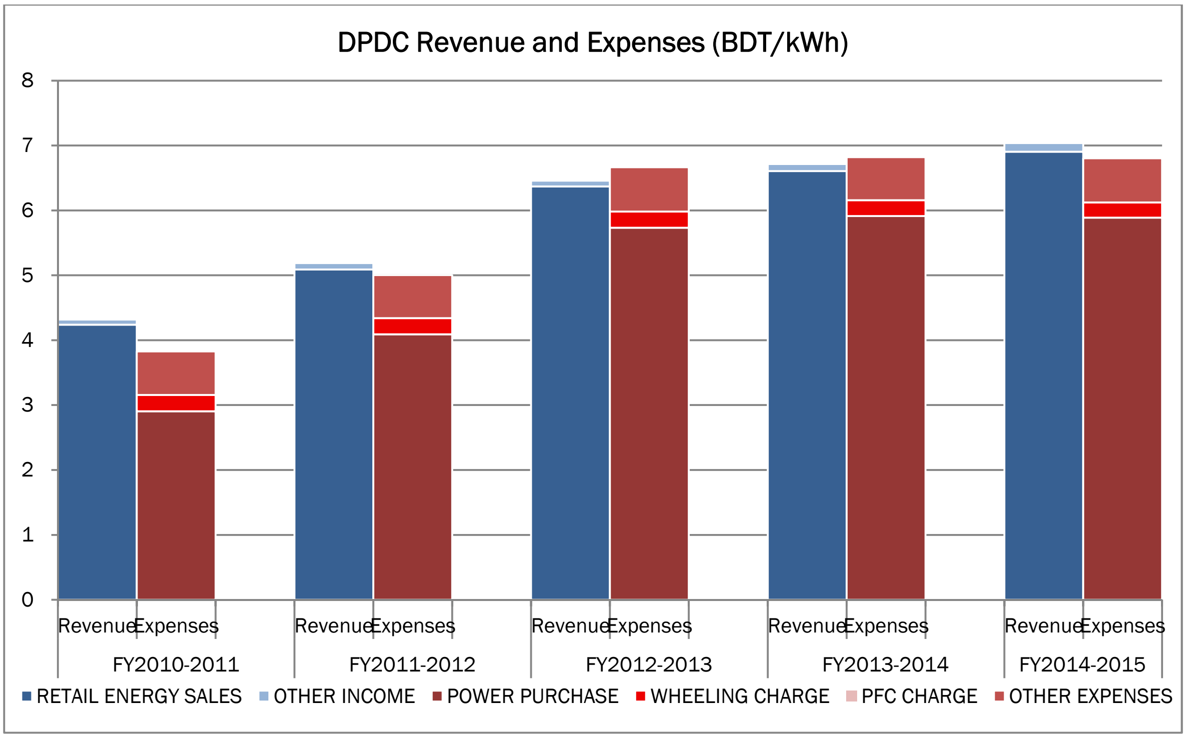
(4) DPDC

In general, DPDC has had balanced operating revenue and expenses for the past several years. In FY2013 and 2014, its operating margins were slightly in a deficit; however, it has regained positive operating margin in FY 2015. Its average revenue rate has been increasing in the past few years, and its average revenue rate has been higher than its bulk rate. The average revenuerate of DPDC is about the same as that of DESCO. Table 20-17 and Figure 20-13 illustrate such situation.

Table 20-17 DPDC Sales and Tariff Rates

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Sales from BPDB (single buyer)	mil. BDT	34,076	37,498	39,424
	GWh	6,593	7,038	7,402
Average Bulk Rate	BDT/kWh	5.17	5.33	5.33
Sales to consumers	mil. BDT	37,851	41,882	46,218
	GWh	5,943	6,341	6,694
Average Revenue Rate	BDT/kWh	6.37	6.60	6.90

Source: DPDC Annual Report



*per kWh of retail sales
Source: DPDC Annual Reports

Figure 20-13 DPDC Operating Revenue and Expenses

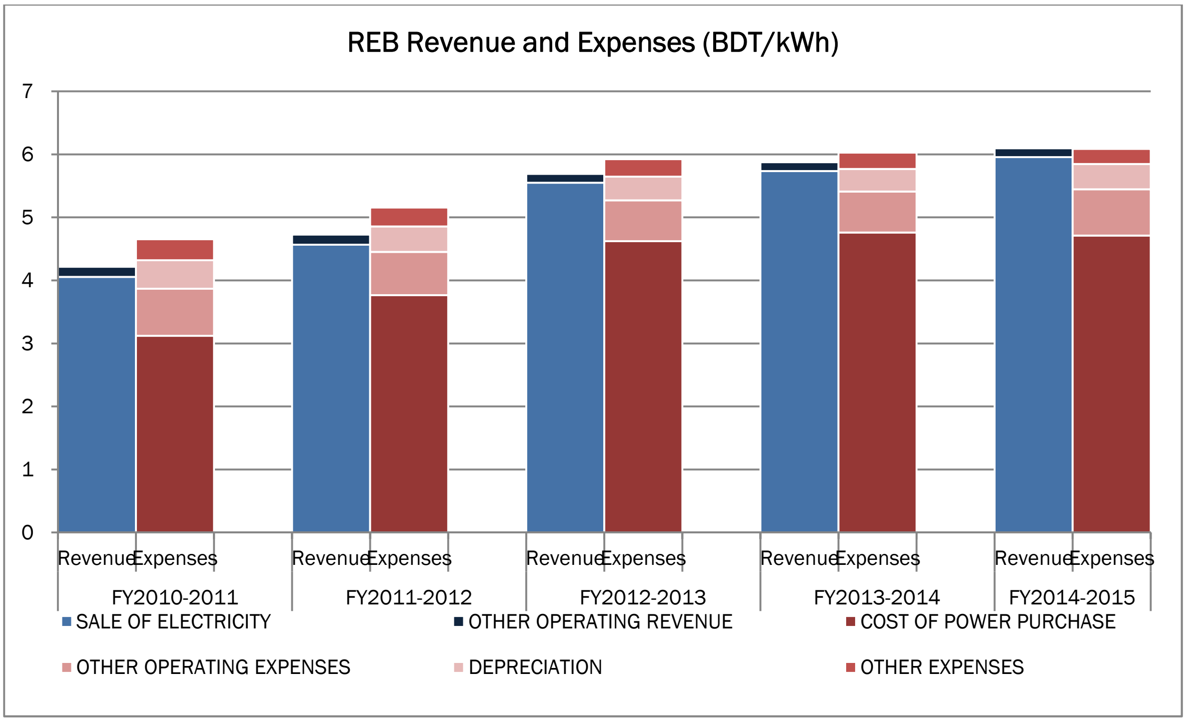
(5) REB

REB has had negative operating margins in the past, but its operating margins have been improving; in FY2014-2015, it was able to record a positive operating margin. Compared with the other distribution entities such as WZPDCL, DESCO, and DPDC, both the average bulk rate and the average revenue rate of REB are significantly lower. The low average revenue rate can be accredited to the composition of REB's distribution customers. On the other hand, it is assumed that the low bulk rate of REB is due to the fact that BPDB's regulated bulk supply rate to REB is set at a lower standard than the other distribution entities.

Table 20-18 REB Sales and Tariff Rates

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Sales from BPDB (single buyer)	mil. BDT	63,580	74,180	81,712
	GWh	14,222	16,161	17,835
Average Bulk Rate	BDT/kWh	4.47	4.59	4.58
Sales to consumers	mil. BDT	76,316	89,362	103,309
	GWh	13,754	15,582	17,346
Average Revenue Rate	BDT/kWh	5.55	5.73	5.96

Source: REB Public Documents



*per kWh of retail sales
Source: REB public documents

Figure 20-14 REB Operating Revenue and Expenses

20.5 Loan Financing to the Power Sector

Businesses in different sectors in the power sector raise funds related to facility investments at each one's discretion from various sources of finance, notably the government of Bangladesh and commercial banks, as well as international donors such as World Bank (WB), Asia Development Bank (ADB), JICA, etc. Loan condition of those sources is summarized below based on interviews and review of public documents review.

20.5.1 Donors' Assistance Programs for the Bangladeshi Power Sector

(1) Overview

Multilateral development partners in the energy sector in Bangladesh are the Asian Development Bank (ADB), Islamic Development Bank, and World Bank. On the other hand, major bilateral aid partners include Japan, France, Germany, Kuwait, Norway, United States, etc. The areas of support includes power generation, transmission and distribution upgrading, energy sector reforms, assistance to the regulatory commission, rural electrification, power plant upgrading capacity addition, capacity building, and planning, etc.

Major financing projects by development partners are listed in the table below.

Table 20-19 Recent Major Financing Projects by Development Partners in the Bangladeshi Power Sector

Development Partners	Project Name	Duration	Amount (million)
ADB, KfW	Development of new 132/33 kV and 33/11 kV substation under DESA Project	2006-2012	$53.00
ADB, IDB	Construction of Ashuganj 450 MW Combined Cycle Power Plant (North)	2011-2015	$365.4
ADB, JBIC	Construction and Expansion of Grid Substation with Distribution Line (Phase 1)	2005-2012	$94.0
ADB	Bangladesh–India Electrical Grid Interconnection Project	2010~	$100
ADB	Power System Expansion and Efficiency Improvement Investment Program	2012~	$700
CIS, Russia	Rehabilitation and Modernization of Ghorashal Thermal Power Station Unit 1 and 2	1997-2012	$30.8
IDA	RURAL ELECTRICITY TRANSMISSION AND DISTRIBUTION (T&D) PROJECT	2014~	$600
IDA	Construction of Siddhirganj 335 MW Peaking Combined Cycle Power Plant	2009-2015	$253.4
IDA	Efficient Lighting Initiative for Bangladesh Part 1 and Part 2	2009-2012	$34.10
IDA	TA for Implementation of Bangladesh Power Sector Reform (Phase 2)	2011-2015	$16.62
JICA	Bheramara Combined Cycle Plant Development (360 MW)	2010-2014	$504.9
JICA	Construction of Haripur 360 MW Combined Cycle Power Plant and Associated Substation	2009-2012	$427.7
JICA	Bangladesh Central Zone Power Distribution Project	2009-2013	$119.4
JICA	Rural Electrification Upgradation Project (Rajshahi, Rangpur, Khulna, and Barisal division)	2010-2015	$161.24
EDCF	Rural Electrifications Expansion Chittagong-Sylhet Division Programme 1	2010-2014	$60.71
KOICA	Solar Power Run Irrigation Pump and Solar Home System	2011-2013	$3.27
KOICA	Solar Power Systems in Bangladesh Parliament	2011-2012	$1.1
Kuwait Fund	Greater Chittagong Power Distribution Project	2009-2013	$12.22
DFID	Increasing Palli Bidyut Samiti's customers by 1 million under its distribution system	2006-2013	$42.41
KfW	Rehabilitation and Modernization of Ashuganj Power Station Unit 3, 4, and 5 (revised)	2000-2011	$125.0
EDCF	Bibiana—Kaliakoir 400 kV and Fenchuganj—Bibiana 230 kV Distribution Line	2010-2013	$209.86
Germany, BMZ	Sustainable Energy for Development	2009-2011	$10.62
KfW	Sustainable Power Sector Development	2007-2012	€23.0
KfW	Transmission Efficiency Improvement through Reactive Power Compensation at Grid Substation and Reinforcement of Goalpara Substation	2008-2012	$26.64
NDF	Power Sector Development	2003-2011	€8.30
NORAD	Power Sector Development	2003-2011	$10.0

USAID	Improved Capacity for Energy Access (focus on the Bangladesh Electricity Regulatory Commission and Rural Electrification)	2008-2011	$7.7
World Bank	Power Sector Development (focus on Bangladesh Electricity Regulatory Commission, Petrobangla, and Power Division)	2004-2011	$15.5
World Bank	Siddhirganj Peaking Power Plant Project and the Bahrabad—Siddhirqanj Pipeline	2008-2016	$350.0
World Bank	Design of Project Management System Framework (focus on power and gas companies)	2008-2010	$0.75
World Bank	Sigddhirganj-Maniknagar 230 kV Distribution Line Construction	2009-2011	$ 47.77

ADB = Asian Development Bank, BMZ = Federal Ministry of Economic Cooperation and Development, CIS= Commonwealth of Independent States, DESA = Dhaka Electricity Supply Agency, DFID = Department for International Development, EDCF = Economic Development Cooperation Fund, IDA =International Development Association, KfW = Kreditanstalt fur Wiederaufbau, JBIC = Japan Bank of International Cooperation, JICA = Japan International Cooperation Agency, KOICA = Korean International Cooperation Agency, kV = kilovolt, MW = megawatt, NDF = Nordic Development Fund, NORAD = Norwegian Agency for Development Cooperation, TA = technical assistance, USAID = United States Agency for International Development.

Source: "Power System Expansion and Efficiency Improvement Investment Program" (ADB) (original Source) Planning Commission Revised Annual Development Programme, May 2012)

The World Bank has been involved in the development of the power sector in Bangladesh for a long time. Since 1989, the World Bank has provided about 1.1 billion USD to support project costs and developmental expenditure in the power sector totaling 4.4 billion USD ("Project Performance Assessment Report", World Bank 2014). In particular, the amount of loan to projects from FY2000 to FY2013 the power sector was approximately 50 million USD.

ADB, during 1993-2008, approved loans totaling 1,756 million USD (1,212 million USD of OCR, 539 million USD from the ADF, and 5 million USD in grants) to the energy sector amounting to 29.6% of total ADB lending to Bangladesh. ADB lending operations consisted of 14 public sector project loans (8 ADF loans and 6 OCR loans) to finance 9 projects, 2 public sector OCR program loans, and 1 non-sovereign loan. The power subsector had six public sector projects valued at 1,291 million USD, and one non-sovereign loan of 50 million USD. The gas subsector had three projects valued at 415 million USD. ADB also provided 19 advisory technical assistance grants valued at 10 million USD during this period ("Bangladesh: Energy Sector", ADB 2009).

(2) Loan conditions

Notable donors which participate in the power sector of Bangladesh are WB, ADB and JICA. They provide businesses in the country's power sector loans with very different conditions as in Table 20-20.

Regarding JICA loan, as Bangladesh has become a lower middle income category country, JICA can provide ODA loan to Bangladesh (inter-governmental loan) at annual interest rate and interest rate during construction of 1.4%, repayment period of 30 years and grace period of 10 years.

Regarding WB loan, although the loan condition varies from project to project, it is assumed in this estimation that interest rate is 5% p.a., repayment period is 15-year with a 5-year grace period.

As for ADB loan, the project owner can borrow 100% of the project cost under a 2% p.a. interest rate, 25-year repayment period with a 5-year grace period.

Table 20-20 Loan Conditions of WB, ADB and JICA Loan

Loan condition	WB	ADB*)	JICA
Annual interest rate	5%	2%	1.4%
Interest rate during construction	5%	2%	1.4%
Repayment period	15 yrs	25 years	30 years
Grace period	5 yrs	5 years	10 years

*) Loan condition in the case of Project Loan by ADB

Source: Interviews and public documents ("Terms and Conditions of Japanese ODA Loans (Effective from October 1, 2014)" for JICA loan, "Terms and Conditions of ADB Loans" for ADB loan and "IBRD Flexible Loan: Major Terms and Conditions" for WB loan)

Regarding the funding scheme, it should be noted that funding international donors are injected to project owners in a 2-step manner. As a results, there exists 2 levels of principal and interest payment, which is principal and interest payment by the government of Bangladesh to donors (step 1), and that of owners to GOB.

The annual interest and interest during construction of loan provided by multi-lateral and bi-lateral financial entities at step 2 are assumed to be the same with that of GOB loan.

20.5.2 Financial Support from the Government of Bangladesh

An enterprise with capital expenditure can be funded by the government as equity and loan. The conditions for this are below. Ratio of equity and loan is 60% to 40%. Annual interests are basically 3%, but if financing from a donor is principal capital, it could be 3-5% depending on a ratio of the financing. In this analysis, the annual interest is set at 3%. The loan currency is Bangladeshi Taka. Pay-back grace period is 5 years. A pay-back period is 15 years after the pay-back grace period. It is necessary to pay interests during the pay-back grace period.

Table 20-21 Loan Conditions of Government of Bangladesh

Equity ratio	60%
Loan ratio	40%
Annual interest rate	3%
Interest rate during construction	3%
Repayment period	20 year
Grace period	5 year

Source: Interviews with BERC, BPDB, etc

20.5.3 Loan Conditions of Commercial Banks to the Power Sector

Loan conditions of commercial banks to the power sector are as follows. Annual interest rate and interest rate during construction are both 13%. Repayment period is 15 years without grace period.

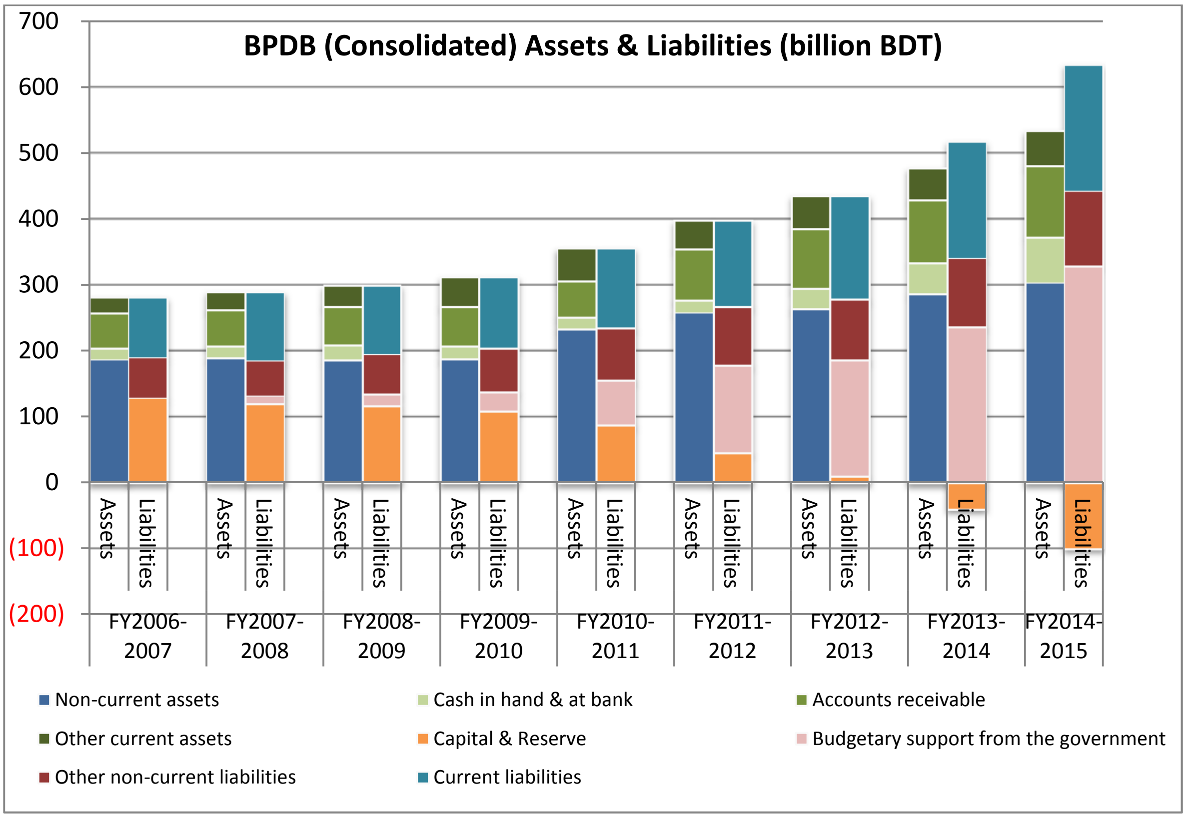
Table 20-22 Loan Conditions of Government of Commercial Banks

Annual interest rate	13%
Interest rate during construction	13%
Repayment period	15 year

Source: Interviews with BPDB

20.6 Subsidization Issues

As discussed in 20.4 , under the current scheme BPDB is shouldering gap of supply cost and selling price of electricity. BPDB is receiving long term loan to cover the gap every year.
Such budgetary support from the government has been rapidly increasing in the past several years, causing its capital and reserve to decrease to a negative value. Such situation can be seen in the balance sheet of BPDB, which is illustrated in Figure 20-15 and Table 20-23. If such situation continues, it is highly likely for BPDB to ask the government to abandon their debt.



Source: BPDB Annual Reports

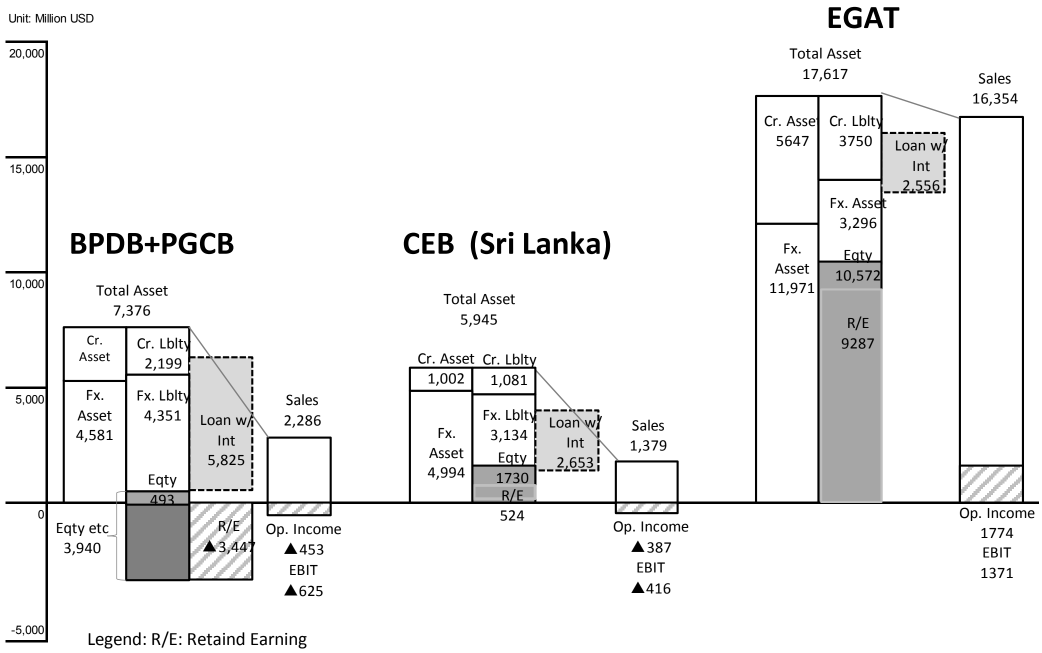
Figure 20-15 Property/Assets and Capital/Liabilities of BPDB (Consolidated)

Table 20-23 Capital & Liabilities of BPDB

CAPITAL & LIABILITIES	FY 2013-2014	FY 2014-2015
AUTHORIZED CAPITAL	200,000,000,000	**200,000,000,000**
CAPITAL & RESERVE		
PAID UP CAPITAL	150,443,838,475	155,632,244,275
NET SURPLUS / (DEFICIT)	-340,758,443,613	-416,481,863,930
APPRAISAL SURPLUS	117,057,871,482	117,057,871,482
GOVERNMENT EQUITY AGAINST DESCO SHARE	2,244,887,760	2,244,887,760
GRANTS	4,964,052,860	5,103,755,860
DEPOSIT WORK FUND	2,337,193,475	2,551,069,570
LIQUIDITY DAMAGE RESERVE	72,053,500	72,053,500
MAINTENANCE & DEVELOPMENT FUND	23,346,890,745	33,690,360,745
ASSETS INSURANCE FUND	315,000,000	330,000,000
	-39,976,655,318	**-99,799,620,739**
LONG TERM LIABILITIES		
GOVERNMENT LOAN	62,476,911,262	63,968,368,012
BUDGETARY SUPPORT FROM GOVT AGAINST SUBSIDY (DIFFERENCE OF BUYING & SELLING RATE)	236,363,146,667	328,215,200,000
FOREIGN LOAN	22,840,558,402	29,334,507,671
	321,680,616,331	**421,518,075,683**
DEPOSIT & PROVISION FUND		
SECURITY DEPOSIT (CONSUMERS)	3,973,342,252	4,393,169,761
GPF & CPF	4,961,372,437	5,597,397,620
GRATUITY & PENSION FUND	9,899,594,665	10,764,731,348
	18,834,309,353	**20,755,298,729**
CURRENT LIABILITIES		
ACCOUNTS PAYABLE	38,220,677,041	41,604,304,952
SECURITY DEPOSIT (CONTRACTORS & SUPPLIERS)	674,368,835	781,958,011
CURRENT PORTION OF LONG TERM LIABILITIES	3,537,936,276	3,532,109,213
DEBT SERVICING LIABILITIES (PRINCIPAL) - BPDB	50,521,214,593	49,894,130,535
DEBT SERVICING LIABILITIES (PRINCIPAL) - PGCB	8,560,879,540	8,996,251,801
DEBT SERVICING LIABILITIES (PRINCIPAL) - APSCL	5,872,071,918	6,018,564,214
DEBT SERVICING LIABILITIES (PRINCIPAL) - WZPDCL	1,950,209,829	1,976,090,084
REIMBURSABLE PROJECT AID	1,061,757,527	1,111,757,527
DEBT SERVICING LIABILITIES (INTEREST)	50,588,784,807	53,744,362,376
INTEREST ON BUDGETARY SUPPORT FROM GOVT (FUND)	15,776,475,914	23,583,097,892
OTHER LIABILITIES	536,181,341	561,372,970
ASSETS ON INSURANCE FUND		
	177,300,557,621	**191,803,999,575**
CLEARING ACCOUNTS	10,499	-81,191,967
TOTAL CAPITAL & LIABILITIES	**477,838,838,486**	**534,196,561,280**

Source: BPDB Annual Report 2014-2015

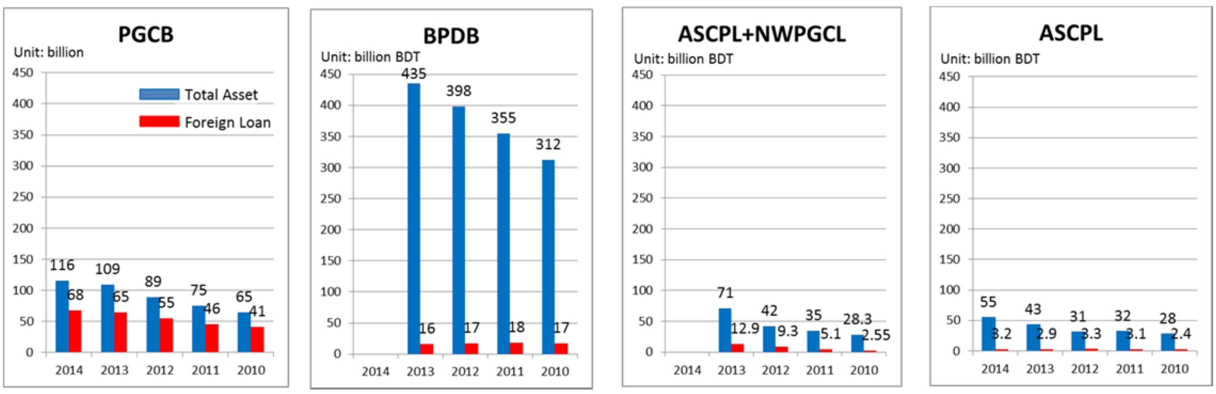
Figure 20-16 illustrates this serious situation of balance sheet of Bangladesh power sector, especially the BPDB (in this figure, the consolidated balance sheet and profit and loss of BPDB and PGCB are illustrated for the sake of inter-utility comparison). EGAT Thailand, sales is very huge to assets. CEB in Sri Lanka, though sales is small to assets, loan with interest remains less than half to its asset, and its retained earning is much better than BPDB. It is very hard to improve balance sheet of BPDB and PGCB at the current amount of sales.



Source: BPDB Annual report, etc.

Figure 20-16 Total Capital & Liabilities

Donors might hesitate to provide loan to BPDB because of this threatening financial situation of BPDB. If we compare the ratio of foreign loan to total asset, the ratio of it for BPDB is very low in comparison with PGCB. Likewise, while APSCL and NWPGCL are attracting foreign donor support of roughly 10% of their assets, foreign donor support that BPDB attracts is less than 5% of their asset, despite its presence to the Bangladesh power sector.



Source: BPDB Annual report, etc.

Figure 20-17 Total Capital & Liabilities

In fact, such issues are already recognized among the government of Bangladesh, according to the article of Financial Express, 29 Aug, 2015, government official commented that they are considering to convert BPDB's large debt into equity. Requisite debt-equity ratio should be 40:60; they must improve their debt-equity ratio promptly. If loan of "Budgetary Support From Govt Against Subsidy (Difference Of Buying & Selling Rate)" is converted into equity, capital and reserve of BPDB increases to 228.4 billion BDT, and its debt-equity ratio improves to 1.34.

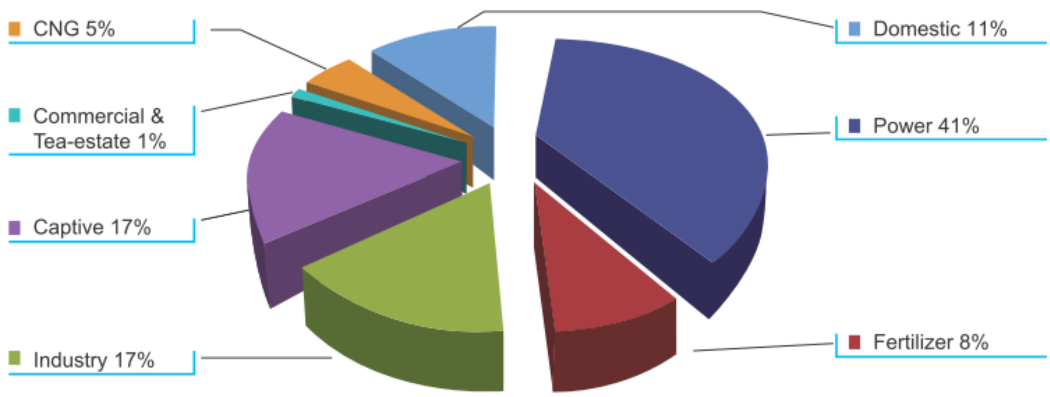
While this proposal may tentatively solve such issues, the situation would continue to worsen if BPDB does not increase its tariff rate, which is further explained in the next section.

20.7 Financial Performance of the Oil & Gas Sector

In Bangladesh, natural gas is under the authority of The Bangladesh Oil, Gas & Mineral Corporation (Petrobangla). Petrobangla also controls mining sector through affiliated companies, which are coal mining company BBCMCL. Oi is under the handling of Bangladesh Petroleum Corporation (BPC).

20.7.1 Petrobangla

Petrobangla is the entity in charge of the country's natural gas sector. Petrobangla not only explores, develops natural gas, coordinates the production, transmission, distribution, and marketing of natural gas resources through subsidiary companies, but also conducts gas exploration activities and take part in production sharing agreements (PSAs) with international oil companies (IOCs) for exploration, development, and production of natural gas. By the end of FY2012, total sales were 795.8 billion cubic feet (BCF), of which the power sector consumed the major share of 41% (see Figure 20-18).



Source: Petrobangla's annual report 2013

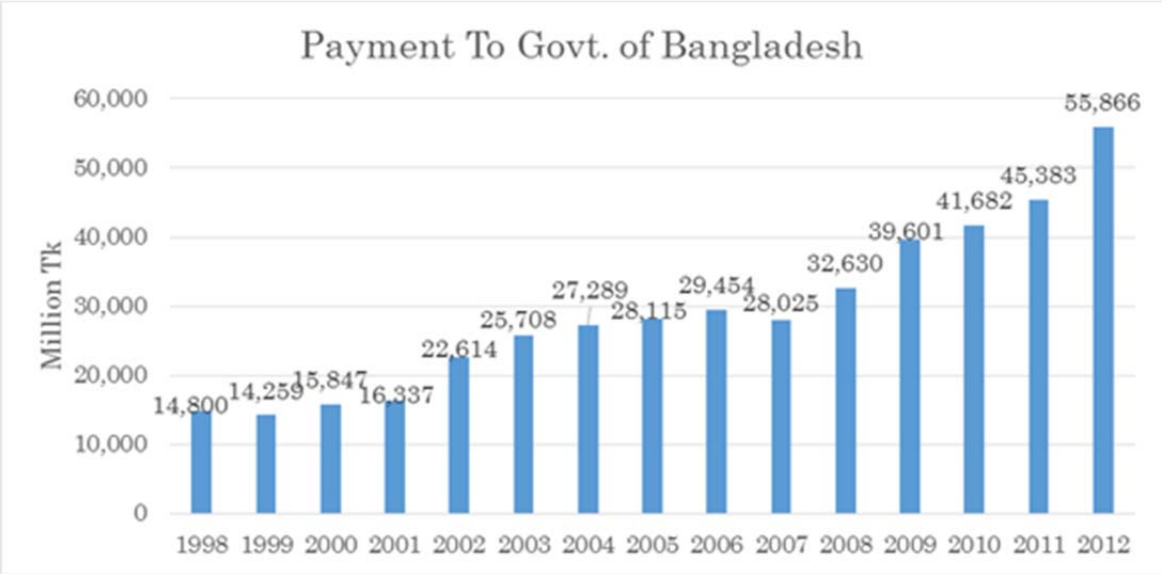
Figure 20-18 Sector Wise Gas Consumption of FY2012

Gas prices for end user are set and approved by BERC. Generally gas prices for the power sector and fertilizer factories that are strongly related to the people's livelihood are set lower while gas prices for industry and the commercial sector are set relatively higher. The revenue from the gas produced by state-owned gas production companies is distributed to the GOB and Petrobangla by 55% and 45% respectively.

For the FY2012, consolidated operating profit of Petrobangla was approximately 29 billion BDT. The gross income from sales of gas, gas derived liquids, coal and hard rock was 254.792 billion BDT, while gross expense, including SD/VAT, interest, depreciation, overhead, margins etc., was 224.796 billion BDT. Pre-tax profit which included miscellaneous income totaled 40.141 billion BDT during the year. After providing for workers participation fund, income tax and dividend paid to the government, the net profit was 21.694 billion BDT for FY2012.

The natural gas sector currently requires no governmental subsidies. In fact, in FY2012, Petrobangla paid to the government of Bangladesh to 55.866 billion BDT.

It must be, however, reiterated that at least 8-10 billion USD might be required for finding and development of untapped domestic gas resource (Gas Sector Master Plan, 2006). It is true that Petrobangla group has earned 40 billion BDT per year, and the accumulation of Gas Development Fund (GDF), set up in 2009 to accelerate the domestic gas resource finding and development, where 15% of gas tariff contribute to the fund, now reaches nearly 50 billion BDT. It is apparent that the current level of Petrobangla's profit and GDF could merely cover one tenth of financial need for the untapped natural gas resources. Moreover, it also has to be reminded that, when substantial LNG import becomes real and the current level of gas retail price remains, an astronomical level of subsidy injection would be required to meet the gas demand.



Source: Petrobangla's annual report 2013

Figure 20-19 Payment to Govt. of Bangladesh from FY1998-2012

Petrobangla is currently contributing to the state revenue, as natural gas price is set by BERC in a way that Petrobangla can recover production cost and generate profits. According to Petrobangla's consolidated balance sheet and income statement (see Table 20-24), Petrobangla generated tax on profit and of 12.748 billion BDT which is an average income tax rate of about 24%. Moreover, Petrobangla group pays dividend at 5,700 million BDT from after tax net profit.
However, as the decrease of share of natural gas in primary energy supply and import of LNG are expected, the natural gas sector will likely need to be subsidized in near future. LNG import is currently being discussed with a view to alleviate the gas supply shortage being faced by existing gas-fired plants.

Table 20-24 Consolidated Income Statement of Petrobangla for FY2012

ITEM HEADING	R. No.	Mil. BDT
SALES:	1	
Gas sales : Inter Group	2	59,084
Gas Sales : End customers	3	116,501
Oil, condensate and other products	4	38,674
PB'S Share of PG	5	23,952
PB'S Share of PC	6	7,235
Supplementary duty & Vat/ Royalty	7	-26,807
Transmission charges, inc line rent	8	5,458
Contributions from Group Companies for exploration	9	485
Successful wells and Fields transferred to Group companies	10	
Management Charge to Co's & Projects	11	361
Other operational income	12	2,042
TOTAL REVENUE (2 To 12)	13	226,985
COST OF SALES	14	
Gas & Condensate purchases : Inter Company	15	79,104
Gas & Condensate purchase from IOC	16	63,848
Contribution to BAPEX for exploration	17	973
Contribution to Gas Development Fund	18	7,280

Unsuccessful exploration	19	
Production cost inc depreciation/depreciation	20	14,500
Transmission charges : Inter Company	21	15,660
Transmission costs, inc depreciation	22	1,728
Distribution cost, inc depreciation	23	1,451
Distribution cost of condensate & other product	24	149
Price Deficit Fund	25	6,836
Group service charges	26	363
Administrative cost/HCDF	27	6,097
TOTAL COST OF SALES (15 To 27)	28	197,988
OPERATIONAL PROFIT (13-28)	29	28,996
Other Income	30	1,640
FINANCIAL COST :	31	
Interest expense	32	784
Less interest income	33	12,427
NET INTEREST (32 -33)	34	-11,643
Translation of exchange rate of loans	35	-1
Intangibles provided for previous year written off	36	
NET PROFIT BEFORE CONTRIBUTION (29+30-34-35-36)	37	42,281
Less Worker's Participation in Profits	38	2,139
NET PROFIT BEFORE TAXATION (37-38)	39	40,141
Tax On Profit	40	12,748
NET PROFIT FOR THE YEAR AFTER TAXATION (39-40)	41	27,394
Add: Profit brought forward from previous year	42	35,438
Add: Profit brought forward from previous year PSC	43	16,745
Add/Deduct: Prior year adjustment	44	-325
DISTRIBUTABLE PROFIT(41 To 44)	45	79,252
Less: Dividend paid	46	5,700
Less: Provision for Deferred Tax	47	-11
BALANCE TRANSFER TO BALANCE SHEET (45-46)	48	73,563

Source: Petrobangla’s annual report 2013

Figure 20-20 Structure of Revenue and Cost

20.7.2 Bangladesh Petroleum Corporation (BPC)

The corporation controls import, refining, storage and marketing of crude and petroleum products with the following affiliated companies: refinery company ERL, lubricant blending ELBL and SAOCL, LPG bottling LPGL, and marketing companies POCL, MPL and JOCL.
Although the domestic prices of petroleum products follow the general trend of world prices, prices in the domestic market are much less volatile than those in the world market. The government absorbs significant portions of the price volatility by providing subsidies on petroleum products. As expected, rising trends in international prices result in a higher import cost for petroleum products in Bangladesh.
The share of furnace oil has experienced a drastic increase, from 5 per cent in FY2009 and FY2009 to 11 per cent in FY2011 and then to 17 per cent in FY2012.
Up until FY2011, BPC had been receiving budgetary support from the government. The amount of

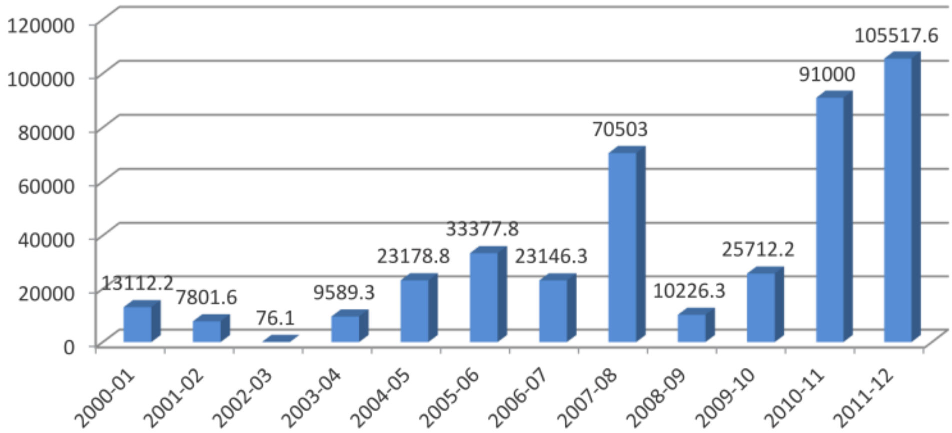
support on petroleum products can be residually estimated by the difference between the import price and the administrative price of different petroleum products in the domestic market. The subsidization of petroleum prices has resulted in significant losses for the BPC's import business.

Table 20-25 Subsidies for Refined Imported Diesel and Furnace Oil

	Sales (million liters)	Per-unit supply cost (bdt/liter)	Selling price (bdt/liter)	Per-unit subsidy (bdt/liter)	Total subsidies (million bdt)
2009-2010					
Diesel	3045.894688	45.22	44	1.22	3715.992
Furnace oil	210.08653	38.00	30	8.002583	1681.235
2010-2011					
Diesel	3841.784894	62	46	16	61468.56
Furnace oil	589.275594	58.33	42	16.33	9622.87
2011-2012					
Diesel	3843.053914	77.45	61	16.45	63218.24
Furnace oil	956.20127	65.13	55	10.13	9686.319

Source: "Energy Subsidies in Bangladesh: A profile of groups vulnerable to reform", IISD 2013

The BPC's operational losses were covered by loans from state-owned commercial banks, direct budgetary transfers and net lending by the government. These loans were provided with an interest rate that was lower than the market rate.



Source: "Energy Subsidies in Bangladesh: A profile of groups vulnerable to reform", IISD 2013

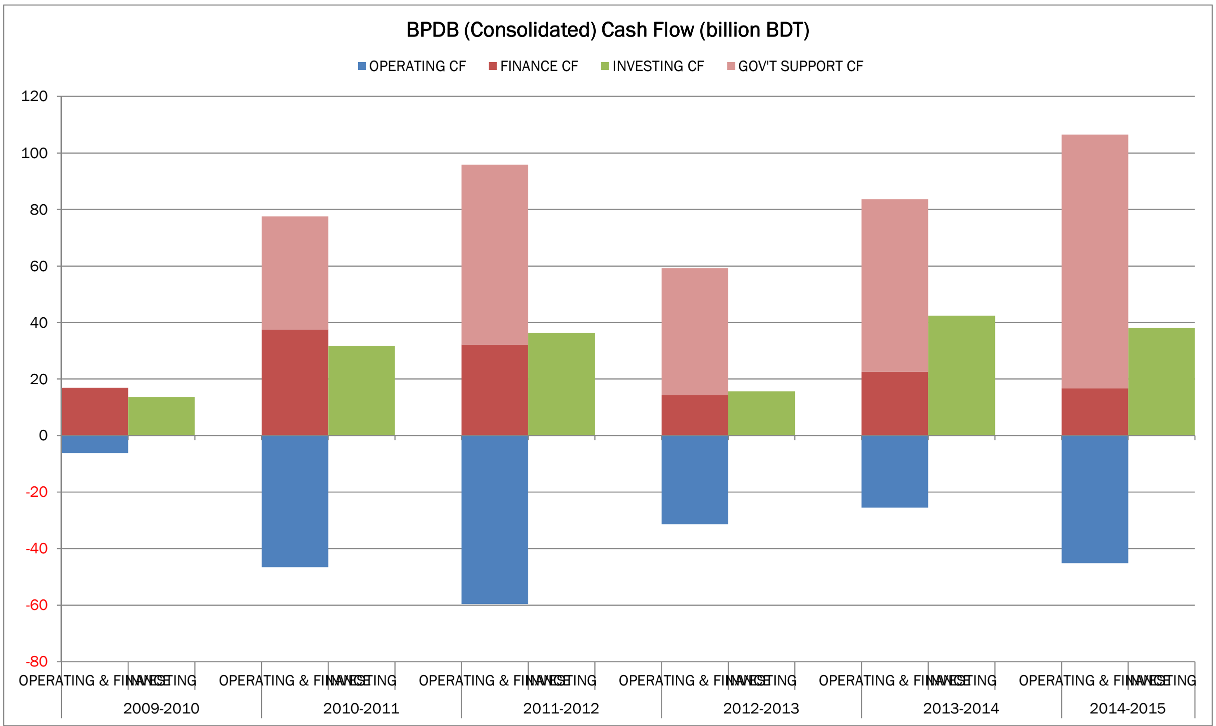
Figure 20-21 Loss Incurred by BPC (Unit: million BDT)

The government also allocates financial resources for the BPC in its annual budgets. These government's budgetary support enabled the BPC to recover its losses resulting from selling petroleum products at prices lower than the import prices.

Chapter 21 Projection of Future Costs of Energy Supply

21.1 Overview of the Costs of Energy Supply

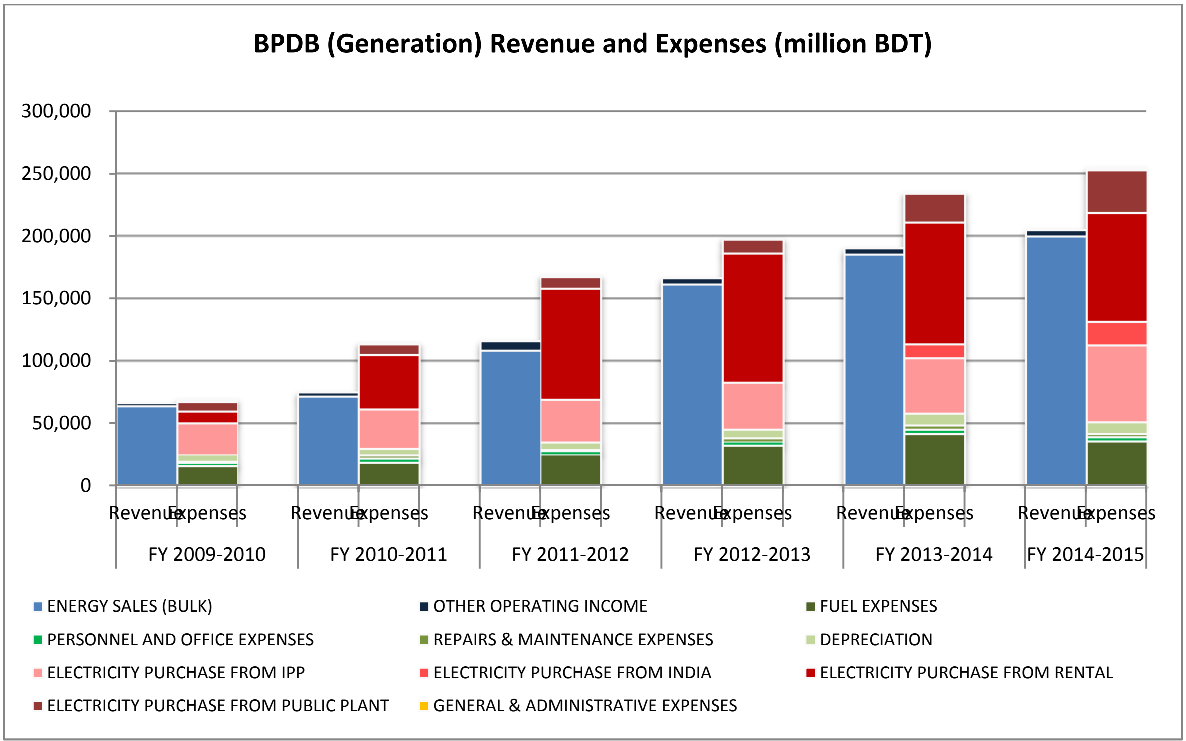
This section analyzes the energy supply cost in Bangladesh, which is heavily subsidized, causing financial deficit in BPDB (such financial situation of the power sector is analyzed in Chapter 22).
Figure 21-1 illustrates the cash flow of BPDB. Its operating cash flow, shown in blue, is of a negative value; BPDB operation itself is in a financial deficit. Such situation is causing a large amount of cash outflow. Considering such situation in BPDB, this section will analyze the energy supply cost of BPDB.



Source: BPDB Annual Reports

Figure 21-1 Cash Flow of BPDB (Consolidated)

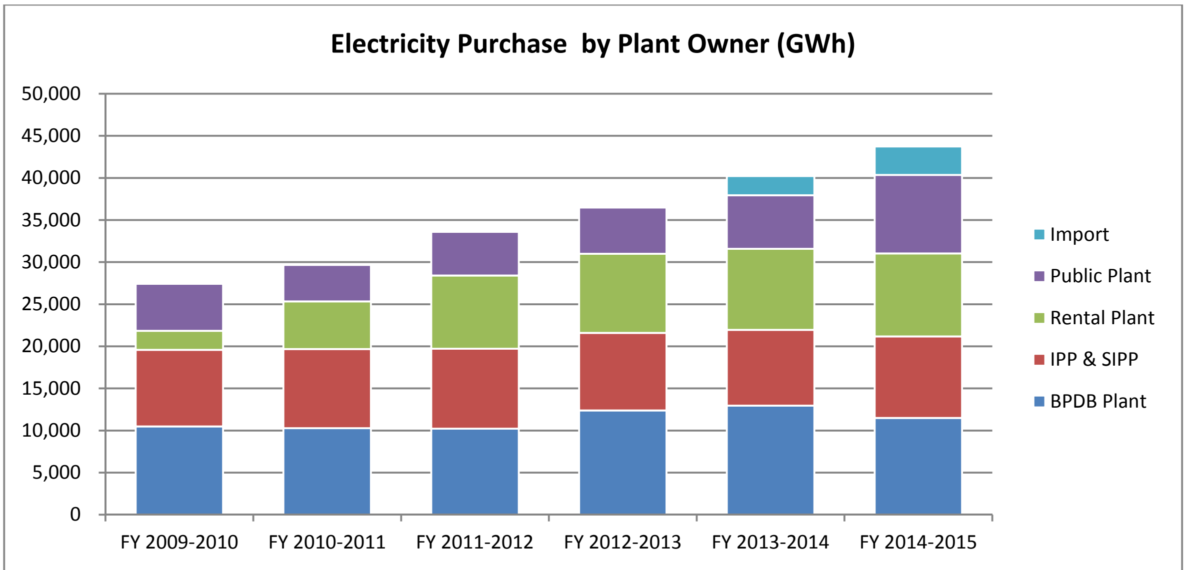
Operating revenue and expenses of the BPDB generation sector, entity that is most in a deficit, is analyzed in the figure below.



Source: BPDB Annual Reports

Figure 21-2 BPDB (Generation) Operation Revenue and Expenses

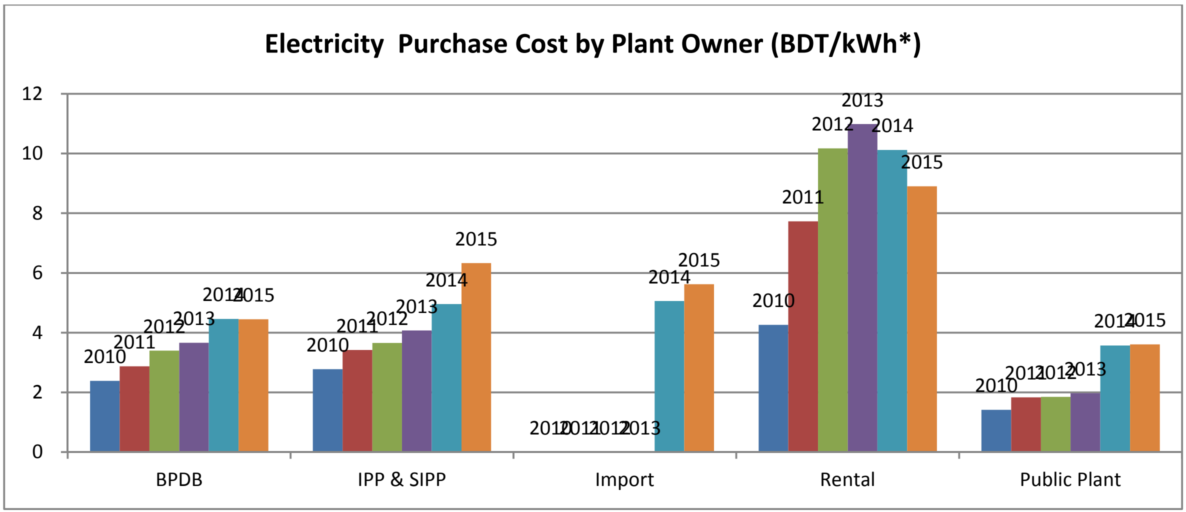
In the past several years, operation expenses in BPDB's generation sector have exceeded its revenue, causing a financial deficit. Most of the operating expenses come from the cost of electricity purchase, shown in red; in FY2014-2015, the portion was as high as 80% of the total operating expenses. The portion of electricity purchase has been increasing as well. Therefore, electricity purchase of BPDB, from the plants of IPP, SIPP, rental, public and import, is further analyzed.



Source: BPDB Annual Reports

Figure 21-3 BPDB Electricity Purchase (by Plant Owner)

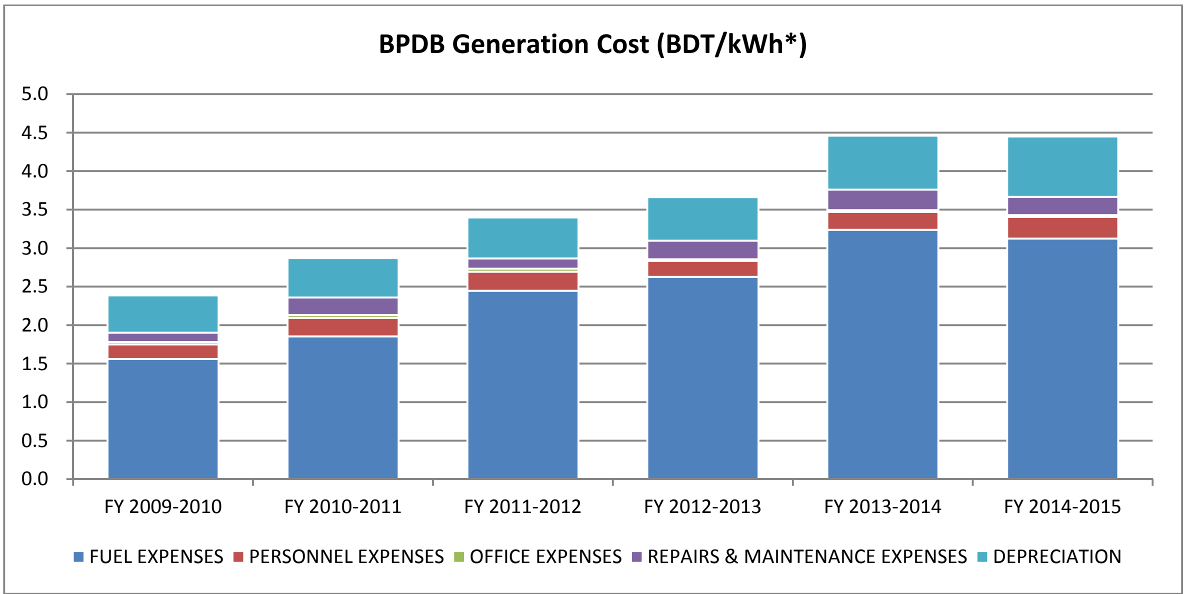
Figure 21-3 illustrates the amount of electricity purchase by BPDB as single buyer (including its own generation). The increase in electricity purchase from rental plants, shown in green, is noticeable.



*per kWh of electricity purchase (net generation for BPDB)
Source: BPDB Annual Reports

Figure 21-4 BPDB Electricity Purchase Cost (by Plant Owner)

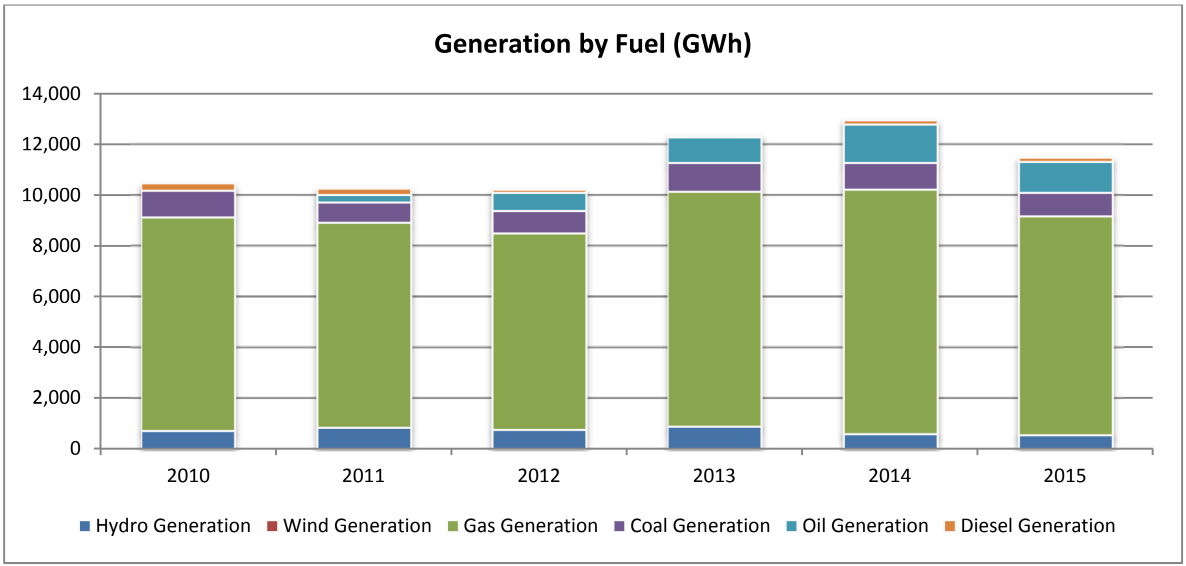
Electricity purchase cost is compared between the types of plant owners in Figure 21-4. The electricity cost of rental plants is significantly higher than the other types of plants; the average electricity purchase cost of rental plants was 8.90 BDT/kWh in FY2014-2015, whereas the average for IPP/SIPP and public plants in the same year was 6.33 BDT/kWh and 3.61 BDT/kWh, respectively. Thus, one of the main contributing factors of increasing electricity cost can be accredited to the increasing electricity purchase from expensive rental plants.
On the other hand, generation cost of BPDB's own power plants is analyzed as well. Increase in generation cost of BPDB's own plants is observable from Figure 21-5.



*per kWh of net generation
Source: BPDB Annual Reports

Figure 21-5 Generation Cost of BPDB's Own Plants

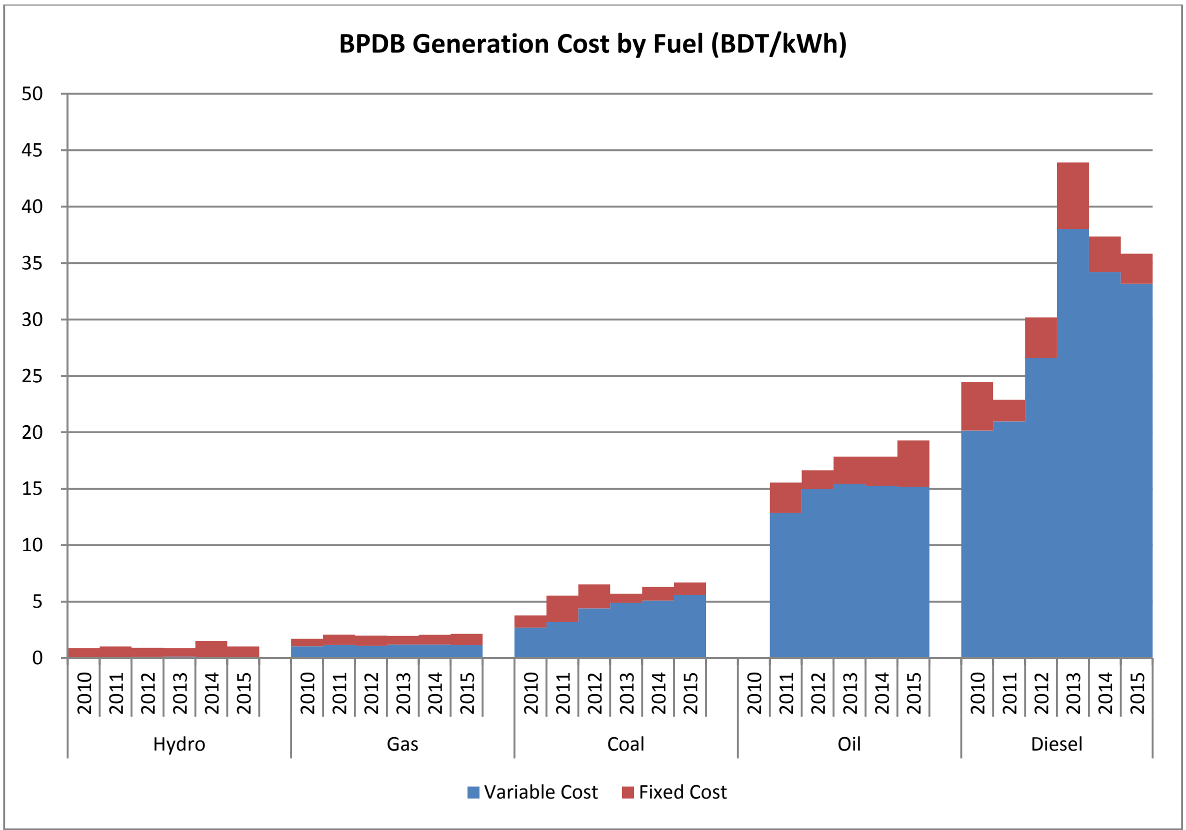
While other costs such as personnel expenses and maintenance expenses have stayed fairly stable, fuel cost, which occupies a large portion of generation cost, is in an increasing trend. Figure 21-6 shows the electricity generation by BPDB in the past several years. While most of the generated electricity comes from gas, the share of oil generation has been increasing in the past few years as well.



Source: BPDB Annual Reports

Figure 21-6 Electricity Generation of BPDB's Own Plants (by Fuel)

Generation cost of each fuel is shown in Figure 21-7. The generation cost of oil and diesel BPDB plants are significantly higher than that of gas, the main source of electricity production in Bangladesh. In FY2014-2015, the generation cost of diesel plants and oil fueled plants was as high as 37.8 BDT/kWh and 19.3 BDT/kWh respectively, whereas the average generation cost of coal and gas fueled plants was 6.7 BDT/kWh and 2.1 BDT/kWh respectively.



*per kWh of net generation
Source: BPDB Annual Reports

Figure 21-7 Generation Cost of BPDB's Own Plants (by Fuel)

In the future, coal-fueled plants will gain higher proportion in the generation mix, and gas fuel cost will become more expensive than today's standard. In addition to this, if electricity generation from oil continues its increasing trend in the future, increase in BPDB's overall generation cost will be inevitable.

In order to mitigate such rising fuel prices and overall generation cost, higher thermal efficiency in power plants will be necessary. According to BPDB's annual report from FY2015, the current average of thermal efficiency in power plants is 33.29% in the public sector.

21.2 Parameters for Estimating the Future Costs of Supply

21.3 Results of Cost Estimation

Chapter 22 Energy Tariff Policy and Impact on National Economy

22.1 Methodologies of the Analysis

In this research, the GTAP model is utilized as the computable general equilibrium model that analyzes impacts of macro economy caused by various policy related to energy and electric power sector, in particular increase of natural gas price and electricity tariff.
The GTAP model is a computable general equilibrium model (CGE model) developed based on the general equilibrium theory of micro economics. This model was created by Professor Hertel at Purdue University in 1992 aimed at impact analysis on tariff reduction or elimination, which covers the whole world.
The data concerning the GTAP model is updated every few years. The latest version at the present is the GTAP DATA BASE 8 based on the global economic data in 2007, which categorizes the whole world into 134 regions and 57 industries. This version became public in 2012, and it contains detailed categories of Asian and African countries. The database consists of data in American dollars.
Since the GTAP model has spread internationally and is considered reliable, it is being used by international organizations such as the World Bank and OECD and research institutes of many countries.
By using the GTAP model, future forecasts have become possible based on exogenous conditions. The primary exogenous variables of the GTAP are population (total population/labor population), tax ratio (such as a ratio of tariff), productivity, capital, and so on. Endogenous variables include various items such as GDP, the amount of trade (by industries/countries), output (by industries), private consumption (by products), and so on. Therefore, it is possible to forecast economies by setting population (total population/labor population) and productivity as well as GDP of countries and regions other than the Indian Ocean Rim Association (such as Japan, China, America, and the EU) as exogenous conditions. Besides, it is also possible to forecast multiple scenarios by changing exogenous conditions.

22.2 Scenario Setting

22.2.1 Single-year analysis

To analyze economic impact of gas price and electricity tariff increase on national economy of Bangladesh, first we analyses impact in current year only (single-year analysis). We analyzed the impact of price increase in 2014, the latest data set can be achieved.

For gas price, we set the following scenarios:
Scenario (a): average electricity tariff increase 50%
Scenario (b): average electricity tariff increase 100%

For electricity price, we set the following scenarios:
Scenario e (a): average electricity price increase 10%
Scenario e (b): average electricity price increase 20%
Scenario e (c): average electricity price increase 30%

In Bangladesh, electricity price for final consumer are different from the size of usage. However, as the methodological limitation of GTAP analysis, we have to set one average price for analysis.

We used the following model for GTAP analysis.
Category of area: Bangladesh, Asian countries, other countries in the other region.
Category of sector: Agriculture, electricity, industry, service.

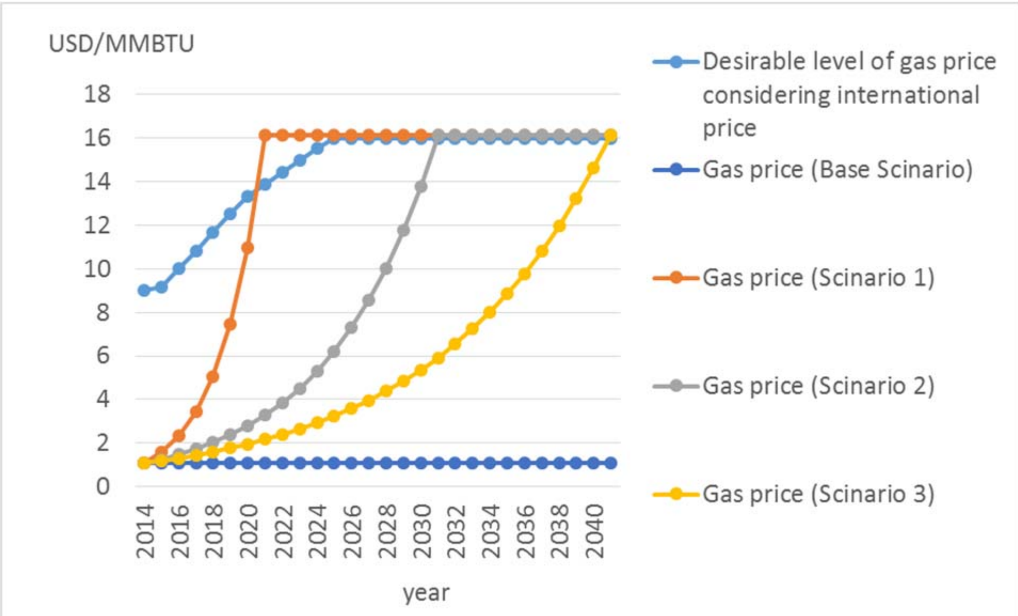
22.2.2 Time series analysis

For analysis of economic impact from 2014 to 2041, we set scenarios about increase of gas prices and electricity tariff

For gas price, we set the following scenarios for analysis. Scenario 1 is set as gas price increase to desirable level of gas price considering international price progressively by 2021, scinario 2 is by 2031, and scinario 3 is by 2041.

Table 22-1 Scenarios of Gas Price Increase

Scenario	Annual Increase of Gas Price in USD
Base Scinario	**0%**
1	**47.2% by 2021** **0% from 2022**
2	**17.3% by 2031** **0% from 2032**
3	**10.6% by 2041**



Source: Estimation by JICA Survey Team

Figure 22-1 Scenario of Increase of Gas Price

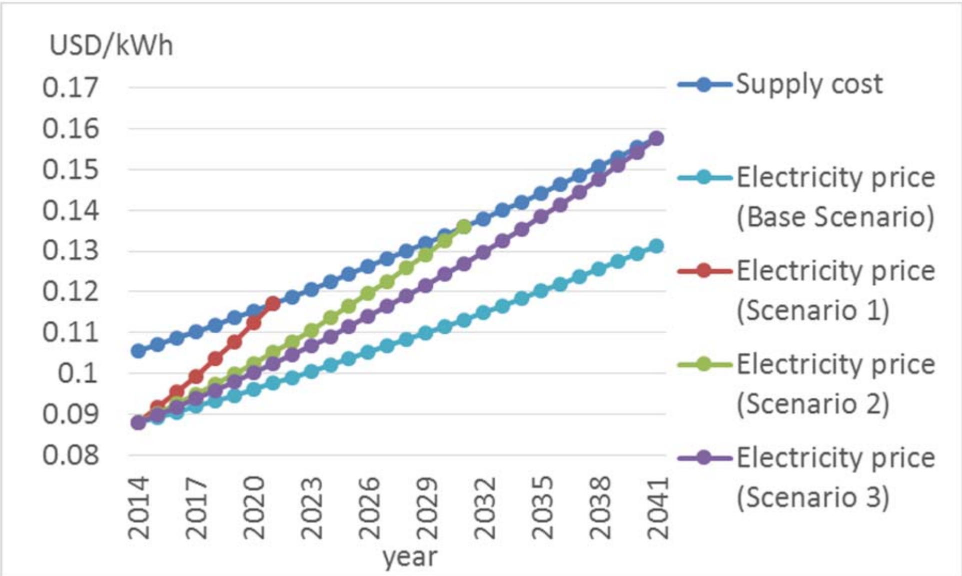
For electricity price, under the assumption that cost of electricity generation increases at 1.5% annually and analyze the impact on macro economy of Bangladesh. Scinario 1 is set as electricity tariff become equal to supply cost by 2021, scinario 2 is by 2031, and scinario 3 is by 2041.

Table 22-2 Scenarios of Electricity Tariff Increase: pattern 1 (cost increase)

Scenario	Annual Increase in USD
Increase of Cost	1.5%
Base Scinario	1.5%
1	4.2% by 2021 1.5% from 2022
2	2.6% by 2031 1.5% from 2032
3	2.2% by 2041

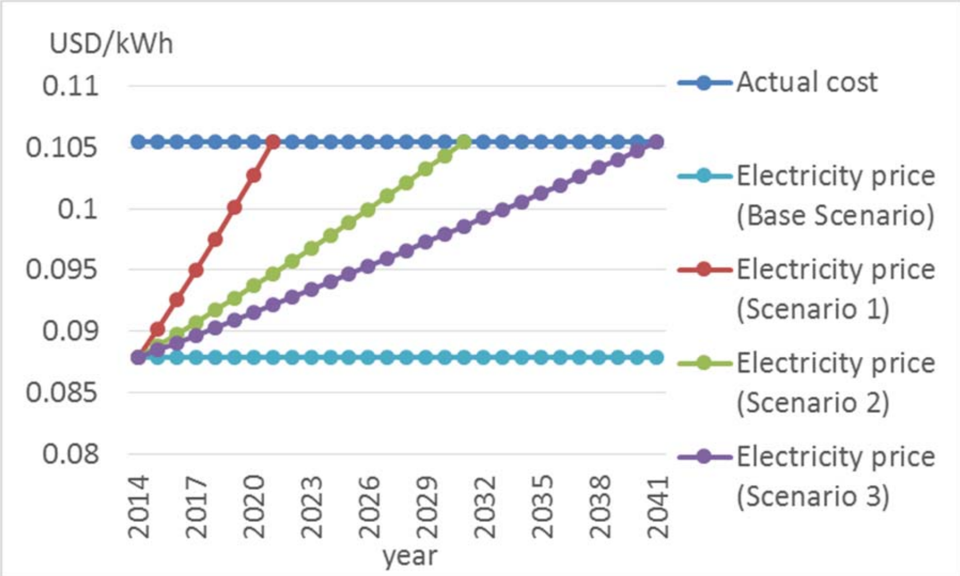
Table 22-3 Scenarios of Electricity Tariff Increase: pattern 2 (no cost increase)

Scenario	Annual Increase in USD
Increase of Cost	0%
Base Scinario	0% + minor fluctuation in the model calculation
1	2.6% by 2021 0% + minor fluctuation in the model calculation from 2022
2	1.1% by 2031 0% + minor fluctuation in the model calculation from 2032
3	0.7% by 2041



Source: Estimation by JICA Survey Team

Figure 22-2 Scenario of Increase of Electricity Tariff (Pattern 1)



Source: Estimation by JICA Survey Team

Figure 22-3 Scenario of Increase of Electricity Tariff (Pattern 2)

The model for GTAP analysis is same as single-year analysis
Category of area: Bangladesh, Asian countries, other countries in the other region.
Category of sector: Agriculture, electricity, industry, service.

22.3 Impacts on Bangladesh National Finance

22.3.1 Impacts of gas price increase on Bangladeshi national economy (single year analysis)

The result of GTAP analysis for increase of gas price is summarized in Table 22-4 to Table 22-6. 50% increase of electricity tariff decreases real GDP by 1.26% (USD 1407.9 million). 100% increase decreases 2.47. In comparison of GDP current growth, this amount might be large.
According to the result of sectoral analysis, shown in Table 22-5 and Table 22-6, in terms of production, about 0.5 to 2.9% negative impact on each sectors other than oil by 50% increase of gas prices. For private sector's consumption, about 0.8 to 8.6% negative impact on each sector by 50% increase of gas prices. Regarding impact on import and export, import of gas become increase significantly by increases of domestic gas prices.

Table 22-4 Impacts of Electricity Tariff Increase on Bangladesh National Economy (single year analysis)

	(a) 50% Increase		(b) 100% Increase	
	Change ratio (%)	Change amount (million USD)	Change ratio (%)	Change amount (million USD)
Impact on real GDP	-1.26	-1407.9	-2.47	-2759.1
Impact on real export	-0.72	-204.7	-1.35	-382.8
Impact on real import	-1.36	-472.6	-2.70	-937.7

Table 22-5 Impacts of Electricity Tariff Increase on Each Sector

	Production		Private sector's consumption	
	(a) 50% Increase	(b) 100% Increase	(a) 50% Increase	(b) 100% Increase
Agricultural sector	-0.53	-1.04	-0.81	-1.59
Coal sector	-0.48	-1.03	-1.13	-2.22
Oil sector	0.25	0.49	-1.42	-2.78
Gas sector	-2.92	-5.40	-8.56	-14.47
Electricity sector	-2.28	-4.33	-4.08	-7.60
Industrial sector	-1.49	-2.93	-1.12	-2.19
Service sector	-1.15	-2.26	-1.41	-2.73

Table 22-6 Impacts of Electricity Tariff Increase on Each Sector

	Real export		Real import	
	(a) 50% Increase	(b) 100% Increase	(a) 50% Increase	(b) 100% Increase
Agricultural sector	8.18	16.90	-5.28	-10.22
Coal sector	5.25	10.13	-2.45	-4.71
Oil sector	3.42	6.88	-1.5	-2.94
Gas sector	0	0.00	39,184	606,589
Electricity sector	-57.23	-79.29	49.18	110.79
Industrial sector	-1.46	-2.86	-0.74	-1.53
Service sector	5.1	10.67	-3.49	-6.93

22.3.2 Impacts of electricity tariff increase on Bangladeshi national economy (single year analysis)

The result of GTAP analysis for increase of electricity tariff is summarized in Table 22-7 to Table 22-9. 10% increase of electricity tariff decreases real GDP by 0.72% (USD 810.7 million). 20% increase decreases 1.45% and 30% increase decrease 2.17%. In comparison of GDP current growth, this amount might be large. Contrary, impact on real export and real import seem to be slightly smaller than impact on real GDP.

According to the result of sectoral analysis, shown in Table 22-8 and Table 22-9, in terms of production, about 0.2 to 0.4% negative impact on each sectors by 10% increase of electricity tariff. For private sector's consumption, about 0.6 to 1% negative impact on each sector by 10% increase of electricity tariff. Effect on import and export is also significant. The amount of electricity export and import are small therefore impact on export and import are small even though change ratio looks large.

Table 22-7 Impacts of Electricity Tariff Increase on Bangladesh National Economy (single year analysis)

	(a) 10% Increase		(b) 20% Increase		(c) 30% Increase	
	Change ratio (%)	Change amount (million USD)	Change ratio (%)	Change amount (million USD)	Change ratio (%)	Change amount (million USD)
Impact on real GDP	-0.72	-810.7	-1.45	-1618.6	-2.17	-2424.0
Impact on real export	-0.28	-79.3	-0.56	-157.7	-0.83	-235.1
Impact on real import	-0.27	-94.7	-0.55	-189.5	-0.82	-284.2

Table 22-8 Impacts of Electricity Tariff Increase on Each Sector

	Production			Private sector's consumption		
	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase
Agricultural sector	-0.21	-0.43	-0.65	-0.59	-1.18	-1.76
Electricity sector	-0.42	-0.77	-1.08	-2.56	-4.92	-7.1
Industrial sector	-0.27	-0.54	-0.81	-0.69	-1.37	-2.05
Service sector	-0.36	-0.72	-1.07	-0.98	-1.95	-2.91

Table 22-9 Impacts of Electricity Tariff Increase on Each Sector

	Real export			Real import		
	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase
Agricultural sector	2.51	5.08	7.71	-1.67	-3.31	-4.93
Electricity sector	-41.33	-63.78	-76.71	33.21	73.37	121.24
Industrial sector	-0.5	-1.00	-1.5	-0.05	-0.10	-0.16
Service sector	1.41	2.85	4.32	-1.3	-2.59	-3.87

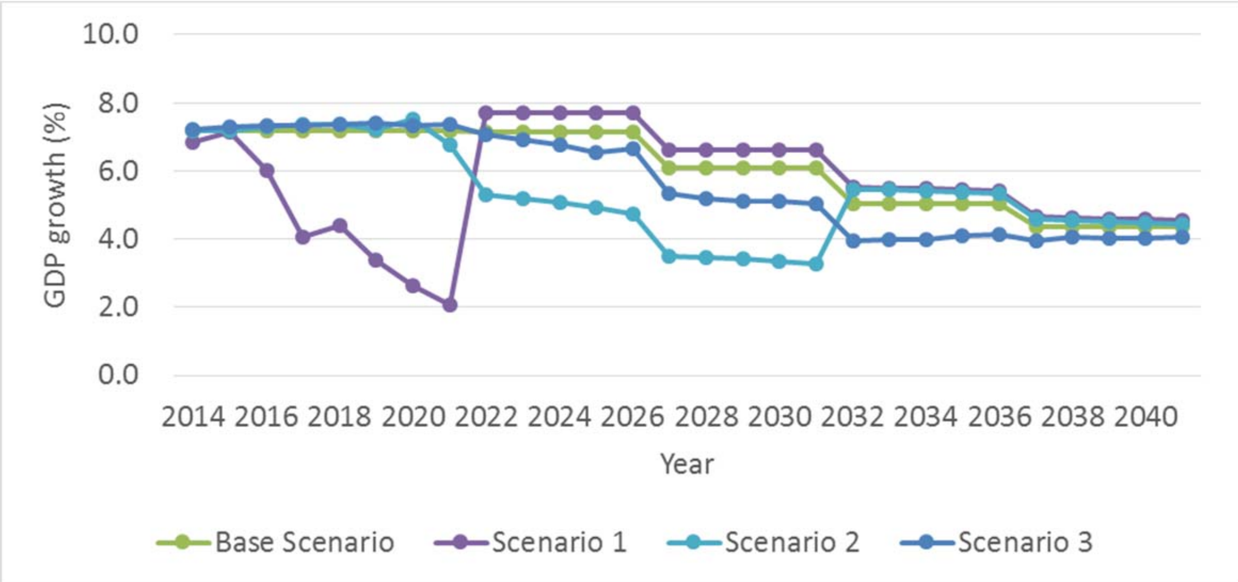
22.3.3 Impacts of gas price increase on Bangladeshi national economy (time series analysis)

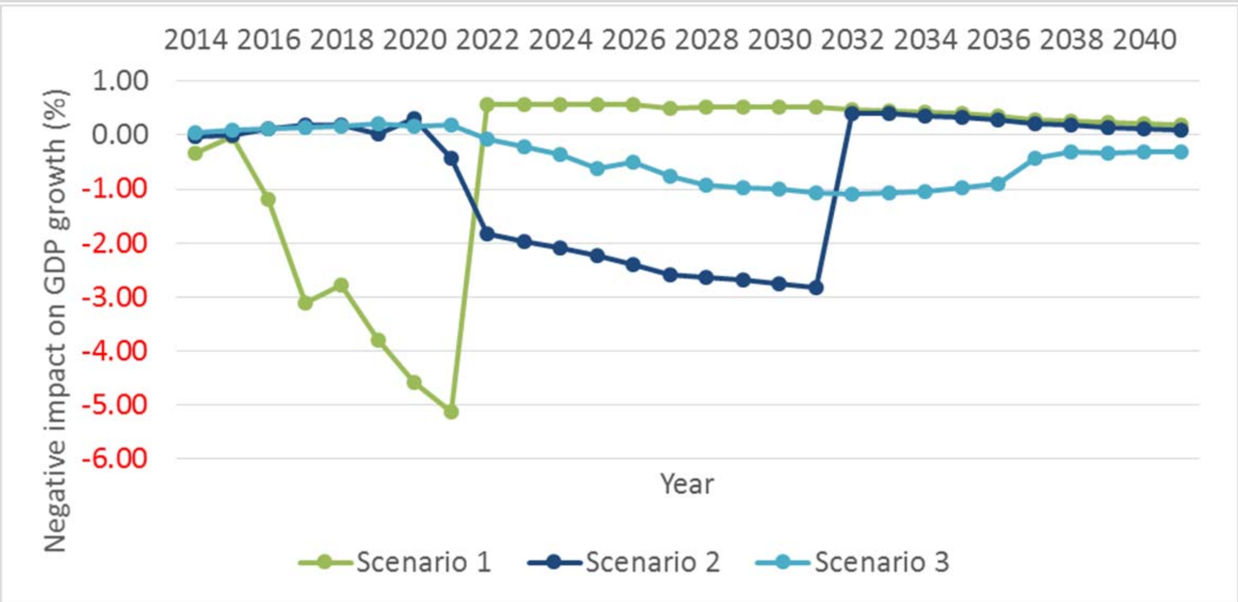
The result of GTAP analysis is summarized in Table 22-11. Gas price decrease 5.13% in 2021 in Scenario 1, decrease 0.2.82% in 2031 in Scenario 2. The negative impact in scenario 1 and 2 might be huge. On the other hand, negative impact in Scenario 3 is less than 1.1%.

Table 22-10 Impacts of Gas Price Increase on Bangladesh National Economy

	2014	2021	2031	2041
Scenario 1	-0.33	-5.13	0.52	0.18
Scenario 2	-0.02	-0.43	-2.82	0.09
Scenario 3	0.04	0.19	-1.08	-0.32

Source: Estimation by JICA Survey Team





Source: Estimation by JICA Survey Team

Figure 22-4 Impacts of Gas Price Increase on Bangladesh National Economy

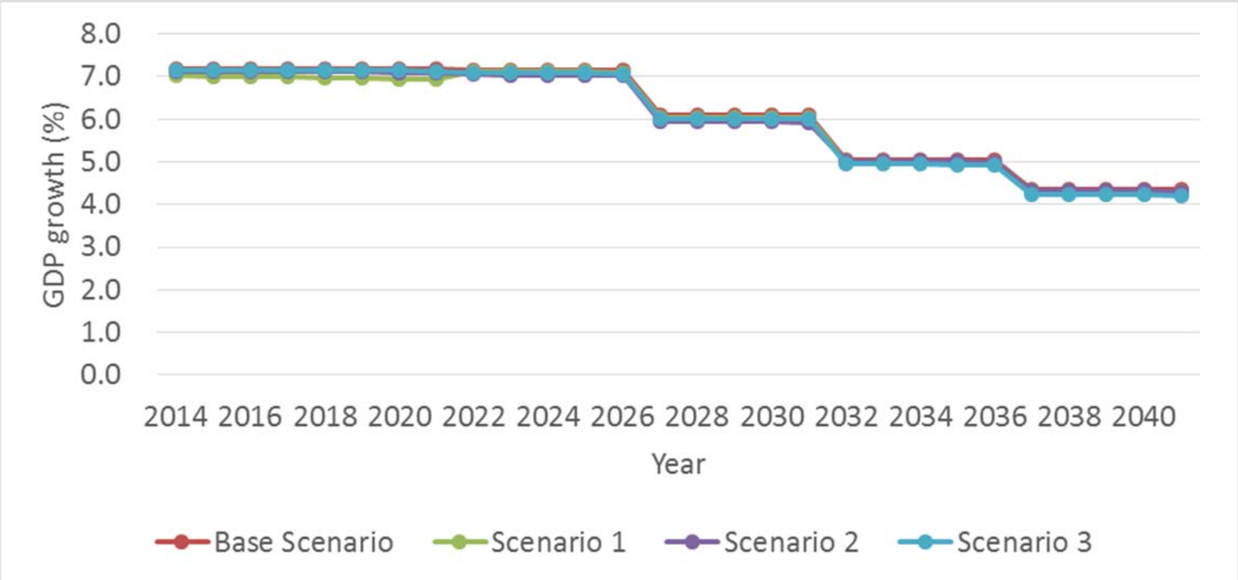
22.3.4 Impacts of electricity tariff increase on Bangladeshi national economy (time series analysis)

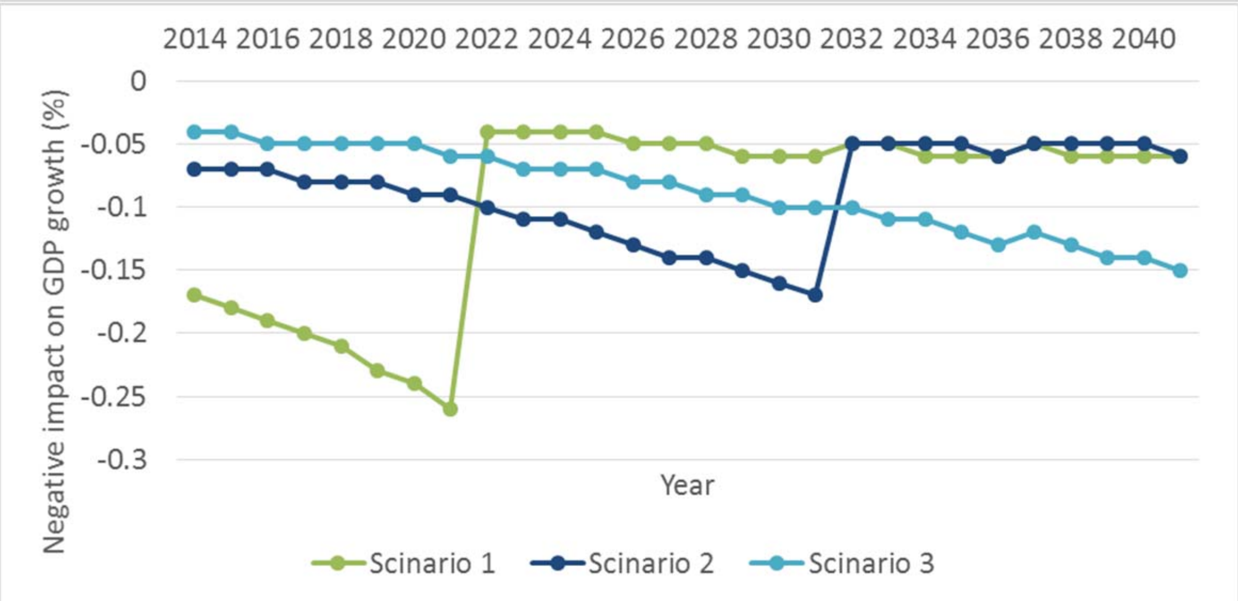
The result of GTAP analysis is summarized in Table 22-11. Electricity tariff decrease 0.27% in 2014 in Scenario 1, electricity tariff decrease 0.17% in 2014 in Scenario 2, and electricity tariff decrease 0.14% in 2014 in Scenario 3. Negative impact on GDP is mitigated as compared with sharp rise in single year analysis.

Table 22-11 Impacts of Electricity Tariff Increase on Bangladesh National Economy (pattern 1)

	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.06	-0.06
Scenario 2	-0.07	-0.09	-0.17	-0.06
Scenario 3	-0.04	-0.06	-0.1	-0.15

Source: Estimation by JICA Survey Team





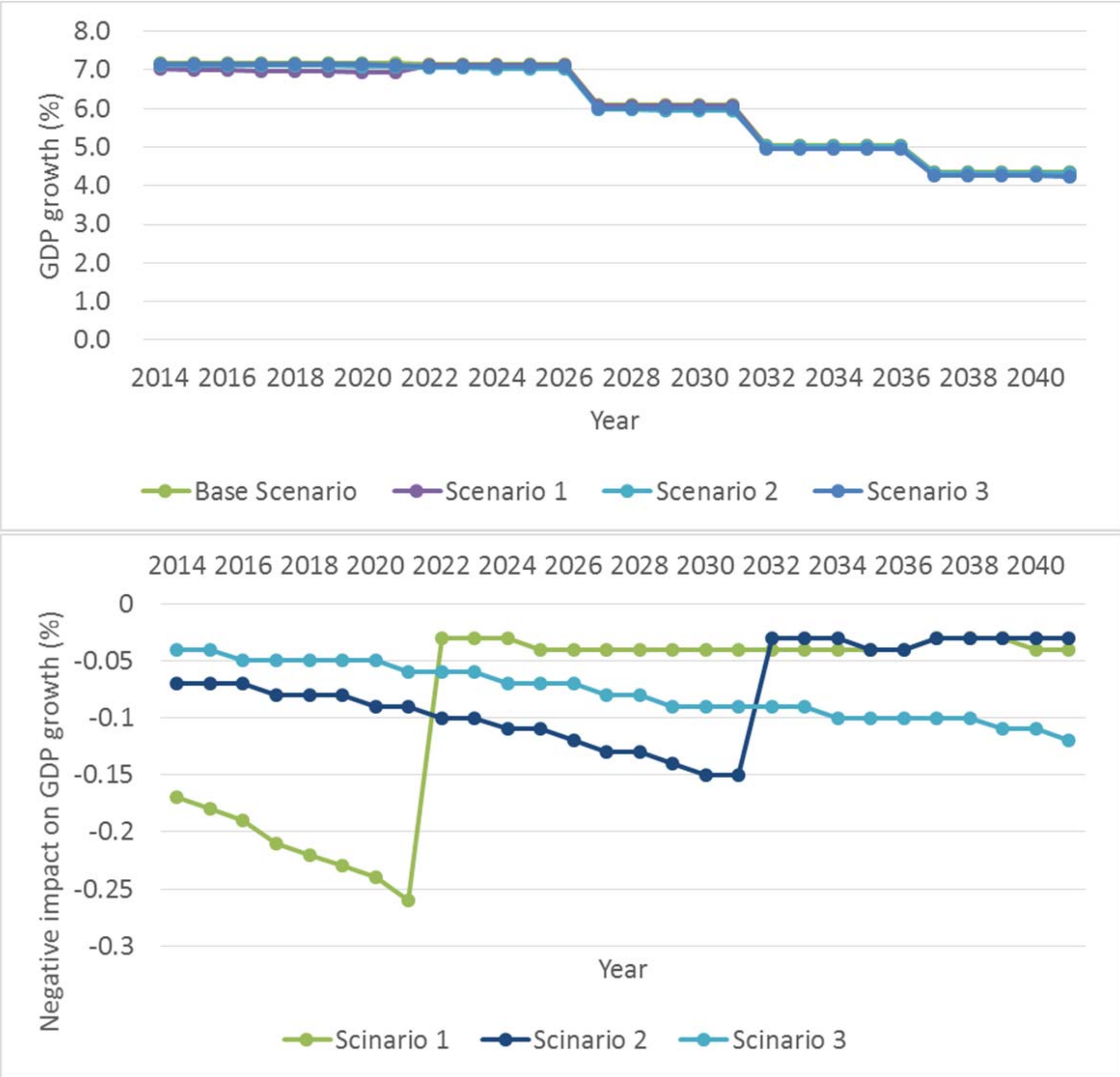
Source: Estimation by JICA Survey Team

Figure 22-5 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Pattern 1)

Table 22-12 Impacts of Electricity Tariff Increase on Bangladesh National Economy (pattern 2)

	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.04	-0.04
Scenario 2	-0.07	-0.09	-0.15	-0.03
Scenario 3	-0.04	-0.06	-0.09	-0.12

Source) Estimation by JICA Survey Team



Source: Estimation by JICA Survey Team

Figure 22-6 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Pattern 2)

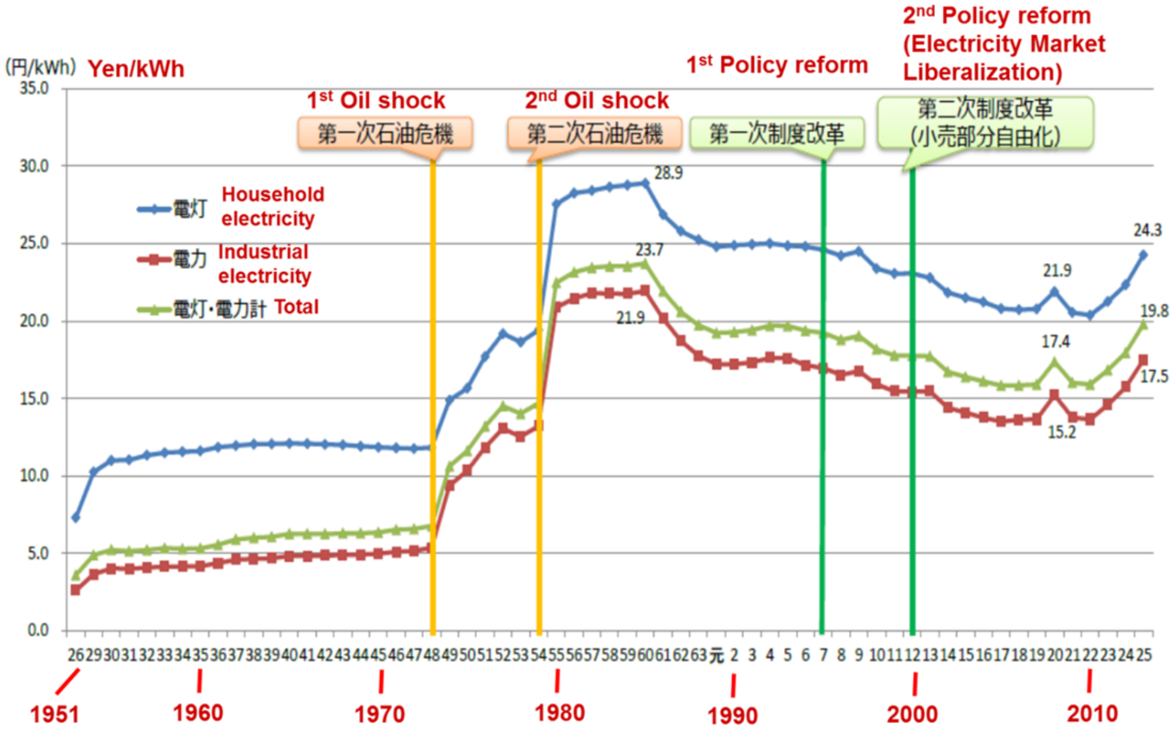
22.4 Policy Recommendations on Increase of Electricity Tariff

22.4.1 Gas Price Reform

As mentioned in previous chapter, increase of natural gas price might give huge negative impact on Bangladesh national economy. According to the demand increase of gas, Bangladesh have to import more natural gas. If Bangladesh cover the gap between domestic gas price and international gas price by subsidy, financial deficit of Bangladesh government will be expanded.
Bangladesh should increase domestic natural gas price gradually. In consideration of huge negative impact, continuous annual increase of 10 to 20% would be suitable for Bangladesh.

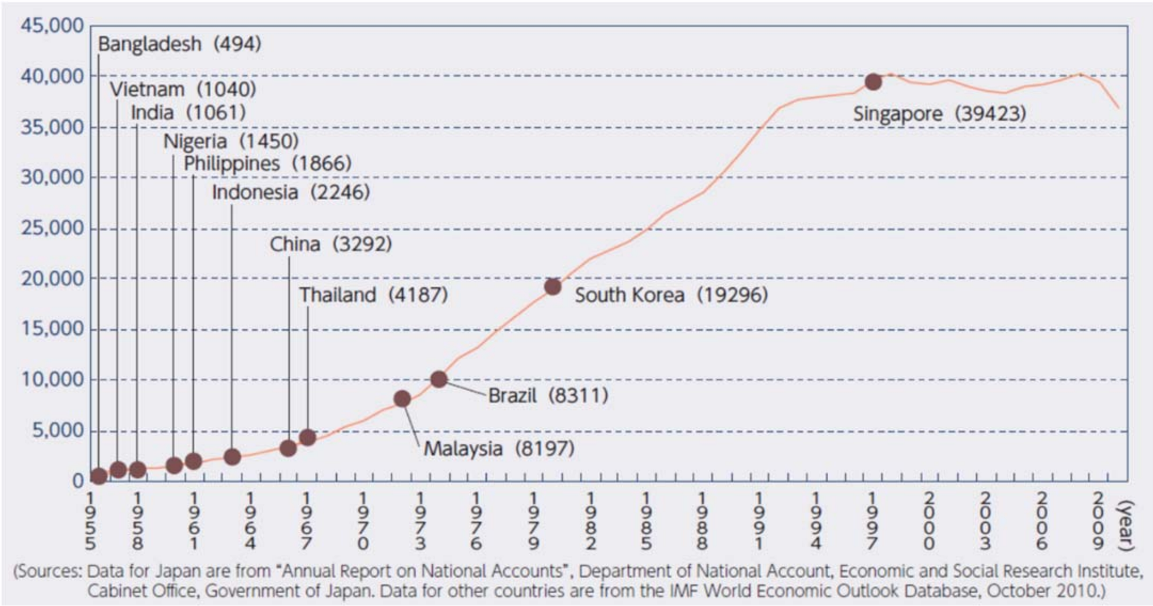
22.4.2 Electricity Tarrif Reform

According to the 22.2 Projection of Financial Balances of the Power Sector, we found that BPDB is in serious budgetary situation. Hence planning of increment of electricity tariff and securing the budget to cover the gap of tariff and supply cost is indispensable. Subsidy provided to BPDB should be cut and also Bulk rate also should be increased accordingly to cover whole supply cost.
However, the result of GTAP analysis, in particular the result of single year analysis, showed that increase of electricity tariff has a negative effect on national economy in Bangladesh. Even in Japan, the electricity tariff has been kept in stable during the economic development stage, namely in 1950's and 1960, and this contributes to the rapid economic development in Japan.



Source: Agency for Natural Resources and Energy, Japan

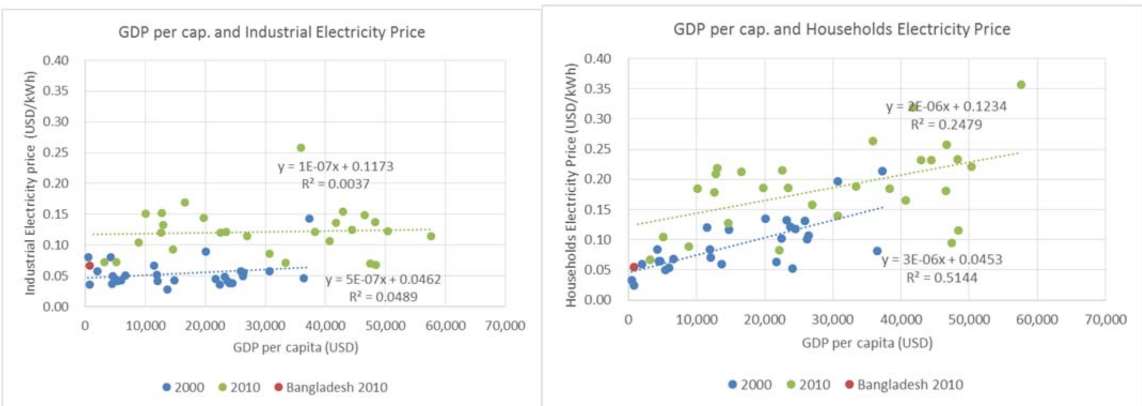
Figure 22-7 Historical Trend of Electricity Tariff in Japan



Source: Ministry of the Environment, Japan, "White Paper, Annual Report 2011"

Figure 22-8 Historical Trend of GDP per Capita in Japan

Also, Bangladesh electricity tariff is currently low in comparison with the other developing countries, but not too much lower then them. Figure 22-9 shows the relation between GDP per capita and electricity tariff in OECD countries except Nordic countries, Switzerland and Luxemburg, and major Asian countries such as China, India, Indonesia, Singapore, Thailand, and Bangladesh. There seems to be no relation between GDP per capita and industrial electricity tariff. In date in 2000, there is a positive correlation between GDP per capita and households electricity tariff (correlation coefficient is 0.72, p=0.000). This means that household's electricity tariffs should be increased in accordance with economic development to cover full supply cost. As indicated in Table 22-13, the current household electricity tariff in Bangladesh is half as those in Thailand.



*GDP per capita is nominal amount using OECD exchange rate.
Source: IEA Energy prices and taxes 2008 and 2012, and BERC

Figure 22-9 GDP per Capita and Electricity Tariff

Table 22-13 GDP per Capita and Electricity Tariff

Unit: USD/kWh

	Industry				Household			
	2000		2010		2000		2010	
	GDP per cap (2000)	Industry Electricity Tariff (2000)	GDP per cap (2010)	Industry Electricity Tariff (2010)	GDP per cap (2000)	Households Electricity Tariff (2000)	GDP per cap (2010)	Households Electricity Tariff (2010)
Australia	21,665	0.045	51,846		21,665	0.063	51,846	
Austria	24,517	0.038	46,660		24,517	0.118	46,660	0.258
Belgium	23,207	0.048	44,383	0.125	23,207	0.132	44,383	0.232
Canada	24,032	0.038	47,464	0.070	24,032	0.053	47,464	0.095
Chile	5,229		12,785	0.152	5,229		12,785	0.209
Czech Rep.	5,995	0.043	19,764	0.144	5,995	0.054	19,764	0.186
Denmark	30,744	0.058	57,648	0.114	30,744	0.197	57,648	0.356
Estonia			14,641	0.093			14,641	0.127
France	22,466	0.036	40,706	0.107	22,466	0.102	40,706	0.165
Germany	23,719	0.041	41,788	0.136	23,719	0.121	41,788	0.319
Greece	12,076	0.042	26,919	0.114	12,076	0.071	26,919	0.158
Hungary	4,620	0.049	13,009	0.133	4,620	0.065	13,009	0.219
Ireland	26,236	0.049	48,261	0.137	26,236	0.101	48,261	0.233
Israel			30,736	0.086			30,736	0.140
Italy	20,059	0.089	35,878	0.258	20,059	0.135	35,878	0.263
Japan	37,300	0.143	42,909	0.154	37,300	0.214	42,909	0.232
Korea	11,948	0.052	22,151		11,948	0.084	22,151	0.083
Mexico	6,650	0.051	8,851	0.104	6,650	0.068	8,851	0.089
Netherlands	25,921	0.057	50,341	0.123	25,921	0.131	50,341	0.221
New Zealand	13,641	0.028	33,394	0.071	13,641	0.060	33,394	0.188
Poland	4,493	0.037	12,598	0.120	4,493	0.065	12,598	0.179
Portugal	11,502	0.067	22,540	0.120	11,502	0.120	22,540	0.215
Slovak Rep.	5,403	0.042	16,555	0.169	5,403	0.050	16,555	0.213
Slovenia			23,439	0.121			23,439	0.186
Spain	14,788	0.043			14,788	0.117		
Turkey	4,215	0.080	10,112	0.151	4,215	0.084	10,112	0.184
UK	26,401	0.055	38,293	0.121	26,401	0.107	38,293	0.184
US	36,450	0.046	48,374	0.068	36,450	0.082	48,374	0.116
China	955		4,515		955		4,515	
India	452	0.080	1,388		452	0.033	1,388	
Indonesia	780	0.036	3,125	0.072	780	0.025	3,125	0.067
Singapore	23,793		46,570	0.148	23,793		46,570	0.181
Thailand	2,016	0.057	5,112	0.072	2,016	0.060	5,112	0.105
Bangladesh	407		760	0.067	407		760	0.054

Source: IEA Statistics, Energy Prices and Taxes, 2008, 2012

Then we recommend Bangladesh to increase tarrif to decrease subsidy to BDBP and cover whole supply cost. In pariclar, household electricity tariff is target for increase of tarrif.

Howeve, rapid annual increase of tarrif gives huge negative impact on Bangladesh economy. In the previous session, we highlighted if Bangladesh increase the tariff progressively, negative impact on Bangladesh economy becomes relatively small. Therefere we recommend Bangladssh to increase domescic tarrif progressibly. Decision about how tariffs should be increased depends on the preference of Ministry of Planning, Bangladesh. However, increse of pricies of basic commodities such as electricity put huge burden on lower income peolle. Therefore as indincated in the following table, keep the price increase in the lowest category in domestic electiricy utility as same as natural cont increase (e.g. 1.5%). For the other castegories, increase tarrif according to the scenario (e.g. 2.6% increase by 3031 and 1.5% after 20032). The increase of electricity tariff in other industril and commpercial category depends are related to the other pindustrial policyes. Hoewver, we recommend to increase it as much as possible to improve financial situation of BPDB.

Table 22-14 Draft idea of Increase of Electricity Tariff

CONSUMER CATEGORY	RANGE (KWH)	BDT/Kwh SEPT 2015	Senario of price increase
Domestic-A	1-50	3.33	Keep minimum increase (e.g. annual 1.5% increase)
	1–75	3.53	
	76–100	5.01	Increase according to the scenario. (e.g annual 2.6% increase by 2031, annual 1.5% increase after 2032) ＋the amount cover the price cost gap of lower catergories
	101–		
	201–	5.19	
	301–	5.42	
	401–	8.51	
	Above	9.93	
Agricultural pumping-B	Flat	2.51	Keep minimum increase (e.g. annual 1.5% increase) or according to the scenario.
Small industry category-C	Flat	7.42	Increase according to the scenario. (e.g annual 2.6% increase by 2031, annual 1.5% increase after 2032)
	Peak	6.64	
	Off peak	9.00	
Non-residential category-D		4.98	
Commercial category-E	Flat	9.58	
	Off peak	8.16	
	Peak	11.55	
Medium Voltage 11 KV General Category-F	Flat	7.32	
	Off peak	6.62	
	Peak	9.33	
Extra High Voltage Category (132KV) G	Flat	6.96	
	Off peak	6.35	
	Peak	9.19	
High Voltage 33 KV General Category-H	Flat	7.20	
	Off peak	6.55	
	Peak	9.28	
Street Lights & Pump –J		6.93	

Source: Develpped based on document of BERC

22.4.3 Capacity building of human resource for financial review

When Bangladesh plan to increase electricity tariff, public acceptance is not achieved without enough effort to increase supply cost. Therefore Bangladesh should find the chances to reduce supply cost and should propose increase of tariff with the reduction of supply cost.
It is difficult for the third party to get involved in the cost reduction process because many information is confidential in the companies. First BPDB should launch the special team to find the unefficient process in terms of cost. Then it is difficult to change the condition of singed contract, therefore established structure to check cost efficiency when BPDB makes new contract. Support from donor such as JICA for capacity building is beneficial.