

The People's Republic of Bangladesh
Ministry of Power, Energy and Mineral Resources

**Integrated Energy and Power
Master Plan Project
in
The People's Republic of Bangladesh
Project Final Report**

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**JAPAN INTERNATIONAL COOPERATION AGENCY
THE INSTITUTE OF ENERGY ECONOMICS, JAPAN**

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Abbreviations

Abbreviation	Word
ADB	Asian Development Bank
AE	Assistant Engineer
AIS	Air Insulated Switchgear
AIT	Advanced Income Tax
AIT	Asian Institute of Technology
AMI	Advanced Metering Infrastructure
APA	Annual Performance Agreement
APSCL	Ashuganj Power Station Company Limited
ASM	Automatic Storage Management
AVR	Automatic Voltage Regulator
BCPCL	Bangladesh-China Power Company (Pvt) Limited
BDT	Bangladeshi taka
BEER	Building Energy and Environment Rating
BERC	Bangladesh Energy Regulatory Commission
BFP	Boiler Feed Pump
BIAM	Bangladesh Institute of Administration and Management
BIFPCL	Bangladesh-India Friendship Power Company Pvt. Limited
BIM	Bangladesh Institute of Management
BOP	Balance of Plant
BPDB	Bangladesh Power Development Board
BPDB	Bangladesh Power Development Board
BPMEC	Bangladesh Power Equipment Manufacturing Company Ltd.
BPMI	Bangladesh Power Management Institute
BREB	Bangladesh Rural Electrification Board
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CAD	Computer-Aided Design
CBET	Cross Border Electricity Trade
CCGT	Combined Cycle Gas Turbine
CCNA	Cisco Certified Network Associate
CCPP	Combined-Cycle Power Plant

Abbreviation	Word
CD	Custom Duty
CE	Chief Engineer
CHP	Combined Heat and Power
CI	Combustion Inspection
CMC	China National Machinery Import & Export Corporation
COVID-19	Coronavirus Disease 2019
CPGCBL	Coal Power Generation Company Bangladesh Limited
CPTU	Central Procurement Technical Unit
CRM	Customer Relationship Management
CSA	Coal Supply Agreement
CSR	Corporate Social Responsibility
CT	Current Transformer
CTA	Coal Transportation Agreement
CWP	Circulating Water Pump
DC	Direct Current
DCS	Distributed Control System
DESCO	Dhaka Electricity Supply Company Limited
DFP	Department of Films & Publications
DGM	Deputy General Manager
DPC	Dispatching Power Control
DPDC	Dhaka Power Distribution Company
DPP	Digital Product Passport
DX	Digital Transformation
EDC	Economic load dispatching control
EDG	Emergency Diesel Generator
EGCB	Electricity Generation Company of Bangladesh
e-GP	Electronic Government Procurement
EMS	Energy Management System
EOI	Expression of Interest
EPC	Engineering, Procurement and Construction

Abbreviation	Word
ERP	Enterprise Resource Planning
ESCB	Engineering Staff College of Bangladesh
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization
FGMO	Free Governor Mode of Operation
FSSS	Furnace Safeguard Supervisory System
FY	Fiscal Year
GF	Governor Free
GIS	Geographic Information System
GIS	Gas Insulated Switchgear
GM	General Manager
GT	Gas Turbine
GTCC	Gas Turbine Fuel Cell combined cycle
HFO	Heavy Fuel Oil
HGPI	Hot Gas Path Inspection
HP	Homepage
HRD	Human Resource Development
HRM	Human Resource Management
HRSG	Heat Recovery Steam Generator
ICT	Information and Communication Technology
IDCOL	Infrastructure Development Company Limited
IEB	The Institute of Engineers, Bangladesh
IEEJ	The Institute of Energy Economics, Japan
IEPMP	Integrated Energy and Power Master Plan
IMS	Integrated Management System
IoT	Internet of things
IPP	Independent Power Producer
ISO	International Organization for Standardization
IT	Information Technology
JICA	Japan International Cooperation Agency

Abbreviation	Word
JVA	Joint Venture Agreement
KPCL	Khulna Power Company Limited
KPI	Key Performance Indicator
LFC	Load Frequency Control
LNG	Liquefied Natural Gas
MCCB	Molded Case Circuit Breaker
MDS	Member Directing Staff
MFS	Mobile Financial System
MHPS	Mitsubishi Hitachi Power Systems
MI	Major Inspection
MoA	Memorandum of Association of Bangladesh Power Management Institute
MoPEMR	Ministry of Power, Energy and Mineral Resources
MoU	Memorandum of Understanding
MPER	Ministry of Power, Energy and Mineral Resources
MS	Microsoft
NAPD	National Academy for Planning & Development
NESCO	Northern Electricity Supply Company Limited
NGO	Non Governmental Organization
NIS	National Integrity Strategy
NLDC	National Load Dispatch Center
NOCS	Network Operation & Customer Service Office (DPDC)
NOx	Nitrogen Oxides
NTPC	National Thermal Power Corporation (Power Company owned by the Indian Government)
NWPGCL	North West Power Generation Company
O&M	Operation and Maintenance
OCSMS	Online Customer Service Management System (DESCO)
OHSAS	Occupational Health and Safety Assessment Series
OJT	On-the-Job-Training
OPGW	Optical Fiber composite overhead Ground Wire
PBS	Palli Bidyuit Samity

Abbreviation	Word
PBS-UPM	Putra Business School - University of Putra Malaysia
PGCB	Power Grid Company of Bangladesh Limited
PIME	Project Formulation, Implementation, Monitoring and Evaluation
PLC	Programmable Logic Controller
PMS	Performance Management System
PPA	Power Purchase Agreement
PPDM	Project Planning, Development and Management
PPE	Personal Protective Equipment
PPM	Project Planning and Management
PPR	Public Procurement Rules
PPTC	Power Plant Training Center (APSCL)
PT	Potential Transformer
R/D	Research and Development
RAC	Real Application Cluster
RFP	Request for Proposal
RMS	Remote Monitoring System
RPATC	Rural Public Administration Training Centre
RPCL	Rural Power Company Limited
RTI	Right to Information
S&D	Sales and Distributions (Divisions)
SAA	Senior Accounts Assistant
SAE	Sub Assistant Engineer
SC	Super Critical pressure plant
SCADA	Supervisory Control and Data Acquisition
SDE	Sub Divisional Engineer
SDGs	Sustainable Development Goals
SF ₆	Sulfur Hexafluoride
SFC	Static Frequency Converter
SO _x	Sulfur Oxides
SREDA	Sustainable & Renewable Energy Development Authority

Abbreviation	Word
STG	Steam Turbine Generator
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TA	Technical Assistance
TNA	Training Needs Assessment
ToT	Training of Trainers
UFLS	Under Frequency Load Shedding
UPS	Uninterruptible Power System
USC	Ultra Super Critical Power Plant
USD	United States Dollar
VAT	Value Added Tax
VR	Virtual Reality
VRE	Variable Renewable Energy
WAPDA	Water and Power Development Authority
WB	World Bank
WZPDCL	West Zone Power Distribution Company Limited.
XEN	Executive Engineer

Summary

This project final report summarizes the work other than the master plan as part of the entire project of Integrated Energy and Power Master Plan Project in Bangladesh, and consists of the following three parts.

I. Wide-area Blackout Countermeasures

In this survey, JICA Team will work with the relevant power companies to consider and formulate short-term countermeasures based on current situation as well as make recommendations for medium- to long-term measures. As a short-term measure, in collaboration with PGCB (Power Grid Company of Bangladesh Limited), the time settings of UFLS (Under Frequency Load Shedding) which is an immediate countermeasure to prevent wide-area blackout by utilizing existing facilities was reviewed. In reviewing the UFLS, it was found that by applying the Rate of Change of Frequency (RoCoF) function and using a delay timer, it would be possible to appropriately control the amount of load shedding and maintain a stable frequency even in the severe accident after the introduction of a large-capacity generator. Although the frequency quality in Bangladesh has been improving in recent years, the grid frequency still deviates from the 49.0Hz to 50.5Hz range required for stable operation of Rooppur Nuclear Power Plant for certain periods of time. The Rooppur Nuclear Power Plant is scheduled to begin trial operation soon, and further improvements in frequency quality are required. The issue that frequency fluctuations were large and continued for long time was identified. As medium- to long-term measures to address this issue, recommendations on improving system operations, ensuring frequency adjustment capabilities, and measures to address flicker loads were made. The following issues were identified regarding grid operations: supply and demand schedules were only made the day before, necessary information such as generator maintenance shutdowns was not shared with the National Load Dispatch Center (NLDC), and demand forecasts were based on individual experience. There is a lack of human resources to improve grid operations. Capacity building and training programs are needed. The followings were recommended in order to ensure frequency regulation: All generators with a certain capacity or more should be required to use Free Governor Mode of Operation (FGMO), the minimum output of thermal power generators should be reduced, and the load change speed should be improved. Regarding measures against flicker load, the introduction of flywheels and revisions to the grid code were proposed. In order to resolve mid- to long-term issues, it was proposed to consider the next technical cooperation project. The proposals include improving the frequency adjustment capabilities of generators, adding frequency control functions to High Voltage Direct Current (HVDC), systematizing operations including supply and demand operation plans, revising related manuals, formulating systems and rules to ensure frequency adjustment capabilities, recommendations for updating NLDC's EMS (Energy Management System)/SCADA (Supervisory Control And Data Acquisition), and human resource development.

II. Needs for Human Resource Development in Power Sector

Ministry of Power, Energy and Mineral Resources (MoPEMR) and JICA has agreed to conduct a study on human resource development in power sector. Recommendations and support measures for future cooperation in human resource development in power sector were considered for the Bangladesh Power Management Institute (BPMI).

BPMI is a training institute for power sector that was established by Power Division (PD) in June 2017. Although it has around three lecture rooms in its temporary office, it does not have any training facilities such as power transmission, substation, power distribution simulation equipment or power plant simulators for conducting practical training, and it also has few trainers. When BPMI organizes practical training using simulation training equipment, they borrow the training equipment owned by power utilities (power generation companies, power transmission companies, power distribution companies, etc.), and the trainers are also assigned from those power utilities. BPMI has a plan to construct a permanent campus (called “Training Academy”) for training purposes in the southwest of Dhaka (Keranigonj district, approximately 28 km from the city center). However, although the land has been secured, there is no funding for the construction costs of the training and accommodation buildings, which are said to be between 30 and 40 million USD.

On the other hand, each organization under PD such as power generation companies, power transmission companies, power distribution companies makes Annual Performance Agreement (APA) with PD every year for committing to a target of training hours per employee per year (60 hours/person/year). None of the organizations have formulated multi-year training plans; they only formulate single-year plan each year. BPM also conducts a training needs survey for each organization each year, formulates single-year training plan, and implements training.

It was concluded that the BPMI's top priority should be to establish basic policies for human resource development and institutions, rather than to develop training facilities, simulation equipment, and other materials and equipment. Main items are as follows.

- (1) Establishment of policies, rules, and strategies regarding BPMI human resource development
- (2) Clarification of the division of roles in human resource development and training activities in the entire power sector of Bangladesh, and determination of the general outline of the training program
- (3) Building an operational and management system for BPMI as a training institution, strengthening operational and management skills and know-how, and clarifying BPMI's future vision and formulating a roadmap.

III. Capacity Building

In this study, capacity building for "Energy Balance Table" and "Energy Demand Forecast Model" was carried out as follows.

(1) Energy Balance Table

Regarding Energy Balance Table, Sustainable and Renewable Energy Development Authority (SREDA) already publishes Energy Balance Table for Bangladesh every year on its website. However, there is a lack of data for industrial sub-sectors. Therefore, to collect data of industrial sub-sectors, Technical Working Group consisting of representatives from each energy company was organized to collect data and examine issues. To collect data, Energy and Mineral Resources Division (EMRD) issued a request letter to energy companies and provided them data format. Each company filled out data form with energy supply data categorized by industry subsector and submitted it to JICA team. JICA team also obtained raw data that was the basis for data provided by each company and verified the data. Energy data other than that of industrial subsector can be collected from Annual Reports and websites of energy companies. This study demonstrated data collection method for industrial sub-sectors. To create Energy Balance Table, knowledge of structure for Energy Balance Table, energy conversion coefficients, and so on is required. SREDA has these knowledge. In addition, in response to the request from counterparts, a prototype model for creating Energy Balance Table was developed.

(2) Energy Demand Forecasting Model

Regarding energy demand forecasting model, training was divided into two teams (EMRD and PD) since the number of participants was large (62 people). Training for EMRD took place from August 20 to September 1, 2022. On the other hand, training for PD took place from September 25 to October 4, 2022. Energy demand forecasting model developed by JICA team was built in Excel. The regression analysis software that serves as the engine for the model was an add-in software called "SimpleE". During the training, each participant installed SimpleE on their own personal computer and was learned how to operate the model, the theory of the model, and how to develop the energy demand forecasting model. In addition, the content of the model developed by JICA team was explained. The participants understood the model content. But more training is needed to update the model by themselves.

I. Wide-area Blackout Countermeasures

1. Introduction

1.1 Background to the Survey

On 4 Oct 2022, the wide area blackout occurred in Bangladesh. With this as a trigger, JICA Study Team of Integrated Energy and Power Master Plan Project in Bangladesh explained the possible cause of the wide-area blackout and measures against it to MoPEMR on 16 October. After this, MoPEMR and JICA have agreed to conduct an additional study on wide-area blackout countermeasures.

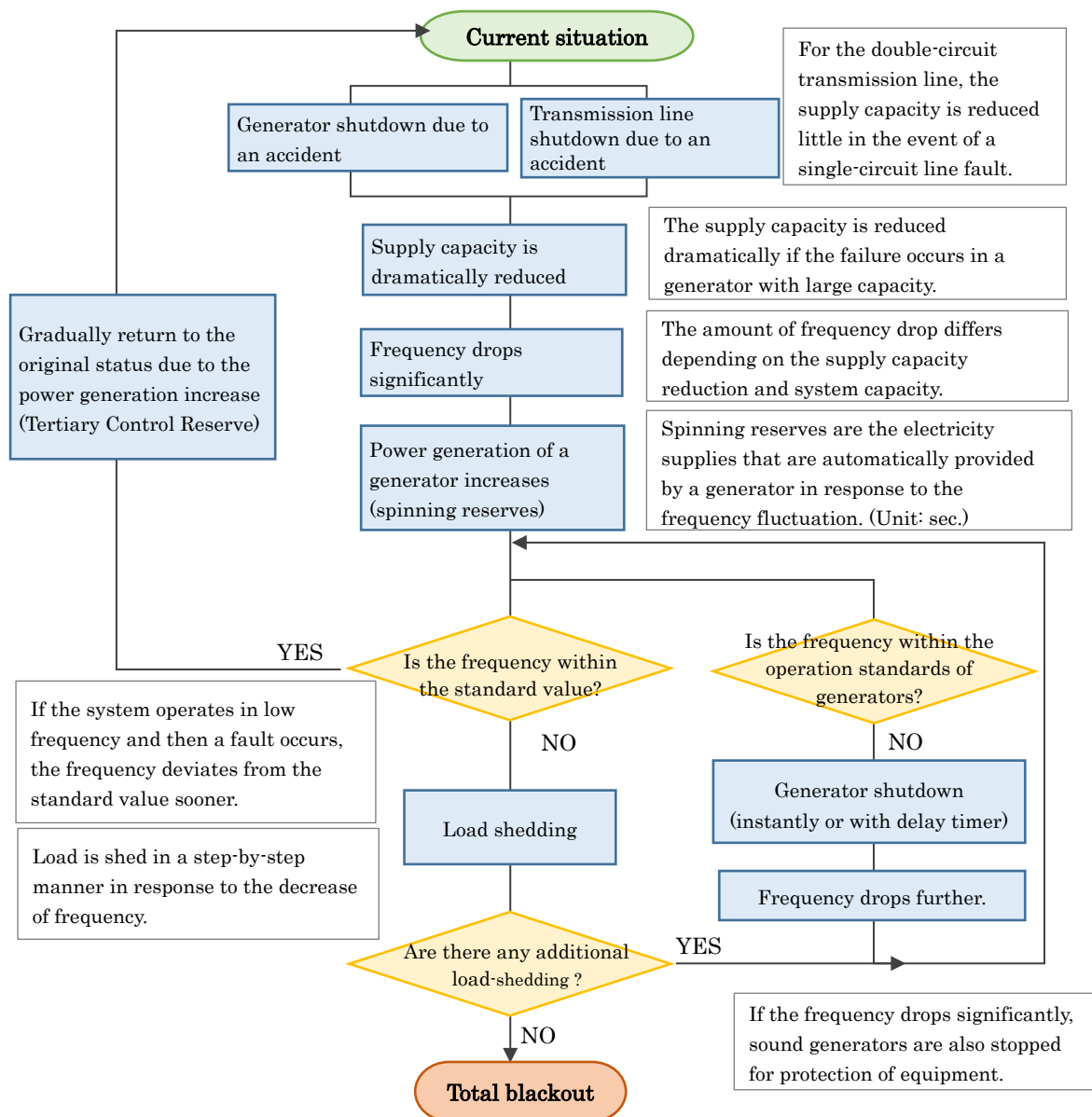
1.2 The Aims of the Survey

The aim of the survey is to study and formulate a short-term measure and make a recommendation for a mid-to-long term measure in response to the wide-area blackout occurred in Bangladesh on 4 Oct 2022, which is based on the understanding of the actual situation, in collaboration with related electric power utilities.

1.3 Overview of the Survey

(1) Collecting Data and Identifying Issues regarding Power System Operation in Bangladesh

Figure 1-1 shows the flow chart of the wide-area blackout, which is organized in accordance with the collected data related to the blackout caused in Bangladesh on 4 Oct 2022.



Source: Study Team

Figure 1-1 Flow chart summarizing the occurrence of the wide-area blackout

In addition, some issues were identified in the daily supply-demand balancing operation procedure through the current analysis on the power system operation. Figure 1-2 shows a typical daily supply and demand operation procedure in Japan.

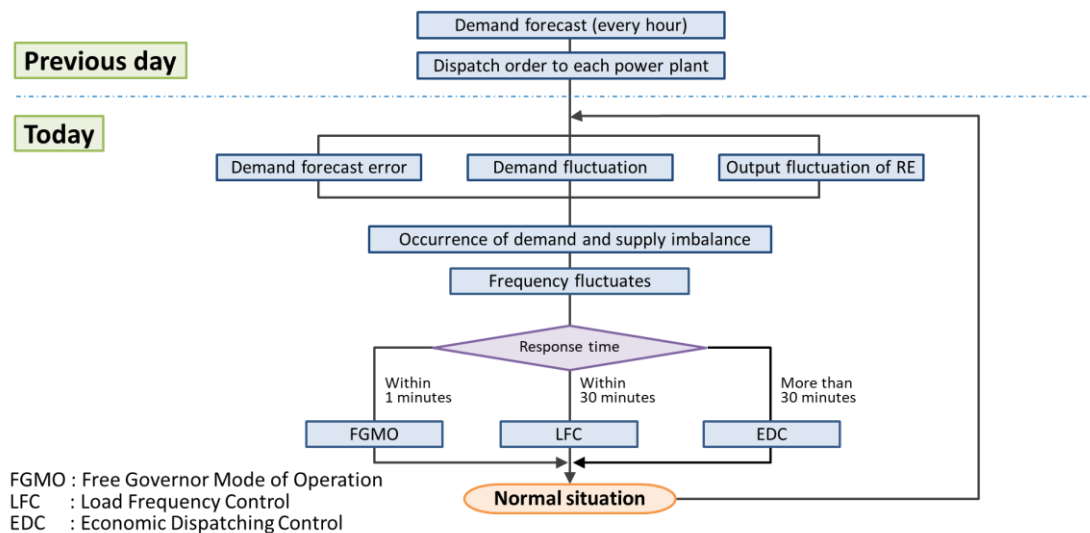


Figure 1-2 Procedures of the daily supply-demand operation

The issues are identified on the basis of the data collected during the trip from 19 to 24 Nov 2022 and discussions are held in light of requests from Bangladesh and the status of studying measures. The following four items A) to D) are examined.

A) Ensuring regulating reserves (Expanding the scope of FGMO)

Although the effort has been made to ensure regulating reserves in Bangladesh in the past, it is not going well as expected. Thus, the data on the previous efforts and current situations is collected.

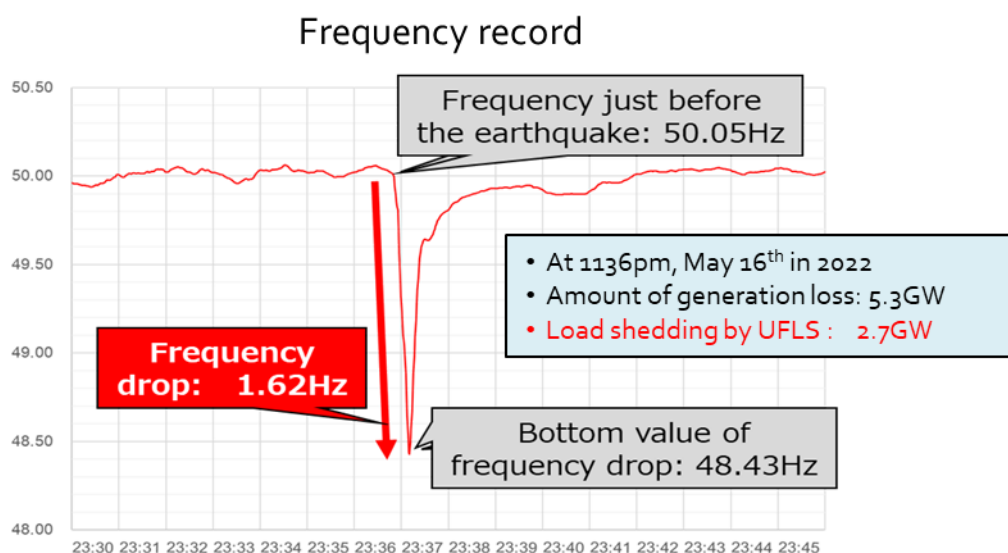


Source: Study Team

Figure 1-3 Basic idea of frequency control

B) Review of the UFLS settings

The current UFLS settings are reviewed and the proposed improvement is studied and formulated. Figure 1-4 shows the line graph indicating the frequency drop in Japan, which is caused by generator trip, and the example of frequency recovery by UFLS.



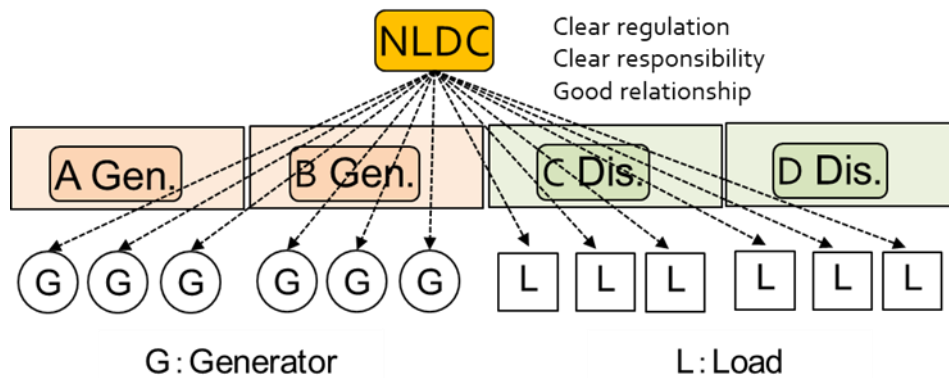
Source: “CIGRE Paris Session 2022, Frequency Situation at 2022 Fukushima Earthquake and Actions Taken for Supply Shortage

Thereafter”

Figure 1-4 Frequency drop in Japan, which is caused by generator trip, and frequency recovery by UFLS

C) Improvement of system operation rules (Supply-demand and system operation planning, coordination of scheduled outage, emergency supply-demand control)

The current status of the supply-demand and system operations, including operation of National Load Dispatch Center (NLDC), specifically, work contents on supply-demand and system operation planning under the normal condition, outage coordination, preparation of emergency supply-demand guidelines, and coordination with related institutions, such as power generating and power distribution companies, is grasped.

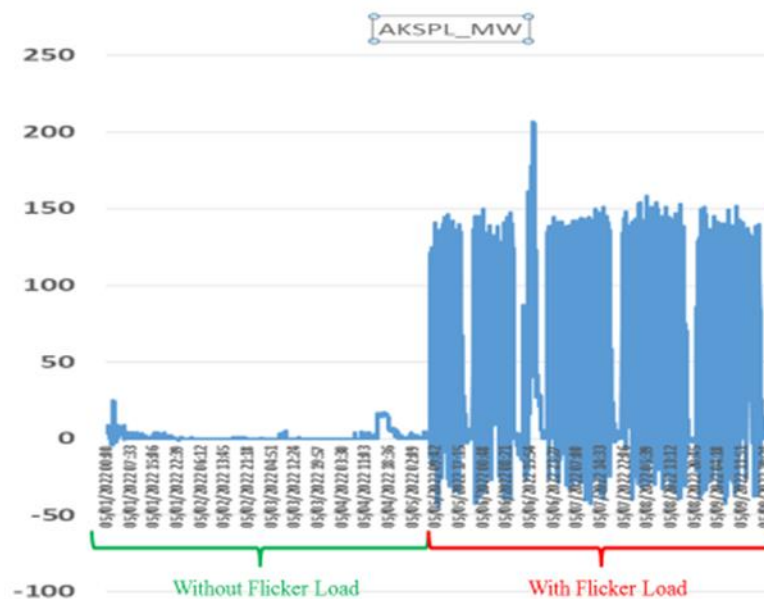


Source: Study Team

Figure 1-5 Building the collaborative relationship between NLDC, power generating and power distribution companies

D) Measures for customers with flicker load

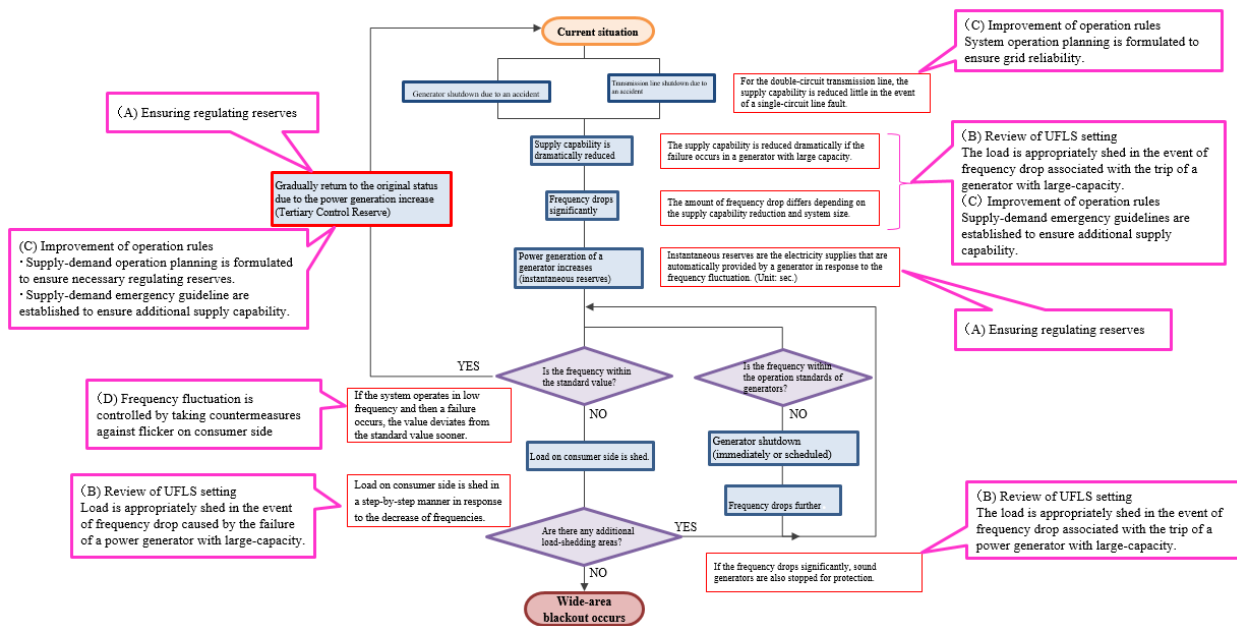
The data about the impact on power system due to customers with flicker load is collected. Figure 1-6 shows the bar chart indicating the example of actual load fluctuation due to customers with flicker load in Bangladesh.



Source: NLDC

Figure 1-6 Example of load fluctuation due to consumers with flicker load

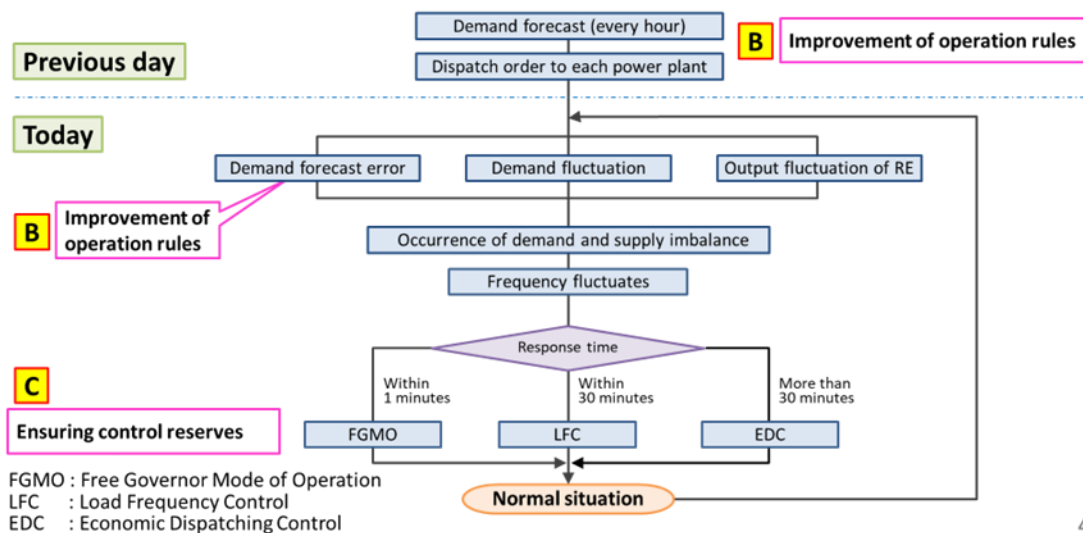
Figure 1-7 shows the flow chart indicating the positions of A) to D) (the flow chart summarizing the occurrence of the wide-area blackout) listed below.



Source: Study Team

Figure 1-7 Flow chart summarizing the occurrence of wide-area blackout and positions of study items

Figure 1-8 shows the positions of the study items A) and C) above in the daily supply and demand operation procedure.



Source: Study Team

Figure 1-8 Procedures of the daily supply-demand operation and positions of study items

(2) Consideration and Evaluation of Recurrence Prevention Measures for Wide-area Blackouts in

Bangladesh

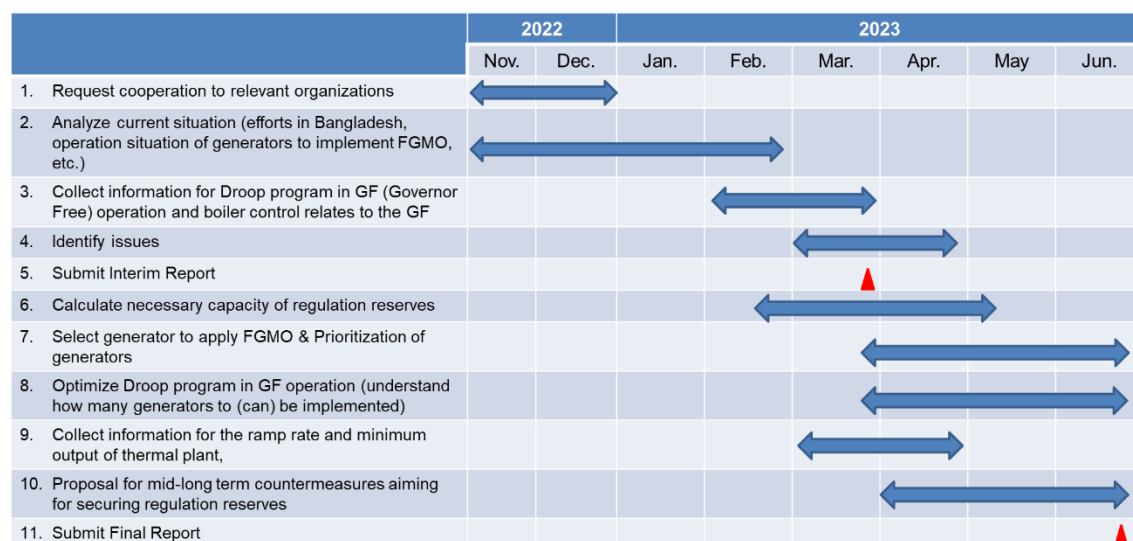
In light of the data regarding the study items A) to D) above, the proposed measures are considered and evaluated.

(3) Reports of Survey Results and Recommendations to Bangladesh

Based on the study results regarding study items A) to D) above, the survey results and recommendations are reported to Bangladesh.

1.4 The Schedule of the Survey

Figure 1-9, Figure 1-10, Figure 1-11 and Figure 1-12 show the schedule of the survey for four items A) to D), respectively.



Source: Study Team

Figure 1-9 The schedule of the survey ((A) Ensuring regulating reserves (Expanding the scope of FGMO))

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1. Gathering data and information	↔							
2. Proposal of study method			↔					
3. Study and presentation of initial setting proposal				↔				
4. Identification of points to be revised, presentation, review, and discussion of proposed revisions					↔	↔		
5. Final discussion								↔
6. Web meetings once a week			↔					
7. Meetings in Dhaka					↔	↔	↔	
8. Submission of Draft Final Report								▲

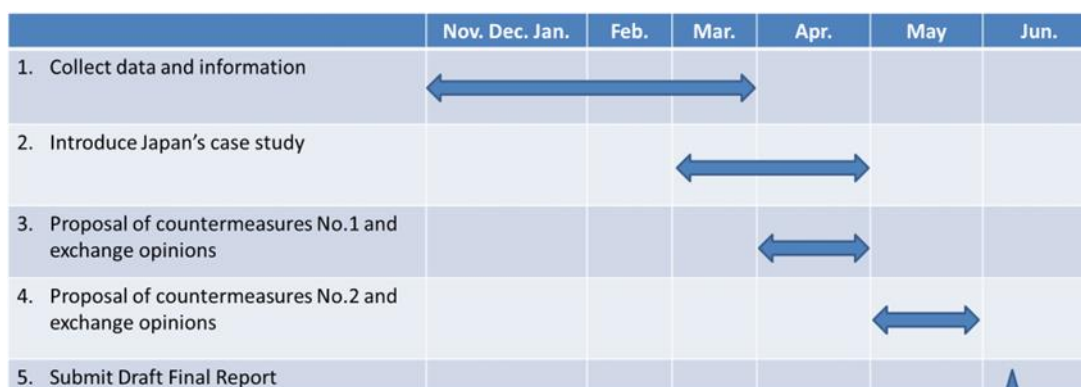
Source: Study Team

Figure 1-10 Schedule of the survey ((B) Review of UFLS settings)

	2022		2023					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1. Define-Scope of work	↔							
2. Understand current situation(work procedures being made between NLDC and distribution companies, operation method)	↔							
3. Develop countermeasures for under emergency conditions of supply and demand balance		↔			↔			
4. Proposal for supply and demand scheduling plan procedure			Introduce procedures in Japan	↔	↔	↔	↔	
5. Proposal for system operation plan procedure				↔	↔	↔	↔	
6. Submit Interim Report						▲		
7. Proposal for scheduled outage coordination				Introduce procedures in Japan	↔	↔	↔	
8. Recommendations for operation rules and HR training						↔	↔	
9. Submit Final Report								▲

Source: Study Team

Figure 1-11 Schedule of the survey ((C) Improvement of system operation rules)

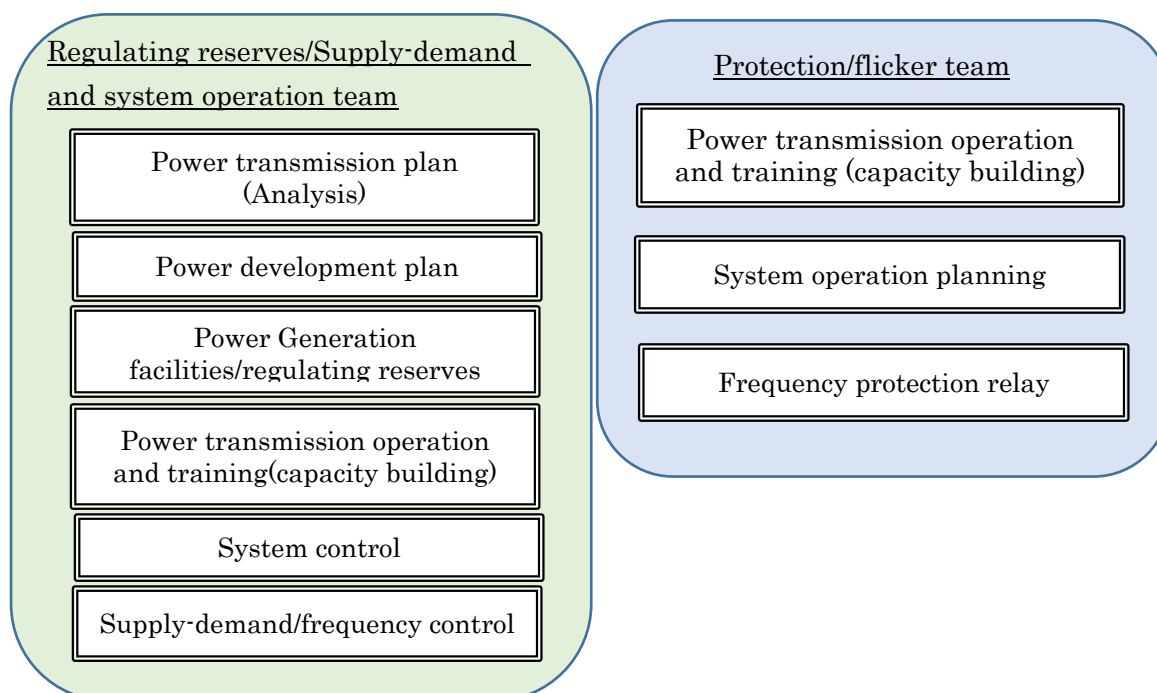


Source: Study Team

Figure 1-12 Schedule of the survey ((D) Measures for the customers with flicker load)

1.5 Organization Structures of the Survey

Figure 1-13 shows the organization structures of the survey.



Source: Study Team

Figure 1-13 Organization structures of the survey

1.6 Relevant Organizations in Bangladesh

Table 1-1 shows the relevant organizations in Bangladesh.

Table 1-1 Relevant organizations in Bangladesh

Utility	Division
Bangladesh Power Development Board (BPDB)	Generation Division
	IPP cell
	Protection Division
	Discom
Power Grid Company of Bangladesh (PGCB)	NLDC
	Protection Division
	SCADA & Maintenance Division
	System Planning
Electricity Generation Company of Bangladesh (EGCB)	
Dhaka Power Distribution Company (DPDC)	
Dhaka Electricity Supply Company (DESCO)	
Bangladesh Energy Regulatory Commission (BERC)	

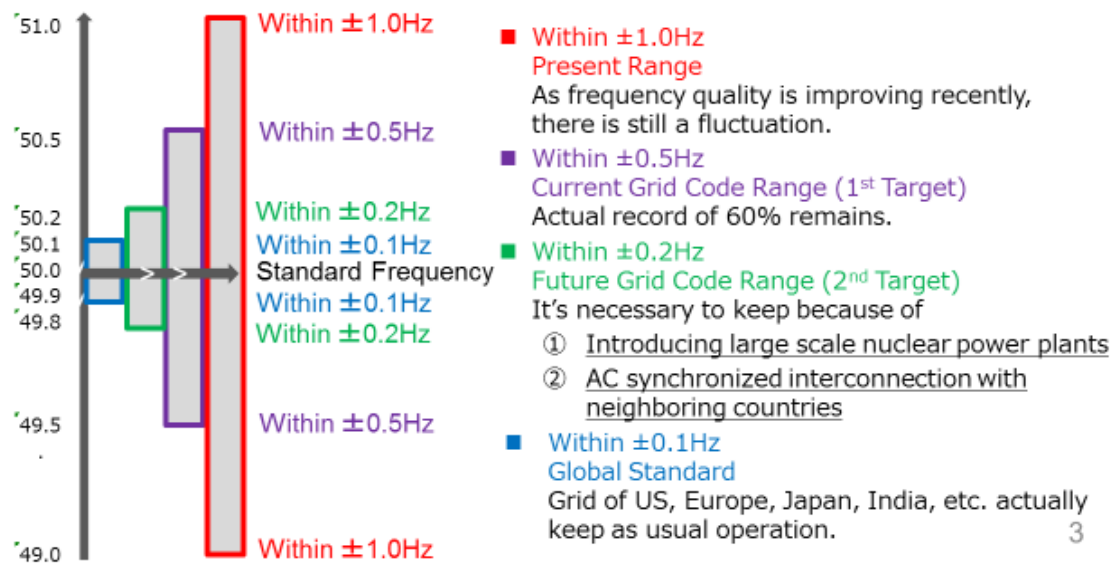
Source: Study Team

2. Issues Related to the Power System Operation in Bangladesh

2.1 Current status and goals of frequency quality

Power supply in Bangladesh is still in the developing phase but it tends to improve every year. The (1) blackouts (service reliability), (2) frequency, and (3) voltage are generally given as the elements of power quality. In particular, these three elements can be the evaluation index in order to improve power quality. In the master plan study, it is expected to achieve further improvement of (1) blackouts due to the economic development and demand growth. In the future, it is desired to improve (2) frequency and (3) voltage regarded as power quality so that the focus will shift to establish the measures.

For improving power quality of (2) frequency and (3) voltage, usually the (2) frequency is improved at first because it affects the entire power system. After that, (3) voltage is improved because the response to individual power system is required. The current status of (2) frequency quality is described in this section.



Source: Study Team

Figure 2-1 Current status and goals of frequency quality in Bangladesh

The standard frequency in Bangladesh is 50 Hz. The AC power system connected has the same frequency at any point so the frequency value is same everywhere in Bangladesh.

The frequency quality tends to improve in recent years and the fluctuation range is getting smaller. The fluctuation is usually about 0.5 Hz or more so it seems that the fluctuation range is within 1.0 Hz. The period when the frequency is controlled within about 0.5 Hz (specified frequency) remains about 70 %. The objective frequency at this time is within 0.5 Hz, which is specified by the grid code.

The Ruppur Nuclear Power Plants are expected to start operation in the near future. The generating output is 2,400 MW in total (2 units with a capacity of 1,200 MW). The first unit was planned to launch test operation in Dec, 2024 and the second unit was planned to launch operation for business by 2024. However, according to the recent economic situation, the plan is delayed to 2024 or after. The consultation with the neighboring countries such as India regarding the interconnection with the AC power continues.

To achieve interconnection with the AC power from the neighboring countries stably, the frequency fluctuation range within 0.2 Hz is required and achieving the range is the goal for the near future.

2.2 Issues

The exact amount of demand is grasped through balancing the demand and supply, and the standard frequency is maintained by controlling the output from the supply side.

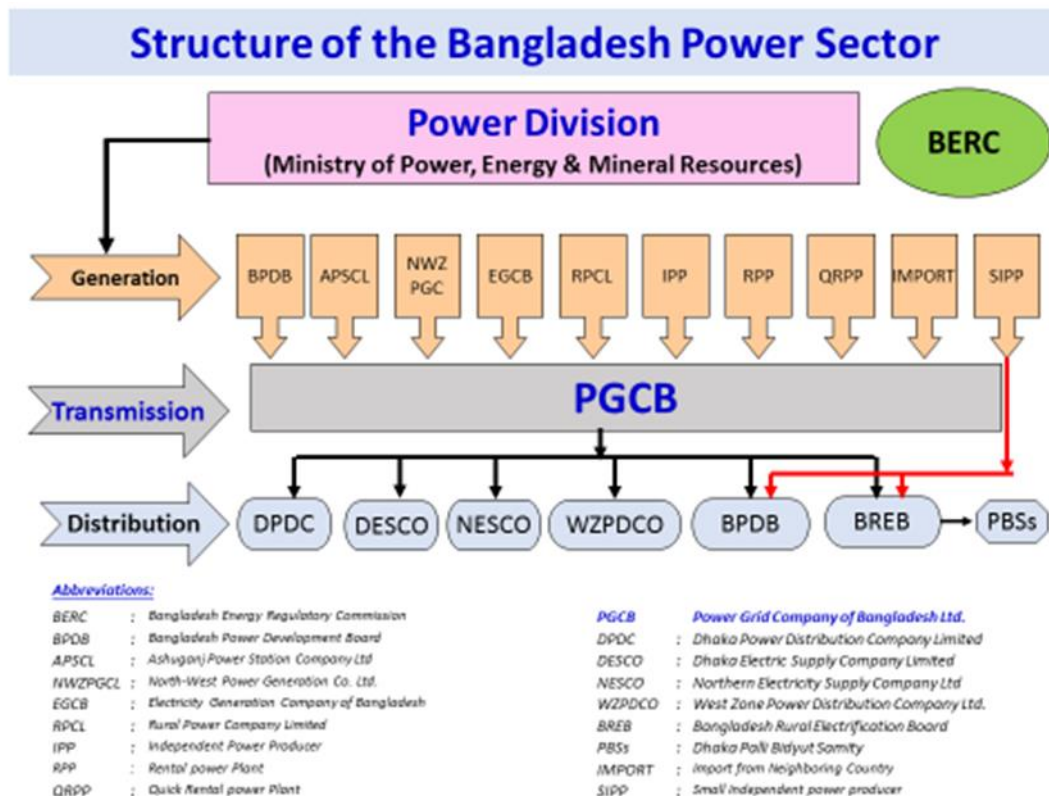
To maintain the standard frequency, it is required to match the power supplied from the generating facilities with power demand appropriately in consideration of establishment of the

power development plan and preparation of necessary generating facilities, and the steady and careful planning based on close information exchange (from mid to long-term to short term such as yearly, monthly, and weekly) is required.

In current status in Bangladesh, necessary generating facilities for frequency regulation are not ensured so securing regulating reserves is necessary.

The items required for improving current frequency quality are shown in the following.

- Supply and demand operation, clarification of roles, establishment of grid codes
 - Daily operation by the related organizations centered on NLDC working together is required in order to achieve operation that match generating power with the demand plan from the mid-long term to short-term, previous day, and on the day precisely. At this moment, the establishment of both rules and operation flow has large room for improvement.
 - There is an actual situation that the operation is not performed under the enough cooperation because the NLDC does not gain the cooperation from each power generator. Authority regulations and penalties must be specified but the system design for payment giving incentives to ensure necessary regulating reserves is currently not enough.
- Demand forecast
 - The demand data and weather data are not collected appropriately and EMS demand forecast does not function. The accuracy must be improved.
 - NLDC doesn't have the energy forecast tools for renewable energy source.
 - The actual and estimated demand reported by the distribution companies is not fully accurate due in part to the limited online data collection points, and the accuracy of forecasts is needed to be improved.
- Energy Management System (EMS)
 - Generation control is not performed by EMS but instructed by NLDC operators via phone. Thus, it is essential to exchange data effectively by connecting each power plant and NLDC online for improvement of frequency quality.
- Monitoring and control systems of distribution companies (SCADA: Supervisory Control And Data Acquisition)
 - In order to improve frequency quality, it is essential to estimate demand accurately and control it quickly when necessary. Currently, only DESCO and WZPDCO have SCADA among six distribution companies. In the absence of SCADA, the remaining companies with their limited resources face challenges in acquiring data precisely and timely.



Source: NLDC

Figure 2-2 Power sector related organizations, including six distribution companies

- Regulating reserves (Primary Control Reserve (PCR), Secondary Control Reserve (SCR), and Tertiary Control Reserve (TCR))
 - The power plants with Free Governor Mode of Operation (FGMO), which supply PCR, are not enough. There are 32 power plants that supply PCR but the majority of the power plants is not in operation (FGMO is applied to 8 to 10 power plants only.) The reason is to avoid the unscheduled fuel consumption because the fuel is insufficient. In addition, there are some technical issues on plant control or valves. Therefore, the FGMO is not kept in operation. According to NLDC, current amount of PCR is not enough to maintain the control area specified by the grid codes continuously.
 - LFC is not used and SCR is not ensured. PCR enables to control the output from each power plant but LFC, which detects an imbalance between supply and demand from frequency deviation and automatically changes output in each power plant, is not used.
 - TCR and regulating reserves must be ensured to respond to the growing demand in the future. It is essential to match the future power planning and transmission planning and ensure a certain amount of regulating reserves continuously.

■ Risk of wide-area blackouts

- In recent years, the large risks of occurring wide-area blackouts remain because several blackout events occur due to the power failure caused by high demand. The maximum capacity of a generation unit is 800 MW but it will be 1,200 MW once the Ruppur Nuclear Power Plant starts test operation (expected after 2024). There is a concern that the large-scale failure may cause frequency drop, resulting in wide-area blackouts.

2.3 Improvement policy

(1) Future improvement policy

To achieve stable supply-demand and system operation, introduction of the nuclear power plants expected after 2023 and power system synchronization (AC interconnection) with neighboring countries, which have government-to-government talks with India, are required. The frequency for the newly installed nuclear power plants is set within the range of 49.0 Hz to 50.5 Hz. Firstly, the frequency fluctuation shall be within the specified range. Synchronization with India has advantages in securing the supply capacity and stabilizing the power system. It is essential to balance supply and demand on the power system in Bangladesh. To this end, the frequency fluctuation shall be within ± 0.2 Hz. The synchronization will match the frequency with India and the frequency fluctuation will be within ± 0.1 Hz. Therefore, the fluctuation must be within ± 0.2 Hz. The following shows the necessary approaches for improving frequency quality.

- Demand forecast, advancement of generation planning and improvement of the accuracy
- Ensuring PCR, SCR, TCR, and regulating reserves
- Introduction and advancement of SCADA/EMS
- Establishing the rules including enhancement of the NLDC's authority and building effective relationship with each organization
 - Design of system for ensuring regulating reserves and measures of appropriate compensation

Achieving these items is required for consensus formation, political measures, and establishment of rules by all stakeholders in energy sectors such as power generation, distribution, retail, and regulations, in addition to PGCB and NLDC that are in charge of system operation so that working groups need to be established.

Involving the organizations to have talks with India, Nepal, Bhutan, etc. on system synchronization and power import and having talks on organic and compatible policies will lead to improve the power quality.

(2) Latest improvement suggestion policy

In light of data collection with relevant parties centered on NLDC and exchange of ideas following the study results of the master plan and the blackout occurred in 4 Oct 2022, improvement suggestions are given in the following areas.

[Establishment of measures for wide-area blackouts]

Mainly regarding supply-demand and frequency regulation, study and establishment of measures (short-term measures) based on the grasp of the actual situation and suggestion related to the future (mid to long-term measures) are given.

■ Short-term measures

Concrete suggestions are given on the basis of experiences in Japan.

(1) Protection/operation

Reviews on the current underfrequency relay settings, and study and establishment of improvements.

→ 3.

■ Mid to long-term measures

The issues are identified and deep-dived to make a concrete suggestion and recommendations for future.

(2) Future demand-supply and transmission system operation planning

Creation of suggestions by consulting with related organizations such as BPDB and NLDC.

1. Suggestions about the road map including system design

2. Primary reserve (FGMO: Free Governor Mode of Operation)、

Preparation plan of Secondary reserve (LFC: Load Frequency Control)

→ 4.

(3) Current supply-demand, system operation

Current operation supports from NLDC

1. Normal

Supply-demand and system operation planning, outage coordination, manuals, operation flows

2. In the case of power shortage

Maintenance of items in the case of supply-demand emergency

3. Regulation with related organizations

→ 5.

(4) Countermeasure for flickers

Study of measures for the consumer's device causing flicker because it affects frequencies

→ 6.

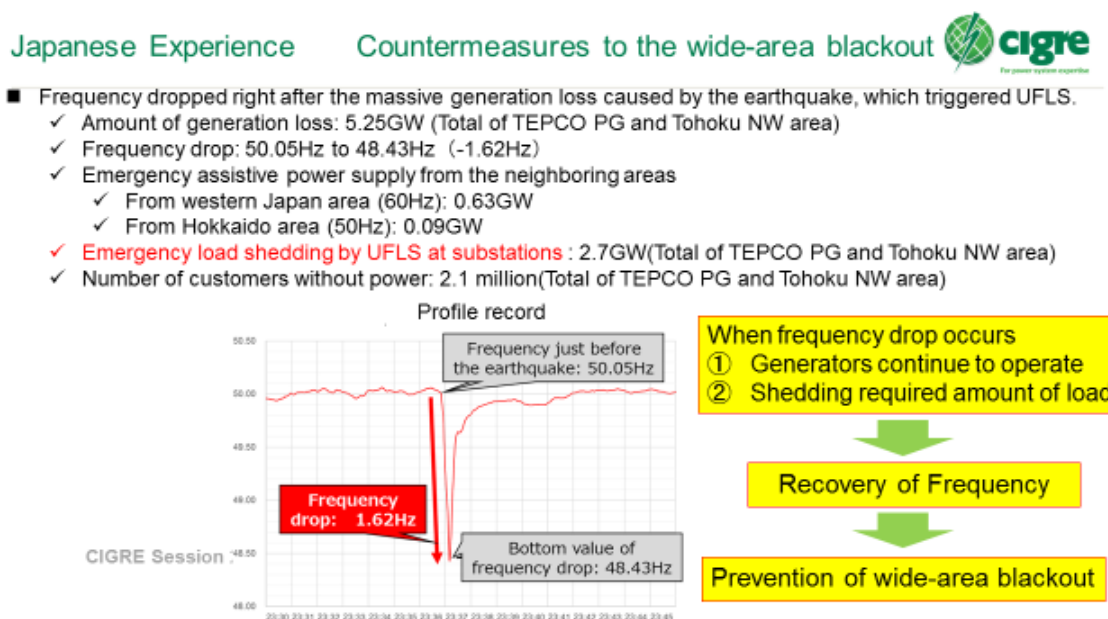
3. Proposal of Renewal UFLS Settings

3.1 Background

The measures for preventing the chain reaction of accidents in the power system triggered by one failure is extremely important as preventive measures for large-scale blackouts. As one of the important measures, underfrequency load shedding(UFLS) are installed in each transmission line. If the power failure is assumed to occur in large power generation facilities, there are some

concerns that the chain reaction of accidents called cascading may occur because the power failure causes a frequency drop and it forces severe operation on a power generator to stop the operation of other power generation facilities operation for protecting the power generation facility. The UFLS are devices that increase frequency and restore stable power system by some load shedding in the case of a frequency drop as preventive measures for cascading.

In Bangladesh, commissioning of nuclear power plants with a capacity of 1,200 MW are expected in 2024, which is larger than the conventional power generation facilities with a capacity of 800 MW, and a larger frequency drop is predicted in the case of power failure assumption. Suggestions regarding revision of UFLS setting values considering the new large units' introduction are given.



Source: "CIGRE Paris Session 2022, Frequency Situation at 2022 Fukushima Earthquake and Actions Taken for Supply Shortage Thereafter"

Figure 3-1 Frequency fluctuation in the domestic case where wide-area blackouts are prevented using underfrequency relays (16 Mar, 2022)

3.2 Outcome of this chapter

By conducting this study, the following outcomes were provided to the NLDC. At present, RoCoF method is in service at a small scale. It has been observed from the recorded PMU data that average frequency drop speed was around 0.33 Hz/sec in the event of tripping of both unit of Adani Unit-1&2. But df/dt was more than 0.38 Hz/sec after tripping event for several hundred milliseconds time duration. So far, the setting value is reviewed once every two to three months. The setting value comes closer to the value recommended by JICA Study Team. The review will continue intermittently.

The timers are not adopted yet because of frequency quality in Bangladesh system and security reasons. Specifically, the frequency fluctuation range is large and sudden generator trips occur frequently. If load shedding is delayed using UFLS, other generators cannot continuously operate, leading to wide-area blackouts. All Delay Timers are still set to 150 ms. In light of improvements of frequency fluctuations, applying the timers will be considered for future.

a. Adoption of new methods for UFLS settings

i. Adoption of RoCoF method, which is a countermeasure against large-scale generator dropout

In the event of a large-scale power failure, there is concern that the frequency drops sharply and the entire system may collapse if some load is not quickly disconnected. As a countermeasure, the RoCoF method is different from the method conventionally used in Bangladesh, which operates when the frequency reaches a certain fixed value (level method), and operates when a drop in frequency in a certain period of time above a certain level (RoCoF: Rate of change of frequency or df/dt) is detected (RoCoF method). The RoCoF method had not been used before, but the JICA Study Team presented a method and proposals for utilizing it.

ii. Use of timers, which is a measure to reduce the amount of load shedding

Conventional settling methods have adopted the level method, and have focused on protecting the entire power system to prevent frequency drops beyond a certain level. While maintaining this principle, a method was adopted to avoid load interruption for some load interruption targets when the frequency recovers by allowing the load interruption to occur after the frequency reaches a certain fixed value and after a set timer value has elapsed. This method enables the load interruption amount to be reduced.

b. Providing a tool for frequency calculation and verifying the calculation results

In order to perform precise frequency calculations for power systems, it is necessary to collect a large amount of appropriate data, mainly related to generator control systems, and this takes a considerable amount of time to achieve. For the UFLS setting study, we have provided a tool to make this frequency calculation simpler and more accurate with a certain level of confidence.

We also provided study results that show a sufficiently match between the actual frequency record and the results calculated from this tool.

c. Adjustment to match the actual situation in Bangladesh.

The reality is that UFLS operations are more frequent in Bangladesh than in Japan, due to a lack of reserve and limited means of frequency recovery other than UFLS, as there have been many generator accidents. Although it is desirable to minimize the amount of load shedding, ensuring UFLS operation and avoiding total blackout is extremely important. The renewal setting was determined after careful discussions to ensure that the principles and situation in Bangladesh were fully taken into account.

d. Informing the study method to enable the next renewal UFLS setting without support

In addition to providing the above tool, we clarified the items and numerical values that should be used as criteria for the calculation results and informed the study method to the Bangladeshi side so that they can conduct their own study when it is necessary to review it in the near future.

3.3 Study procedure

The study is performed in the following orders:

- (1) Collect data and information related to setting study. Especially, data for specifications of under-frequency relays.
- (2) Calculate various constants. Especially, frequency characteristic constants of the system.
- (3) Calculate the elements of df/dt . Study setting and timer values in each stage.
- (4) Calculate the level elements. Study setting and timer values in each stage.
- (5) Analyze the sensitivity. Confirm responses to other demand levels and power failures.

In the actual study, the above steps (2) through (5) were conducted, a renewal UFLS setting was created, and presented to the NLDC (mainly the persons in charge of protection relays), followed by careful discussions to identify points to be revised and to find a direction, then steps (2) through (5) were conducted again, and the revised setting was presented.

Since February, weekly web meetings have been held, and discussions have been conducted under close collaboration, with on-site consultations held at key opportunities.

Table 3-1 Study schedule

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1. Gathering data and information								
2. Proposal of study method								
3. Study and presentation of initial setting proposal								
4. Identification of points to be revised, presentation, review, and discussion of proposed revisions								
5. Final discussion								
6. Web meetings once a week								
7. Meetings in Dhaka								
8. Submission of Draft Final Report								

Source: Study Team

3,4 Collection of data and information related to setting study

The following data and information were provided from NLDC for this study. The following is a summary of the important information regarding the current UFLS settling values and the actual status for each relay type. A delay of 200 ms was set uniformly in this simulation, taking into account the time required for relay operation and fixed timers, in confirmation with the PGCB.

Table 3-2 Data and information related to setting study

No.	Items
1	Information about relays already installed ✓ Installation locations (substations and transmission lines) ✓ Setting values ✓ Manufacturers, models
2	Relay specifications ✓ Relay characteristics ✓ Setting items, Setting range ✓ Sequence diagram ✓ Input to relays
3	Assumption of power system for study ✓ Maximum demand ✓ Minimum demand ✓ Maximum unit generator loss case and amount of power failures
4	Frequency fluctuation records

Source: Study Team

Table 3-3 Overview of current UFLS setting

	Levels					
	< 49.00Hz	< 48.90Hz	< 48.85Hz	< 48.80Hz	< 48.75Hz	< 48.70Hz
MW ratio to total system demand	5.6%	7.0%	7.6%	7.0%	6.1%	4.7%
	fixed 150ms timer					
	38%					
Nuber of feeders	51	64	57	39	37	36
	284					

Source: Study Team

Table 3-4 Application status of each type of relays

Vendors	No.	Type	Feeders	Total MW	RoCoF availability	RoCoF Feeders	RoCoF Total MW
CEE	1	HDG 7020	17	270			
Abbm	2	M FVU 21	52	818			
Abbm (Transmission)	3	P 127	26	673	available	17	301
GE	4	P 141	12	185	available	12	185
Schneider (Distribution)	5	P 142	22	177	available	14	84
	6	P 140	10	107	available	10	107
Siemens	7	7S J81	5	85	available	5	85
	8	7S J85	8	180	available	8	180
	9	7S J8041	2	21			
	10	7S J622	6	115			
ABB	11	REF630	10	242	available	10	242
	12	REU 615	52	771	available	52	771
BBC (predecessor company of ABB)	13	FCX 103b/1	8	119			
Siemens	14	7S J82	10	164	available	6	88
	15	7S R 12	3	38			
Total			243	3965		134	2043

51.5%

Source: Study Team

3.5 Formula for calculating frequency

In this study, the following equation derived on the basis of motion equation of generators and modeled for the entire system is used to calculate the frequency values.

$$f = f_0 + \frac{s-d}{k \cdot (1-s)} - \left\{ f_0 - f_{t=0} + \frac{s-d}{k \cdot (1-s)} \right\} \cdot e^{-\frac{f_0 \cdot r \cdot k \cdot (1-s)}{M_0 \cdot (1-d)} \cdot t}$$

- M_0 : Generator's (unit) inertia constant (MW base)
- f_0 : Standard frequency
- P_M : Generator machine input
- P_E : Generator electric output
- P_{E0} : Generator electric output before fault
- P_0 : Generator amount
- d : Power dropout rate
- s : Load shedding rate
- k : Load's System Constant
- r : P_{E0} / P_0
- f : Frequency
- t : time
- $f_{t=0}$: Frequency at $t=0$

The above formulas show that the frequency drop is within a certain range, although it varies with each grid condition. The simulation was performed for the fastest case (Fast case) and the slowest case (Slow case), using the following constants based on the actual results in Bangladesh.

Fast case			Slow case		
r	=	1.0	r	=	0.6
M_0	=	9 s	M_0	=	11 s
k	=	2 %MW/Hz	k	=	4 %MW/Hz

Figure 3-2 Constants used in frequency calculations based on actual frequency drops

3.6 Proposed renewal UFLS settings

The proposed renewal UFLS settings obtained as a result of this study are shown in Table 3-5.

Table 3-5 Proposed renewal UFLS settings

RoCoF				Levels											
> 0.40Hz/sec and < 49.8Hz		> 0.20Hz/sec and < 49.8Hz		< 49.20Hz		< 49.00Hz		< 48.90Hz		< 48.80Hz		< 48.70Hz		< 48.60Hz	
2%	No Timer	2%	No Timer	2%	30sec	2%	No Timer	2%	No Timer	2%	No Timer	2%	No Timer	2%	No Timer
2%	No Timer	2%	No Timer	2%	60sec	2%	No Timer	2%	No Timer	2%	1sec	2%	1sec	2%	1sec
2%	No Timer	2%	No Timer			2%	No Timer	2%	No Timer	2%	2sec	2%	2sec	2%	2sec
2%	No Timer					2%	1sec	2%	1sec						
2%	No Timer					2%	2sec								
2%	No Timer														
2%	No Timer														
2%	No Timer														
14%		6%		4%		10%		8%		6%		6%		6%	
20%				40%											

Source: Study Team

The reasons for these settings (items considered for performing the settings) are described below.

■ Level Method

- The settling criteria are as follows.
 - ✧ The operating responsibility is to operate when the frequency drops below 49.0 Hz.
 - ✧ Since the underfrequency relays settling value for some IPPs is 48.5 Hz, the frequency value shall not reach 48.5 Hz even at the lowest point of the frequency value.
 - ✧ The target accident of the maximum unit generator loss is 24%.
The assumed accident case is a 1.2GW nuclear unit dropout at a minimum system demand of 5.0GW.
- The ratio for target feeders of the load shedding is 40%.
The reason is that, based on simulation and actual accident record, the maximum accident case that can be saved by the UFLS is a 30-40% power loss.
- The target for load shedding without timers at 49.0 Hz and 48.9 Hz is 12% in total.
The reason is the equivalent of 0.6 GW of power dropout, which is the largest number among large units at a minimum power demand of 5.0GW. In addition, this figure is equivalent in the current setting.
- The frequency tolerance of newly installed nuclear units is 49.0 Hz to 50.5 Hz, with allowable operating limits of 47.5 Hz minimum limit and 52.0 Hz maximum limit. Considering the normal lower limit of 49.0 Hz, when the frequency stays near that frequency, even slightly higher than 49.0 Hz, the UFLS is set to operate after a certain

timer has elapsed.

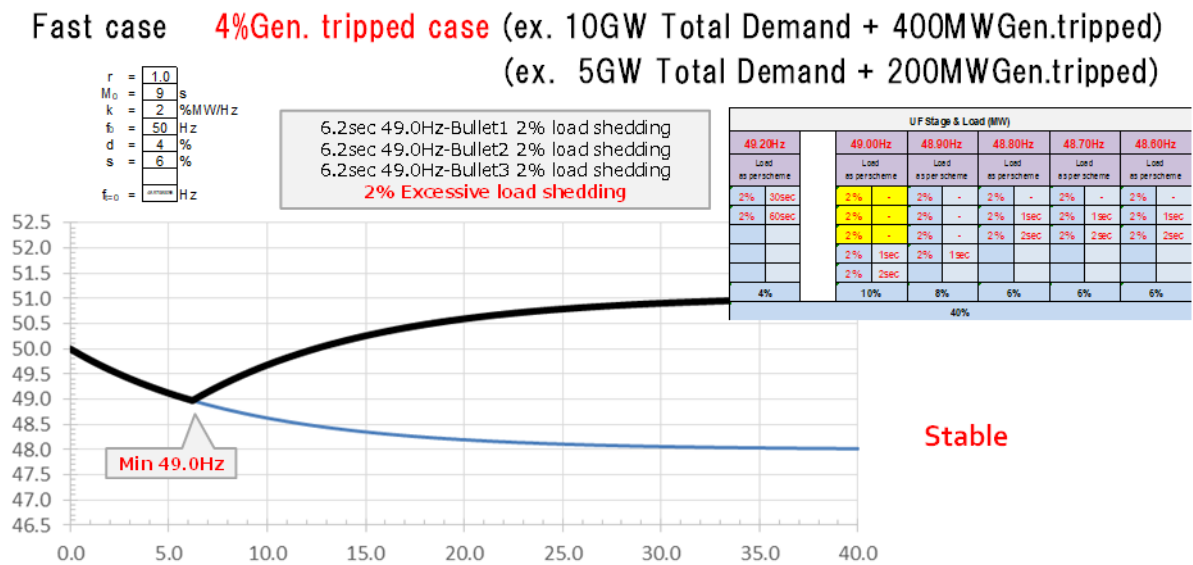
■ RoCoF method

➤ The setting criteria are as follows.

- ✧ When a sudden drop in frequency to a large power unit dropout is detected, the UFLS shall be operated as early as possible, even if the frequency is higher than 49.0 Hz, so that the frequency does not fall below 48.5 Hz.
- ✧ The amount of cutoff by RoCoF method should be determined considering that the frequency starts to rise with the operation of the level method at 49.0 Hz.

3.7 Simulation Results

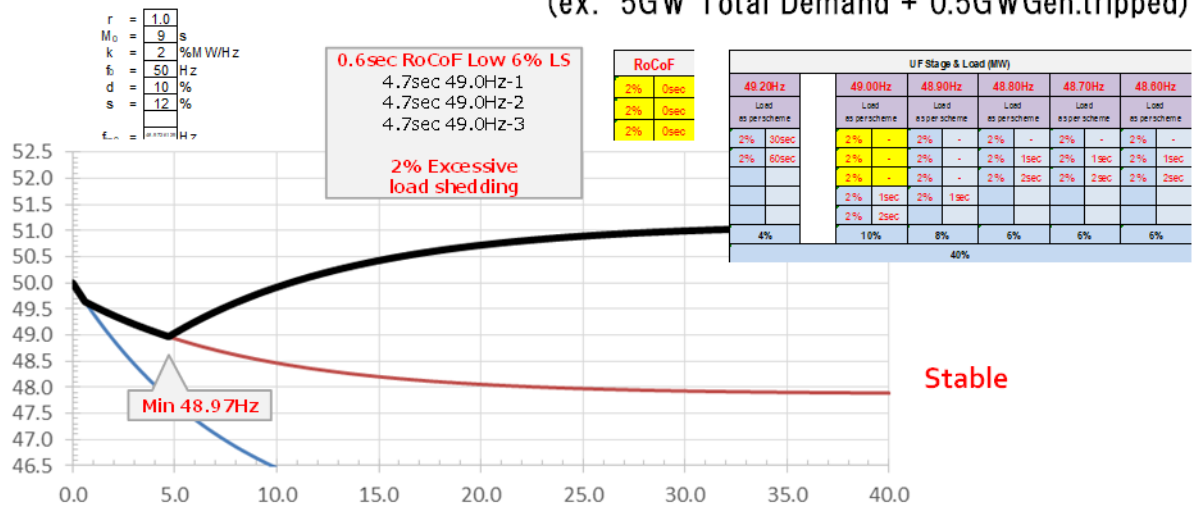
Typical simulation results for the proposed settings are shown below.



Source: Study Team

Figure 3-3 Frequency fluctuation and UFLS operation results for 4% Gen. tripped case

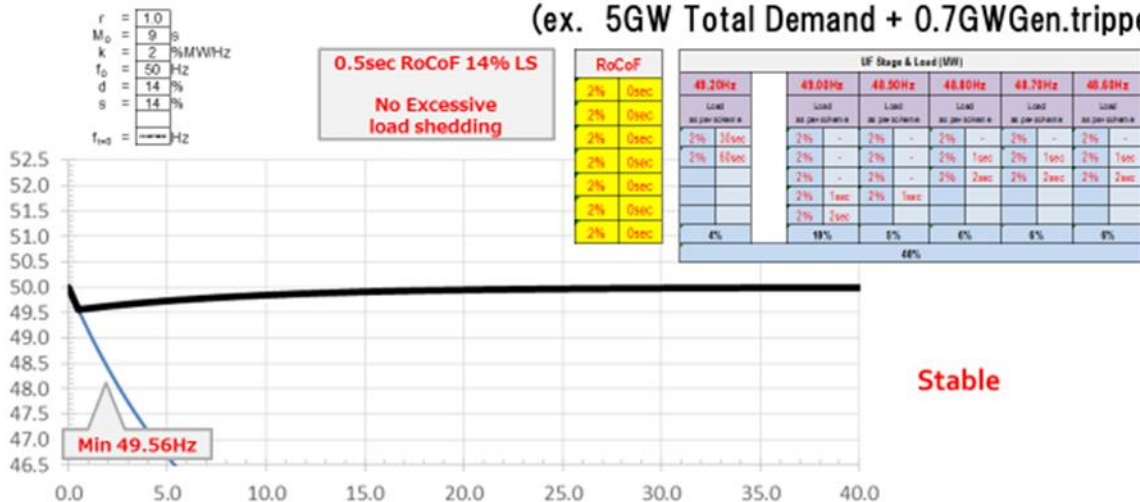
Fast case **10%Gen. tripped case** (ex. 10GW Total Demand + 1.0GW Gen.tripped)
(ex. 5GW Total Demand + 0.5GW Gen.tripped)



Source: Study Team

Figure 3-4 Frequency fluctuation and UFLS operation results for 10% Gen. tripped case

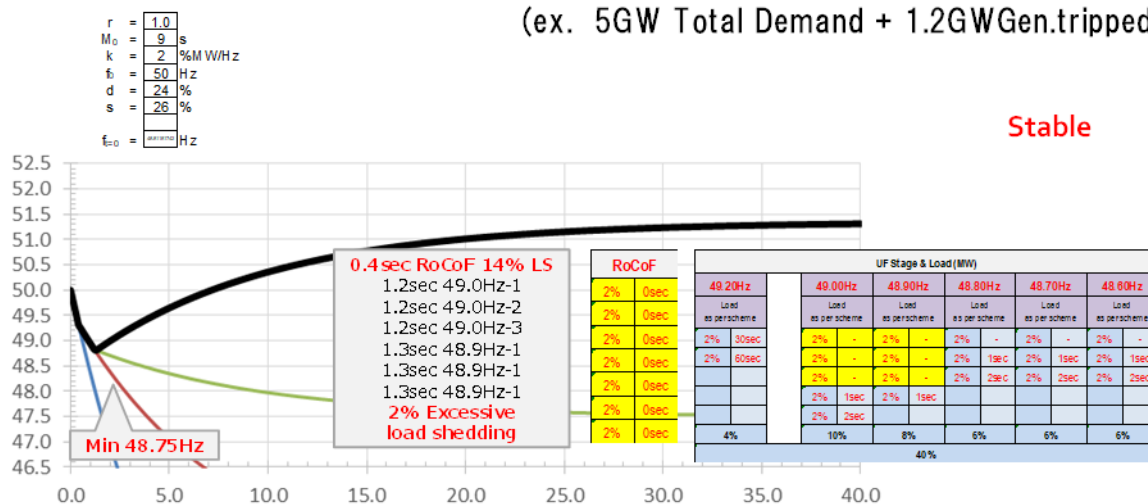
Fast case **14%Gen. tripped case** (ex. 10GW Total Demand + 1.4GW Gen.tripped)
(ex. 5GW Total Demand + 0.7GW Gen.tripped)



Source: Study Team

Figure 3-5 Frequency fluctuation and UFLS operation results for 14% Gen. tripped case

Fast case **24%Gen. tripped case** (ex. 10GW Total Demand + 2.4GWGen.tripped)
(ex. 5GW Total Demand + 1.2GWGen.tripped)



Source: Study Team

Figure 3-6 Frequency fluctuation and UFLS operation results for 24% Gen. tripped case

3.8 Validation of the frequency calculation model

The model was verified by comparing the calculations results with the actual frequency results. Specifically, df/dt was calculated based on the frequency results of five 250 MW or greater power loss or load shedding events, and a combination of parameters was obtained to match the df/dt values. The following table shows the results of calculating how many values of r would be obtained when the inertia constant M_0 was 9 or 11 and the frequency characteristic k was 1.85 or 4.

As a result, the calculation results show that the value of r is within a certain range.

Although they do not coincide because of the different grid conditions, the fact that they fall within approximately the same range confirms that the frequency calculation results can be considered to calculate reasonable values to a certain degree.

However, while reliable simulation results were obtained for generator failures of 250 MW or more, as in the case of the accidents used here, in some cases, sufficient approximation results were not obtained for generator failures of less than 250 MW. One reason for this may be the relatively large effects of FGMO operation and frequency characteristics of the load that offset the effects for generator dropouts. The fact that the simulation results actually show larger frequency fluctuations suggests that this may be the reason.

Table 3-6 Validation of the model using actual accident records Results 1

Incident	A Payra Tripped				B Eastern Grid Fail				C Rampal Tripped				D Mymensing zone Disconnected				E Payra + BEPCL Tripped			
Date	2022/8/11				2022/10/4				2022/10/24				2023/2/24				2023/3/15			
Tripped/Disconnected	490				1322				266				302				666			
System Demand	10333				7032				7851				8470				10131			
Ratio	4.7%				18.8%				3.4%				3.6%				6.6%			
df/dt actual record	0.1300				0.6500				0.1100				0.0980				0.1625			
	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4
M0	9	9	11	11	9	9	11	11	9	9	11	11	9	9	11	11	9	9	11	11
k	1.85	4	1.85	4	1.85	4	1.85	4	1.85	4	1.85	4	1.85	4	1.85	4	1.85	4	1.85	4
r	0.48	0.50	0.59	0.61	0.59	0.73	0.72	0.89	0.58	0.60	0.71	0.74	0.50	0.52	0.62	0.64	0.42	0.44	0.52	0.53
df/dt calculated value (difference)	0.1294 0.0008	0.1301 -0.0001	0.1303 -0.0003	0.1305 -0.0005	0.6521 -0.0021	0.6511 -0.0011	0.6504 -0.0004	0.6519 -0.0019	0.1096 0.0004	0.1098 0.0002	0.1101 -0.0001	0.1092 0.0008	0.0966 0.0014	0.0980 0.0000	0.0981 -0.0001	0.0975 0.0005	0.1604 0.0021	0.1625 0.0000	0.1611 0.0014	0.1633 -0.0008

Source: Study Team

Table 3-7 Validation of the model using actual accident records Results 2

	A1	B1	C1	D1	E1	Min.	Max.	Ave.	Min.	Max.	Ave.
r	0.48	0.59	0.58	0.50	0.42	0.42	0.59	0.51	0.42	0.73	0.54
M0	9										
k	1.85										

	A2	B2	C2	D2	E2	Min.	Max.	Ave.	Min.	Max.	Ave.
r	0.50	0.73	0.60	0.52	0.44	0.44	0.73	0.56			
M0	9										
k	4										

	A3	B3	C3	D3	E3	Min.	Max.	Ave.	Min.	Max.	Ave.
r	0.59	0.72	0.71	0.62	0.52	0.52	0.72	0.63	0.52	0.89	0.66
M0	11										
k	1.85										

	A4	B4	C4	D4	E4	Min.	Max.	Ave.	Min.	Max.	Ave.
r	0.61	0.89	0.74	0.64	0.53	0.53	0.89	0.68			
M0	11										
k	4										

Source: Study Team

3.9 Matters to be addressed

By updating the UFLS settings, a measure to prevent large-scale power outages was implemented. Although the introduction of the RoCoF and timer methods reduced the number of outages to a certain degree, it was still a continuation of the current UFLS settings in which a large number of outages were implemented early in order to settle the system so that it would not fall below 48.5 Hz.

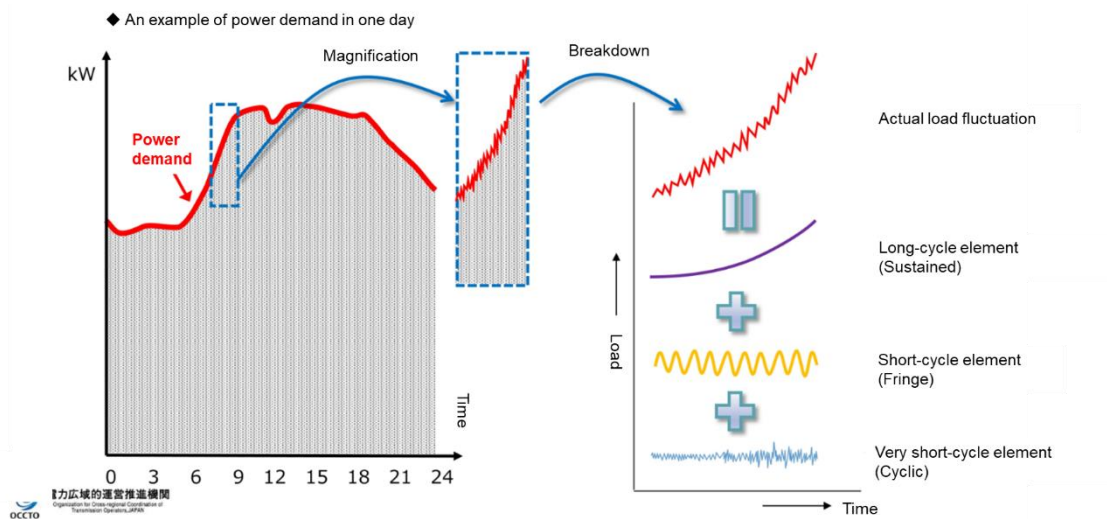
The current grid code calls for continued operation down to 48.0 Hz and sets the allowable limit of operation at 47.5 Hz. While understanding the actual conditions of each generator, we believe it is necessary to continue efforts to request, to the extent possible, that the underfrequency protection relay on the generator side be adjusted to 47.5 Hz.

If this is achieved, it will be possible to further reduce the amount of load shedding by the UFLS in the event of a major power outage, leading to a smaller outage range.

4. Ensuring Regulating Reserve

4.1 Calculation of the Necessary Amount of Regulating Reserve

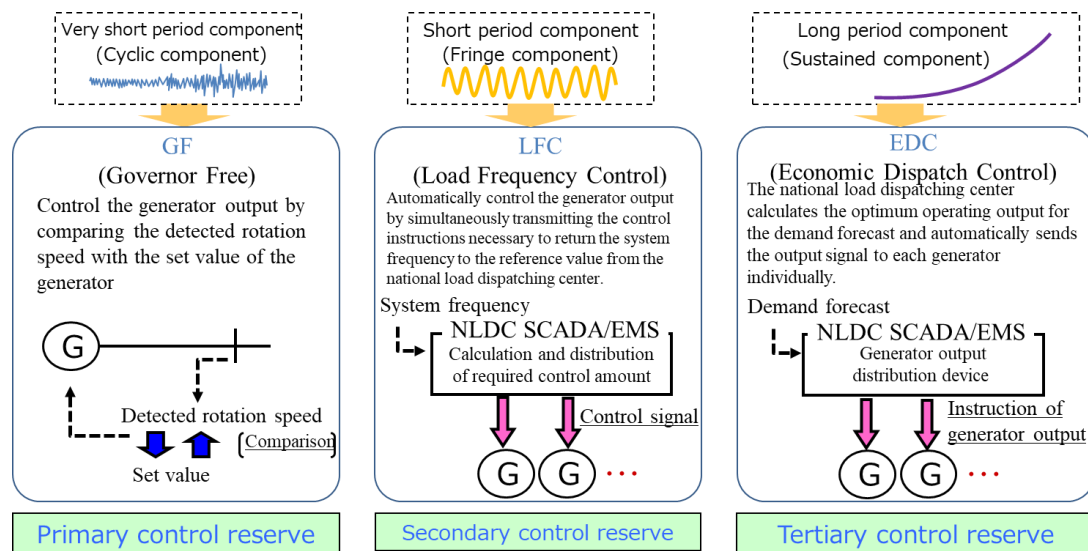
Power demand is changing every moment along with the electricity usage status such as operation in factories and switching lights in households. As described on Figure 4-1, the power demand fluctuation can be separated into 3 elements, which are Long-cycle element (Sustained), Short-cycle element (Fringe), and Very short-cycle element (Cyclic).



Source: “Approaches for calculating the necessary amount of Primary control reserve to Tertiary control reserve (5 Nov, 2019),
small committee of considering the balancing market, OCCTO”

Figure 4-1 Constantly changing Power Demand

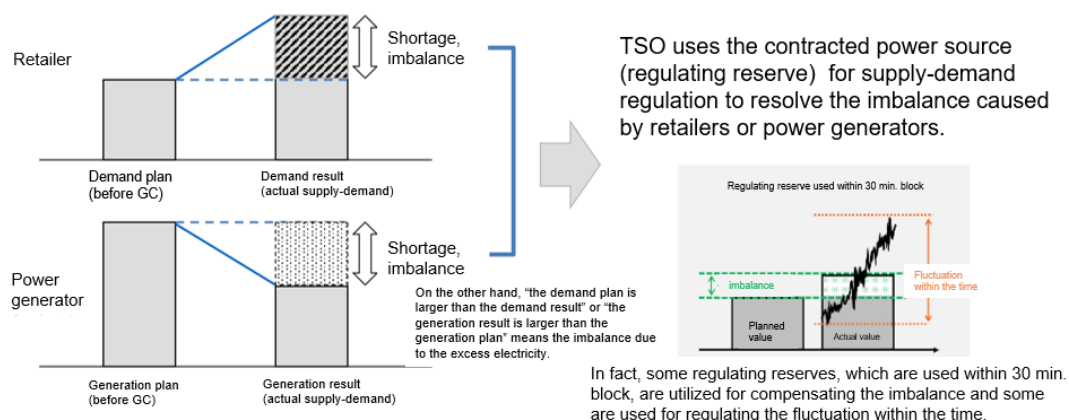
Figure 4-2 shows the frequency control functions in response to each fluctuation component. On the left of Figure 4-2 is very short period component, and the governor free operation responds to this fluctuation as a frequency control function. Governor free operation controls generator output by comparing the detected rotation speed with the set value of the generator. On the center of Figure 4-2 is short period component, and the LFC (Load Frequency Control) responds to this fluctuation as a frequency control function. LFC automatically controls the generator output by simultaneously transmitting the control instructions necessary to return the system frequency to the reference value from the Central Load Dispatching Center. On the right of Figure 4-2 is long period component, and the EDC (Economic Dispatch Control) responds to this fluctuation as a frequency control function. EDC is a function that automatically controls the generator output by sending the optimum generator operating output for the demand forecast individually to each generator. The optimum generator operating output for the demand forecast is calculated at the central load dispatching center.



Source: “Approaches for calculating the necessary amount of Primary control reserve to Tertiary control reserve (5 Nov, 2019), small committee of considering the balancing market, OCCTO”

Figure 4-2 Frequency Control Function of the Generator

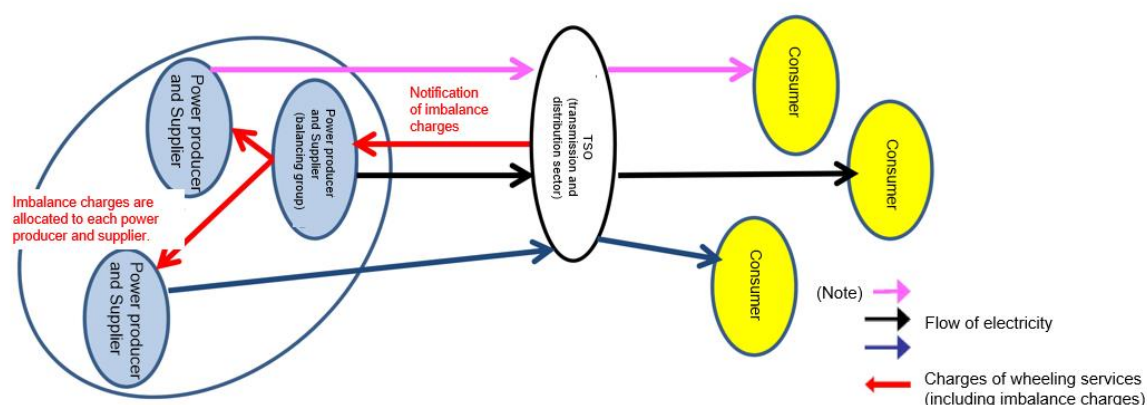
Figure 4-3 shows the structure of current supply-demand balancing in Japan. After the liberalization of a retail electricity market since FY2016 in Japan, the planned value balancing system has been introduced. Since then, the retailer and generator create the demand plan and generation plan for a 30-min. block, which divide a day into 48 blocks, and match the supply and demand by one hour before the actual supply-demand (Gate Close (GC)). If the imbalance between the actual supply-demand and planned demand occurs, the TSO (Transmission System Operator) gives the instruction of power source (regulating reserve) and regulates the electricity to solve the imbalance.



Source: “Imbalance charge system (28 Jan, 2022) Electricity and Gas Market Surveillance Commission Administration Office, Network Business Monitoring Division”

Figure 4-3 The structure of supply-demand balancing

Figure 4-4 shows the conceptual diagram of balancing group introduced in wheeling services in Japan. The electric power company, which launches a business along with the liberalization of entry of electricity retail business, is called “Power producer and supplier (PPS)”, and the PPSs and TSO have a contract of a wheeling service and a representative contractor is selected from the PPSs. The system is referred to as a balancing group. Balancing generation and consumption is achieved by all PPSs forming the group. Thus, the larger the group scale, the smaller the risk causing the imbalance.



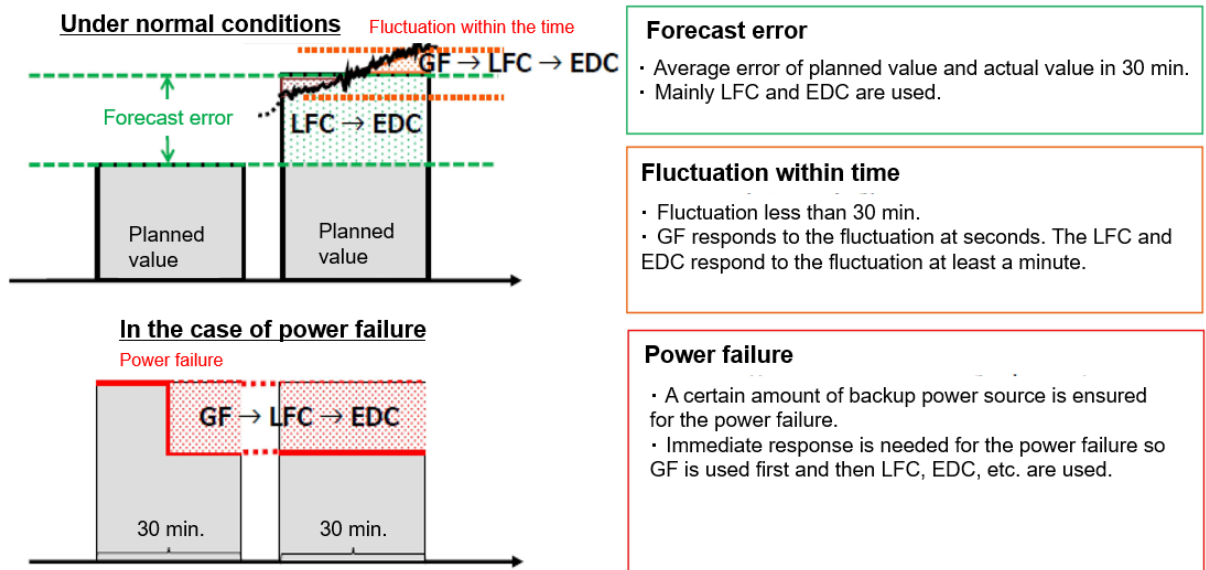
*The third party can take care of notification of the imbalance charges and paperwork of settlement of charges.

Source: “Material submitted to the administration office of the 4th system design working group -Ensuring regulating reserve- 9 Dec, 2013, METI)

Figure 4-4 Conceptual diagram of balancing group

The events handled by regulating reserves are mainly divided into two categories: under the normal condition and in the event of an accident. Under the normal condition, demand forecast error, renewable energy output forecast error, and fluctuations in load and renewable energy are handled, and in the event of an accident, power failure is handled.

An electricity retailer forecasts the demand and creates the demand plan but the difference between the forecast and demand can occur. This is called forecast error, and the demand and supply are balanced by using regulating reserve. The error between the forecast and actual values of renewable energy source output are also regulated using the regulating reserve. The actual demand keeps changing every moment and the output of renewable energy source is changing every moment. This situation is also handled by matching the demand and supply using the regulating reserve. The power source is sometimes stopped (sudden loss of generator) because of unexpected troubles. The error between demand and supply caused by such unexpected trouble is handled by regulating reserve.



Source: “Issues to solve by establishing balancing markets (6 June, 2017), Agency for Natural Resources and Energy”

Figure 4-5 Events handled by regulating reserves

The electricity has characteristics that it cannot be stored (simultaneously consumed) so the demand changing every moment (consumption) is balanced by matching electricity supply simultaneously. The supply capacity of matching the demand and supply, which is not grasped preliminarily, is “regulating reserve” and it has an important role in maintaining the frequency and supplying the electricity stably. In Japan, the balancing market in which the reserve is traded has been established since FY2021. Table 4-1 shows the requirement of products in the balancing market in Japan.

Table 4-1 Requirement of products in the balancing market in Japan

	Primary	Secondary		Tertiary	
	Frequency Containment Reserve (FCR)	Synchronized Frequency Restoration Reserve (S-FRR)	Frequency Restoration Reserve (FRR)	Replacement Reserve (RR)	Replacement Reserve-for FIT (RR-FIT)
Instruction /control	—	instruction/control (LFC signal)	instruction/control (EDC signal)	instruction/control	instruction
Monitoring	online (Offline is available with some conditions ^{*2})	online	online	online	Online/ Offline
Telecommunication Method	Dedicated line ^{*1} (Unnecessary if it is monitored offline)	Dedicated line ^{*1}	Dedicated line ^{*1}	Dedicated line ^{*1}	Dedicated line ^{*1} Or VPN
Response speed	Within 10 sec.	Within 5 min.	Within 5 min.	Within 15 min. ^{*3}	Within 45 min.
Length of sustention	5+ min. ^{*3}	30+ min.	30+ min.	3+ hour	3+ hour
Parallel necessity	Necessary	Necessary	Optional	Optional	Optional
Instruction interval	- (Automatic)	0.5 sec to tens of seconds ^{*4}	1 minute to some minutes ^{*4}	1 minute to some minutes ^{*4}	30 minutes
Monitoring interval	One to several sec. ^{*2}	About 1 to 5 sec. ^{*4}	About 1 to 5 sec. ^{*4}	About 1 to 5 sec. ^{*4}	1 to 30 min. ^{*5}
Upper Limit of Bidding	Amount of increase or decrease within 10 sec. AND bandwidth of governor-free mode	Amount of increase or decrease within 5 min. AND bandwidth of LFC mode	Amount of increase or decrease within 5 min. AND bandwidth of online control	Amount of increase or decrease within 15 min. AND bandwidth of online control	Amount of increase or decrease within 45 min. AND bandwidth of online control
Minimum bid amount (Bid increase)	5 MW (1 MW if it is monitored offline)	5 MW ^{*1,4}	5 MW ^{*1,4}	5 MW (1kW)	5 MW Or 1 MW)
Bid unit	1 kW	1 kW	1 kW	1 kW	1 kW
Regulating direction	up and down	up and down	up and down	up and down	up and down

*1 Connection to simple dispatching system and Central Load Dispatching Office system is under consideration in the government in terms of cyber security so it will be considered again.

*2 Numerical data must be submitted later. (The way of obtaining and providing the data will be considered.)

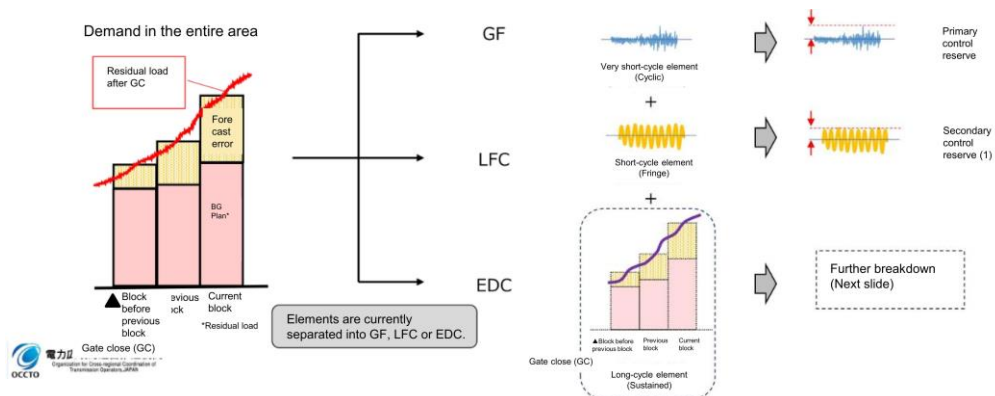
*3 Response speed in Okinawa area is set separately in light of the area-specific condition.

*4 Communication protocol and instruction interval, etc. must be considered separately in the case where connection to Central Load Dispatching Office system and simple dispatching system is possible.

*5 As 30 min. at maximum, adjusting to the cycle collected by operators is allowed

Source: “Organization of points regarding the balancing market and future plan (1 Aug, 2019),
small committee of considering the balancing market, OCCTO”

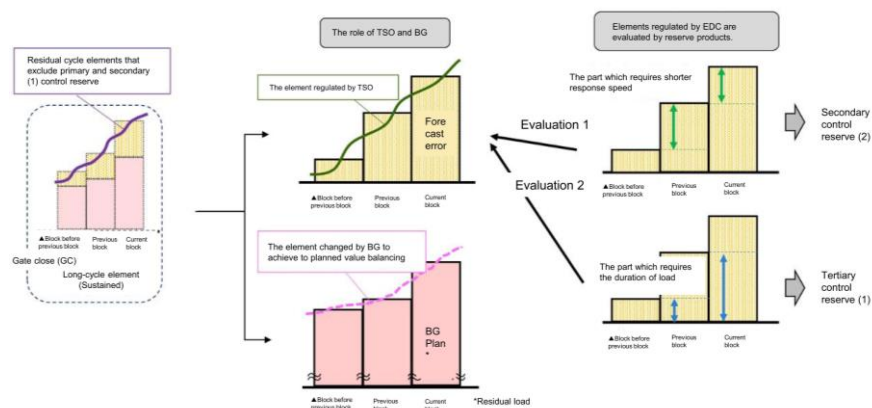
The residual load is defined as the load calculated by deducting the output of PV power (excluding the self-consumption) and wind power from the power demand (excluding the self-consumption of PV). Figure 4-6 shows the relationship between the frequency control function of generators and the components of the fluctuation in the residual load (30 min. or less). On the other hand, the power generation plan whose unit is 30-minute block, which is created by a balancing group (BG), is submitted but the power output for the next block is changed by the balancing group in order to achieve to balance the planned value. It is thought that the long-period component currently being adjusted by Economic Dispatch Control (EDC) includes a certain amount of the increase in the power output of the balancing group. Therefore, the long-cycle elements are further separated and the necessary amount is calculated on the basis of the data.



Source: “Approaches for calculating the necessary amount of primary control reserve to tertiary control reserve (5 Nov, 2019), small committee of considering the balancing market, OCCTO”

Figure 4-6 Residual load elements separation and regulating reserve responding to the elements

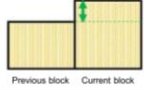
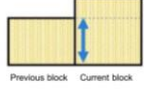
When the long-cycle element currently regulated by EDC is quantified, the residual forecast error in each 30 min. block (the average of 30 min. residual load – the BG planned value) is used to calculate the necessary amount for the fluctuation regulated by EDC. When the residual forecast error is evaluated, the differences between the current block and the block that is 30 min. before or after the current block are handled by secondary control reserve (2) whose response speed is short and the part of the block which keeps the load to the next block is handled by tertiary control reserve (1) to calculate the necessary amount.



Source: “Approaches for calculating the necessary amount of primary control reserve to tertiary control reserve (5 Nov, 2019), small committee of considering the balancing market, OCCTO”

Figure 4-7 Separation of long-cycle elements

Figure 4-8 shows the approaches for extracting the data of the necessary amount of regulating reserves responding to the fluctuation under the normal condition in light of the function of regulating reserves.

■ In light of the functions of each regulating reserve, the following approaches are used to extract the data for calculating the necessary amount of each product.		
Product category	Image diagram	Method of extracting data for calculating the necessary amount
Primary control reserve		Original data of residual load ^{*1} — The 10-min. cycle element ^{*2} of residual load ^{*1}
Secondary control reserve (1)		The 10-min. cycle element ^{*2} of residual load ^{*1} — The 30-min. cycle element ^{*2} of residual load ^{*1}
Secondary control reserve (2)		Difference between the blocks of the 30-min. average residual forecast error ^{*3}
Tertiary control reserve (1)		Continuing amount from the previous block of the 30-min. average residual forecast error ^{*3}

Source: “Approaches for calculating the necessary amount of primary control reserve to tertiary control reserve (5 Nov, 2019), small committee of considering the balancing market, OCCTO”

Figure 4-8 The approaches for extracting the data of the necessary amount of regulating reserves

The maximum electricity generation capacity per unit is the necessary capacity to respond to the loss of generator due to an accident.

In one example of the area with 50 Hz in Japan, the maximum electricity generation capacity per unit is currently 1,000 MW for the system capacity of approximately 70 GW so the system capacity ratio is 1.4 %.

Table 4-2 and Figure 4-9 show the method for calculating the necessary amount of regulating reserve (including under the normal condition and in the event of a failure) and the statistical processing method, respectively.

Table 4-2 Method for calculating the necessary amount (including under the normal condition and in the event of a failure)

Regulating reserve	Method for calculating the necessary amount
Primary Control Reserve	3σ equivalent value ^{*3} of (Original data of residual load ^{*1} – the 10-min. cycle element of original data ^{*1}) + Maximum electricity generation capacity per unit
Secondary Control Reserve (S-FRR)	3σ equivalent value ^{*3} of (The 10-min. cycle element of original data ^{*1} – the 30-min. cycle element of original data ^{*1}) + Maximum electricity generation capacity per unit
Secondary Control Reserve (FRR)	3σ equivalent value ^{*3} of (Difference between the blocks of the 30-min. average residual forecast error)

Tertiary Control Reserve (RR)	3σ equivalent value* ³ of (Continuing amount from the previous block of the 30-min. average residual forecast error* ³) + Maximum electricity generation capacity per unit
--------------------------------------	---

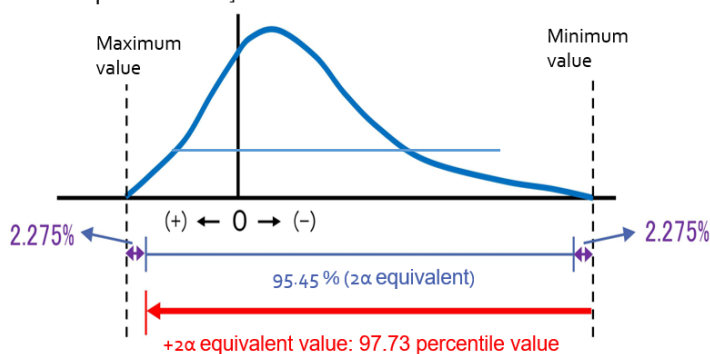
*1 The measurement data of residual load (1 sec. to 10 sec.)

*2 The 30 min. average of measurement for 30-sec. residual load – (BG demand planning – the forecast value of renewable energy at the time of GC)

*3 “ 3σ equivalent value”: it is a so-called maximum value that is statistically processed. To respond to the error that is equivalent to the previous result, the value is statistically processed in accordance with the previous result. Specifically, the value of 99.87 percent (in the case of 10,000 data in total, it is the 9,987th value counted from the smallest.) is used.

Source: Created by Study Team on the basis of “Approaches for calculating the necessary amount of primary control reserve to tertiary control reserve (5 Nov, 2019), small committee of considering the balancing market, OCCTO”

[Conceptual diagram of $+2\alpha$ equivalent value]



Source: “Data analysis results up to July (1 Sep, 2016), Committee office regarding regulating reserve and supply-demand balance evaluation, etc. , OCCTO”

Figure 4-9 Statistical processing method for calculating the necessary amount

Table 4-3 shows the specification of the load data received from NLDC for the calculation of the required amount of frequency control reserve.

Table 4-3 Load Data Specification

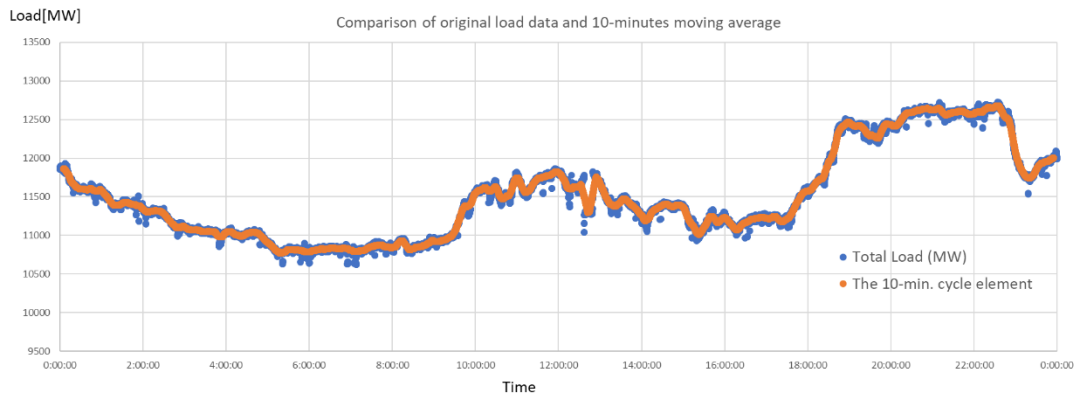
Specification	Value
Data collection date	For weekday: Wednesday, May 10, 2023 For holiday: Friday, May 5, 2023
Time interval	1 second
Period	24 hours a day

Source: Study Team

Figure 4-10 and Figure 4-11 shows the results of comparing the original load data and the 10-

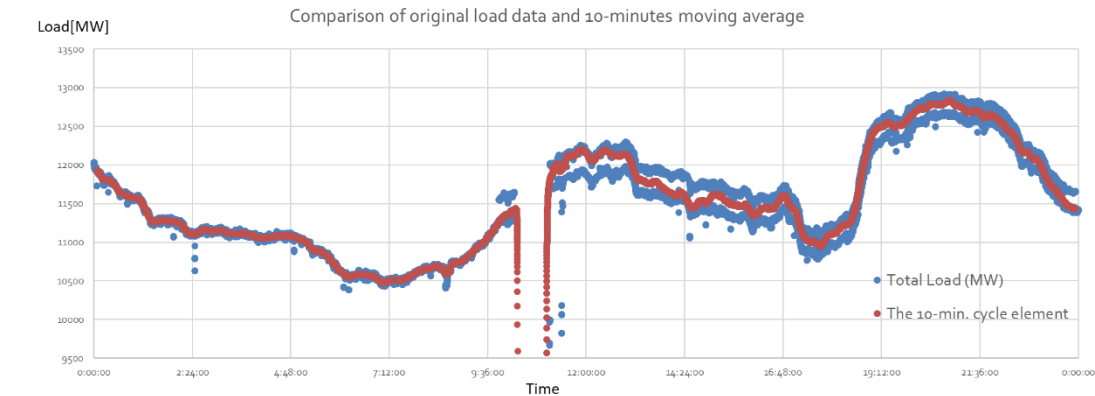
minute moving average using the total load data on Tuesday May 9, 2023 and Wednesday May 10, 2023 in order to understand the load fluctuations on weekdays. (The drop in load around noon in Figure 4-11 is due to missing data.)

It can be seen that the load fluctuations are greater in the afternoon and at night than in the morning. Figure 4-12 and Figure 4-13 shows the hourly 3σ equivalent value of the difference between the original load data and the 10-minute moving average.



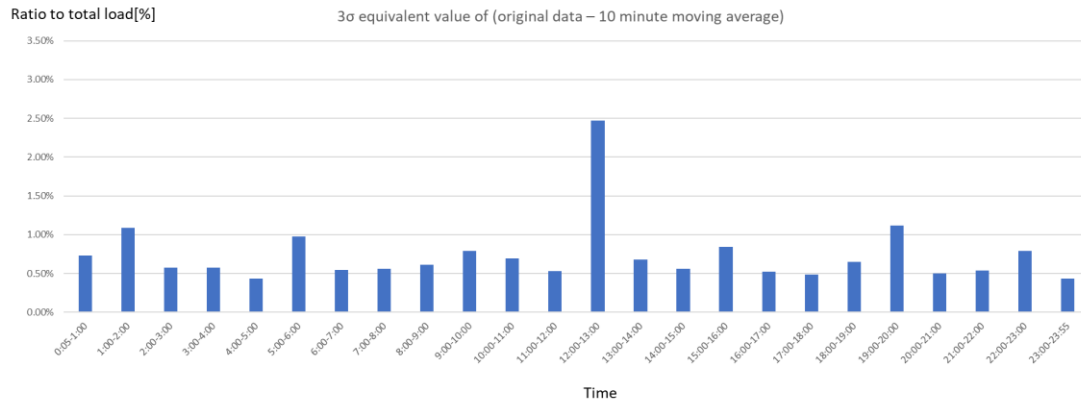
Source: Study Team (Based on NLDC data)

Figure 4-10 Comparison of original load data and 10-min. moving average (Weekday Tue., May 9, 2023)



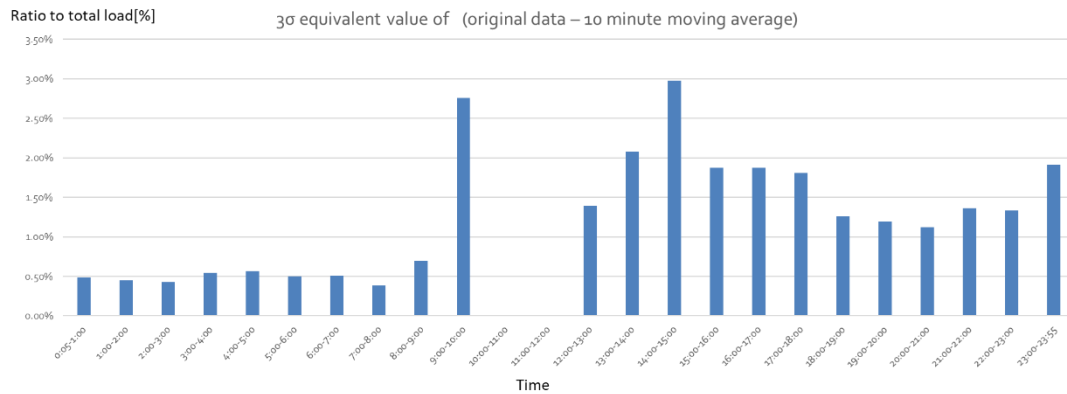
Source: Study Team (Based on NLDC data)

Figure 4-11 Comparison of original load data and 10-min. moving average (Weekday Wed., May 10, 2023)



Source: Study Team (Based on NLDC data)

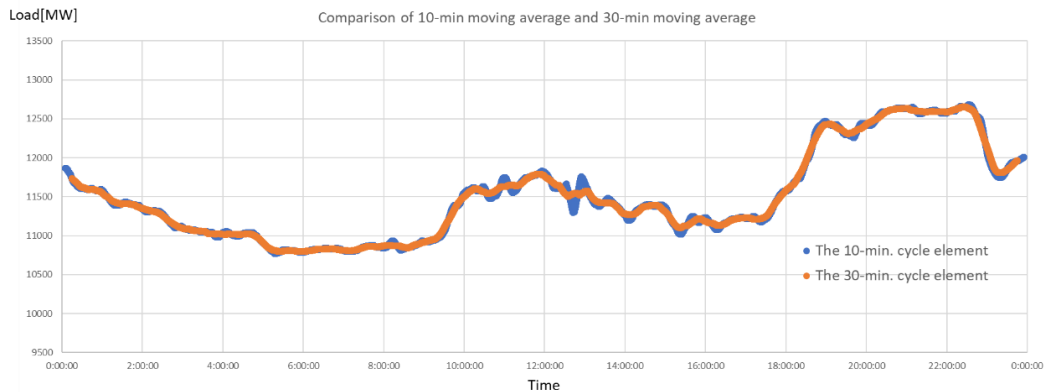
Figure 4-12 3 σ equivalent value of (original data – 10 min. moving average) (Weekday Tue., May 9, 2023)



Source: Study Team (Based on NLDC data)

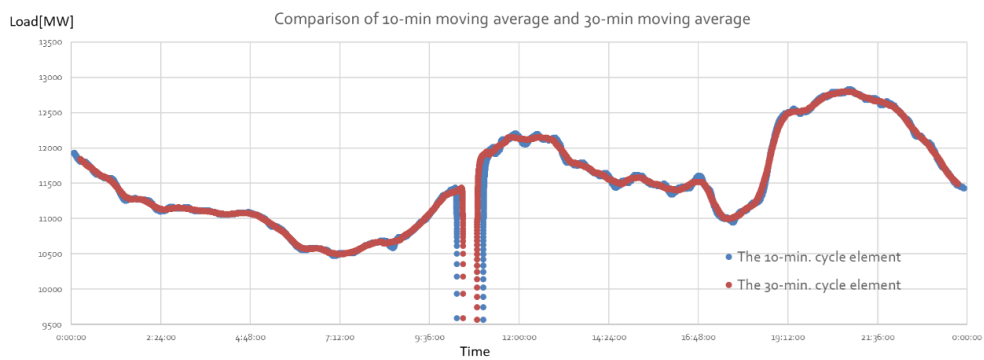
Figure 4-13 3 σ equivalent value of (original data – 10 min. moving average) (Weekday Wed., May 10, 2023)

A comparison of the 10-minute and 30-minute moving averages using the total load data on Tuesday May 9, 2023 and Wednesday May 10, 2023 is shown in Figure 4-14 and Figure 4-15. The difference between the 10-minute moving average and the 30-minute moving average is slightly smaller than the difference between the original load data and the 10-minute moving average. Figure 4-16 and Figure 4-17 shows the hourly 3 σ difference between the 10-minute moving average and the 30-minute moving average.



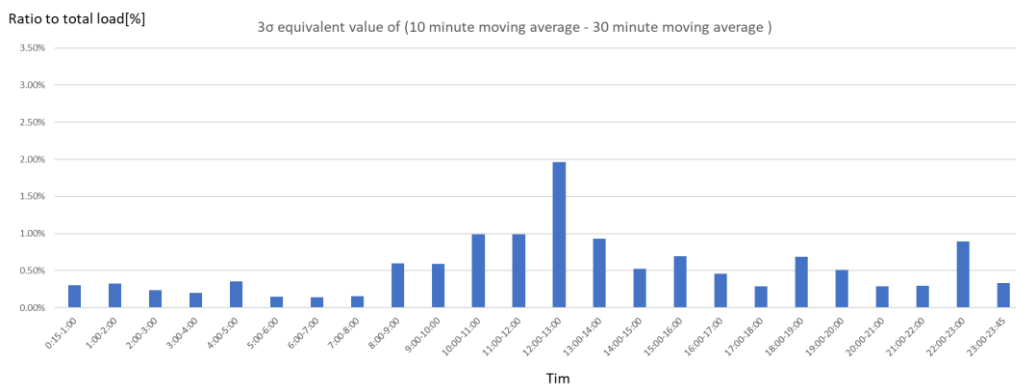
Source: Study Team (Based on NLDC data)

Figure 4-14 Comparison of 10-min. moving average and 30-min. moving average (Weekday Tue., May 9, 2023)



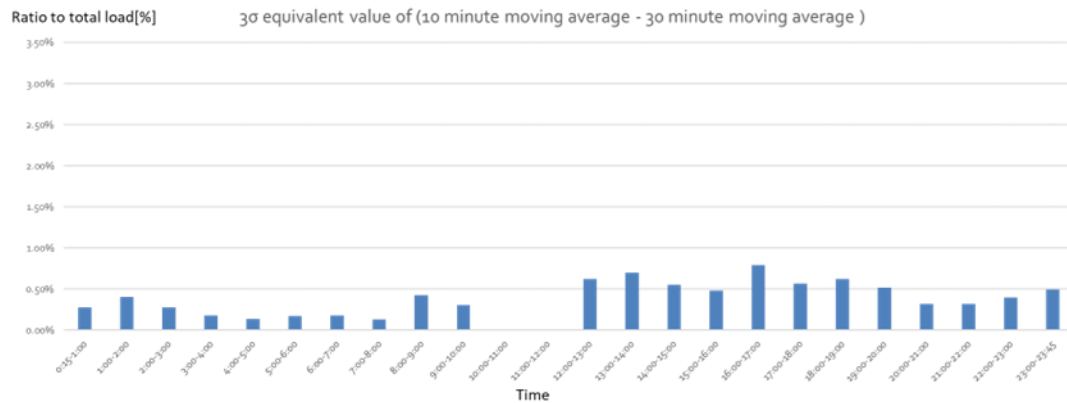
Source: Study Team (Based on NLDC data)

Figure 4-15 Comparison of 10-min. moving average and 30-min. moving average (Weekday Wed., May 10, 2023)



Source: Study Team (Based on NLDC data)

Figure 4-16 3σ equivalent value of (10-min. moving average – 30-min. moving average) (Weekday Tue., May 9, 2023)

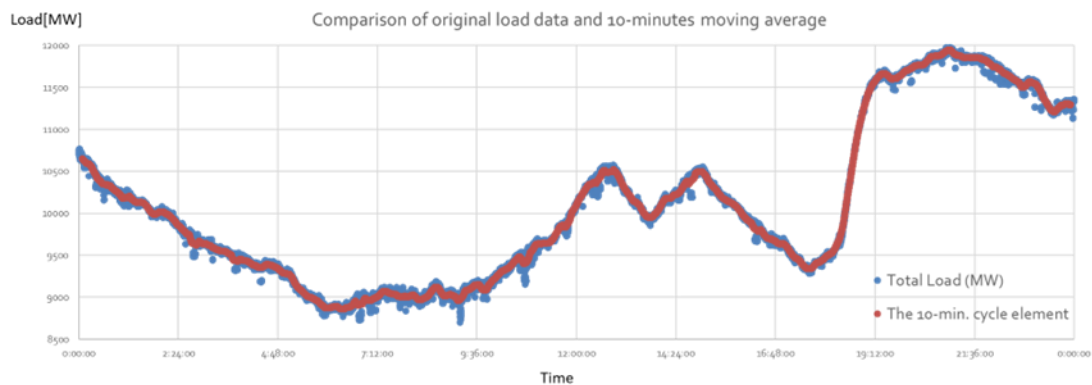


Source: Study Team (Based on NLDC data)

Figure 4-17 3 σ equivalent value of (10-min. moving average – 30-min. moving average) (Weekday Wed., May 10, 2023)

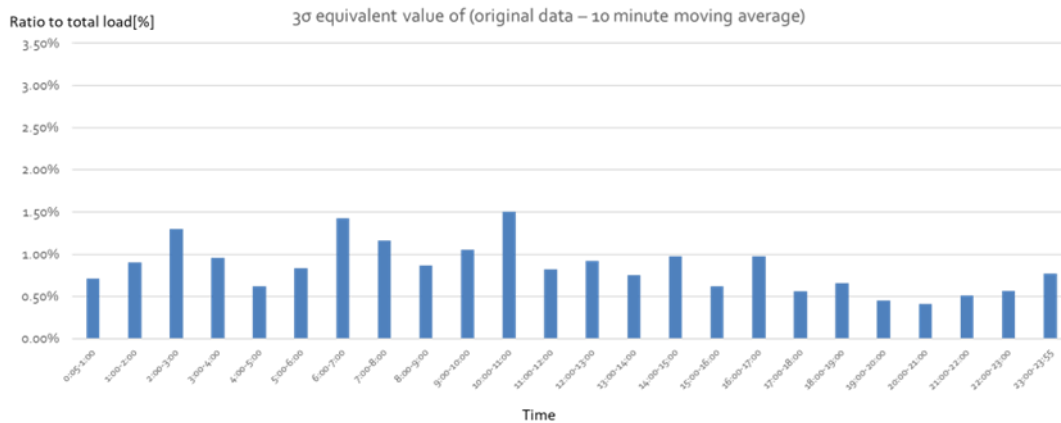
Figure 4-18 shows the results of comparing the original load data and the 10-minute moving average value using the total load data on Friday May 5, 2023 in order to understand the load fluctuations on holidays.

The load fluctuation on May 5th is smaller throughout the day than on May 10th. Figure 4-19 shows the hourly 3 σ equivalent value of the difference between the original load data and the 10-minute moving average.



Source: Study Team (Based on NLDC data)

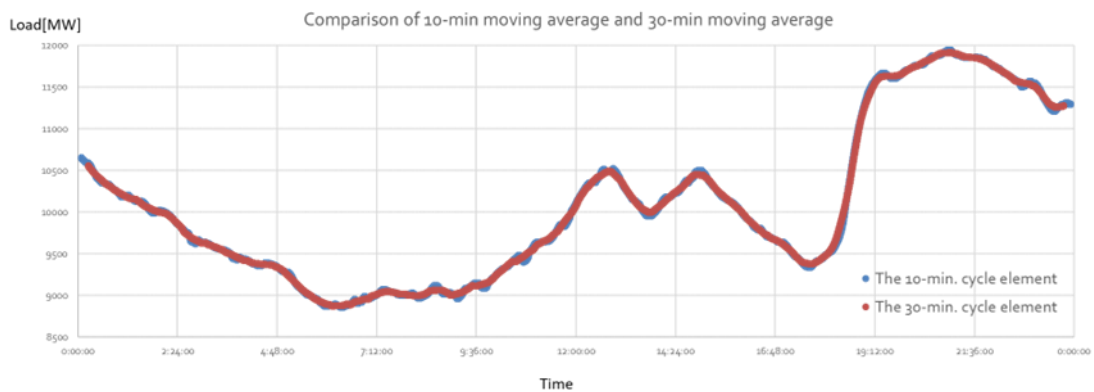
Figure 4-18 Comparison of original load data and 10-min. moving average (Holiday: Fri., May 5, 2023)



Source: Study Team (Based on NLDC data)

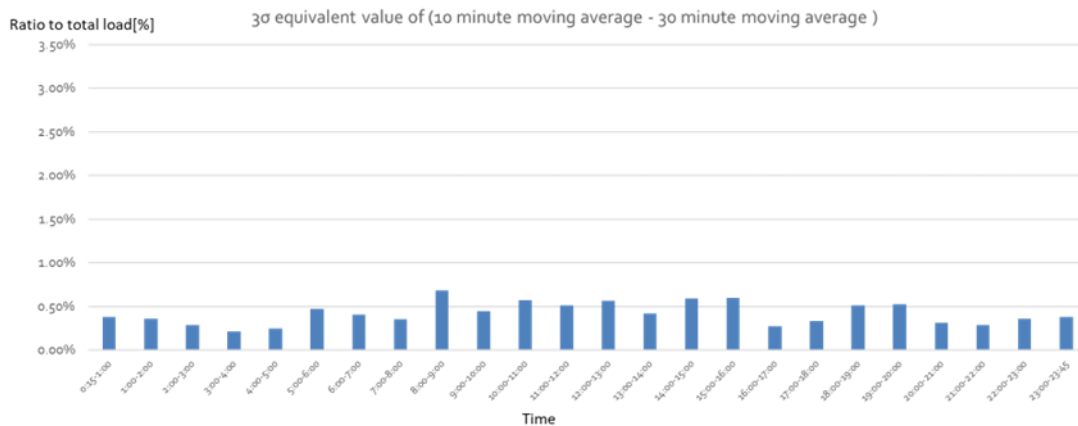
Figure 4-19 3 σ equivalent value of (original data – 10 min. moving average) (Holiday: Fri., May 5, 2023)

A comparison of the 10-minute and 30-minute moving averages using the total load data on Friday, May 5, 2023 is shown in Figure 4-20. The difference between the 10-minute moving average and the 30-minute moving average is smaller than the difference between the original load data and the 10-minute moving average. Figure 4-21 shows the hourly 3 σ equivalent value of the difference between the 10-minute moving average and the 30-minute moving average.



Source: Study Team (Based on NLDC data)

Figure 4-20 Comparison of 10-min. moving average and 30-min. moving average (Holiday: Fri., May 5, 2023)



Source: Study Team (Based on NLDC data)

Figure 4-21 3σ equivalent value of (10-min. moving average – 30-min. moving average)
(Holiday: Fri., May 5, 2023)

Table 4-4 shows the calculation results of the required primary control reserve and secondary control reserve in consideration of load fluctuations under normal condition.

Table 4-4 Calculation results of the required amount of primary/secondary control reserve under normal condition

	Primary control reserve 3σ equivalent value of (original data – 10 min. moving average)	Secondary control reserve 3σ equivalent value of (10 minute moving average - 30 minute moving average)
Weekdays: Tue., May 9, 2023	206 MW (1.93% of minimum demand)	202 MW (1.90% of minimum demand)
Weekdays: Wed., May 10, 2023	273 MW (2.63% of minimum demand)	80 MW (0.77% of minimum demand))
Holiday: Fri., May 5, 2023	111 MW (1.28% of minimum demand))	60 MW (0.69% of minimum demand))

Source: Study Team

Table 4-5 shows the calculation results of the primary and secondary control reserves in consideration of load fluctuations under normal condition and trip of a generation unit with maximum capacity.

In the example of Japan shown in Table 4-2, the secondary control reserve is divided into S-FRR and secondary control reserve (FRR), and the calculation method for the tertiary reserve is also described. Regarding the calculation method of the FRR and the tertiary control reserve, it was proposed based on the unique situation in Japan that a certain scale of pumped storage hydro power plants is introduced and the 30-minute balancing rule is applied. For this reason, the

calculation methods for the FRR and the tertiary control reserve are not applicable to the calculation of the required amount in Bangladesh. Some of the load data did not include offline load data, so the calculated value was not used as is, but the ratio to the total load was calculated and rounded up. In addition, the unit capacity of 750 MW was adopted as the current maximum capacity for a single generation unit.

There is option to consider to use either bigger value as required control reserve, since when required control value is decided from required control reserve is assumed from calculated required amount from load fluctuations under normal condition and the total load of maximum capacity for a single generation unit, there are possibility that required amount will be too large.

Table 4-5 Required amount of regulating reserve under normal condition and N-1 contingency

Category	Event	Calculation Method	Required amount of control reserve
Primary control reserve	Load fluctuation under normal condition	3σ equivalent value of (Original load data – 10-min. cycle element)	2-3% of total load
	N-1 Contingency	Max generation capacity per unit	750[MW]
Secondary control reserve	Load fluctuation under normal condition	3σ equivalent value of (10-min. cycle element – 30-min. cycle element)	2-3% of total load
	N-1 Contingency	Max generation capacity per unit	750[MW]

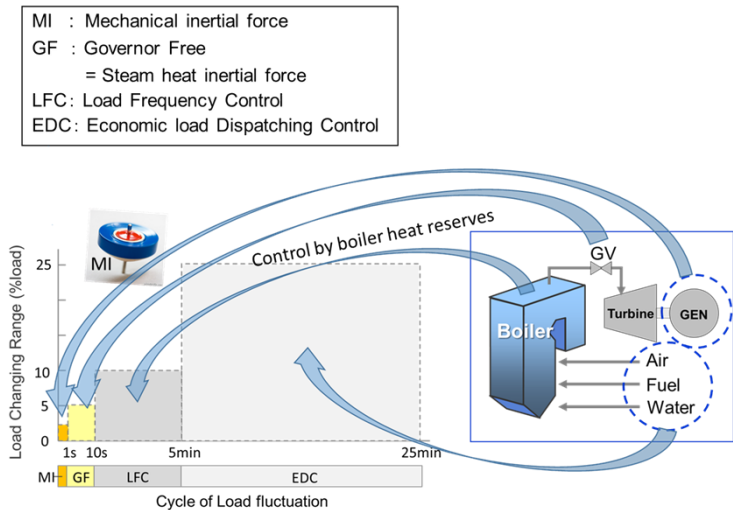
Source: Study Team

In this survey, the required amount was calculated using the limited data such as 2days for a weekday and 1 day for a weekend. In considering the introduction amount of FGMO and LFC and applying it to actual operation, it is necessary to collect data for a longer period and calculate the necessary amount.

4.2 The Role of Thermal Power Plants in Regulating Frequency

Figure 4-22 shows the thermal power control in response to load fluctuations in the standard cycle in Japan. Thermal power output is controlled with inertia of generator and governor free

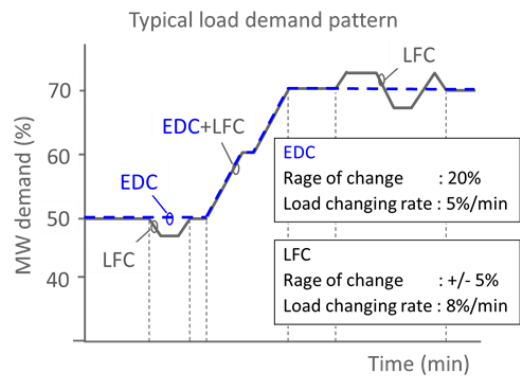
function for load fluctuation within 10 seconds. Generator output is controlled with LFC function for load fluctuation within 5 minutes and generator output is controlled through boiler control, including water, fuel, and air for load fluctuation over 25 minutes.



Source: Study Team

Figure 4-22 Thermal power output control for the cycle of load fluctuation

Figure 4-23 shows the example of output signal LFC and EDC from Central Load Dispatching Center. The blue line in Figure 4-23 describes the EDC signal, which is the output signal from the Central Load Dispatching Center and the grey line in Figure 4-23 describes the LFC signal. In this example, the range of output change from LFC is $\pm 5\%$ and load changing rate is 8%/min. The range of output change from EDC is 20% and load changing rate is 5%/min. Generally, load changing rate of LFC is faster than EDC, even though the range of output change is small.

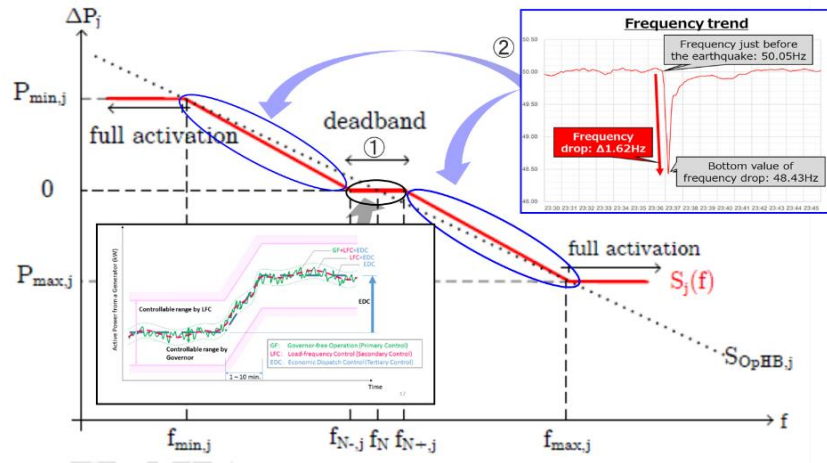


Source: Study Team

Figure 4-23 Example of the LFC and EDC signals from Central Load Dispatching Center

Droop program is one of the frequency regulation functions by Free Governor Mode of Operation (FGMO). Figure 4-24 shows the Droop program and its function. the frequency is

plotted on the horizontal axis and generator outputs on the vertical axis in Figure 4-24. The Droop program controls outputs of thermal power at high speed in the case of significant fluctuations in the system frequency. The dead band is set not to control the frequency by the Droop program if the system frequency is within normal fluctuation. Setting the Droop program properly will regulate frequency fluctuations.

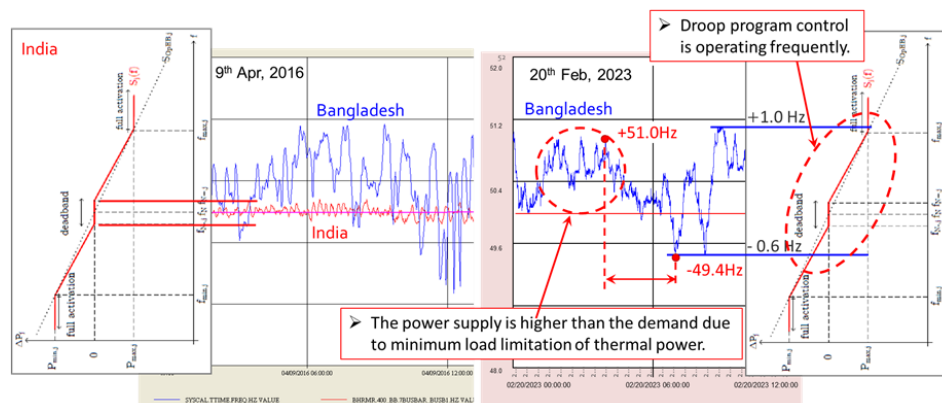


Source: Study Team

Figure 4-24 Droop program and its function

<Frequency fluctuation comparison between Bangladesh and India>

Figure 4-25 shows the frequency fluctuation comparison between Bangladesh and India. The frequency fluctuation in India is maintained within the dead band of the Droop program. On the other hand, the frequency fluctuation in Bangladesh is outside of the dead band. Dead band range of Droop program should be matched with the normal frequency fluctuation range, for governor will not excessively respond with the normal fluctuation. In case of large fluctuations, such as a loss of a large generator, it is desirable that the frequency deviates from the dead band and the thermal power output is controlled according to the droop characteristics set to Droop program.



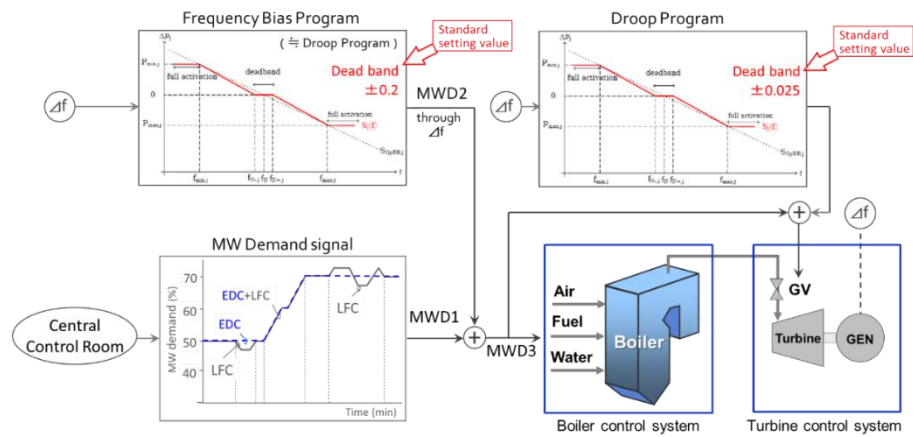
Source: Study Team

Figure 4-25 Comparison of frequency fluctuation in Bangladesh and India

<Frequency control function in Japan>

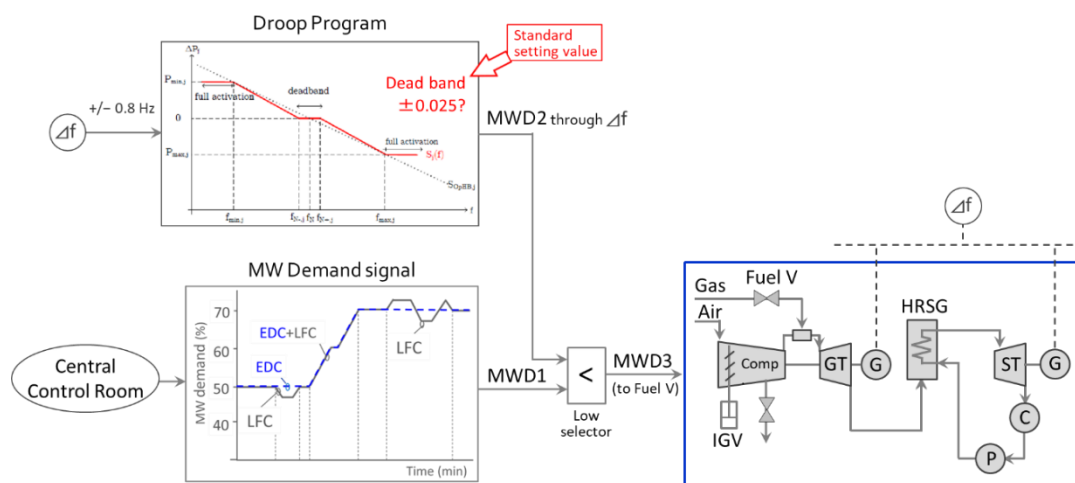
Figure 4-26 shows the frequency control function in coal-fired power control system in Japan, and Figure 4-27 shows the frequency control function in gas-fired power control system in Japan.

The MWD3 signal, which is the sum of the MWD2 signal from frequency deviation program of FGMO and the MWD1 signal (DPC+LFC) delivered from the Central Load Dispatch Center, is input to the boiler control program and turbine control program. MWD2 is the output from the frequency deviation program when the system frequency measured by the rotation speed of the generator is input to the frequency deviation program. If the frequency fluctuations are within the dead band, the output signal is zero. However, if the frequency deviates from the dead band, the MWD2 signal is output.



Source: Study Team

Figure 4-26 Frequency control function in coal-fired power control system (Japan)

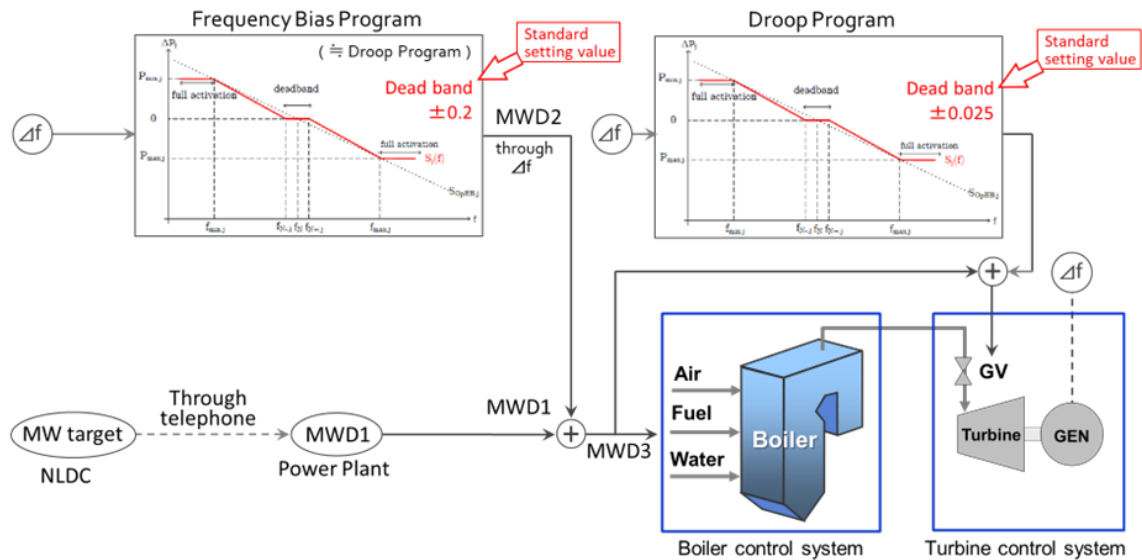


Source: Study Team

Figure 4-27 Frequency control function in gas-fired power control system (Japan)

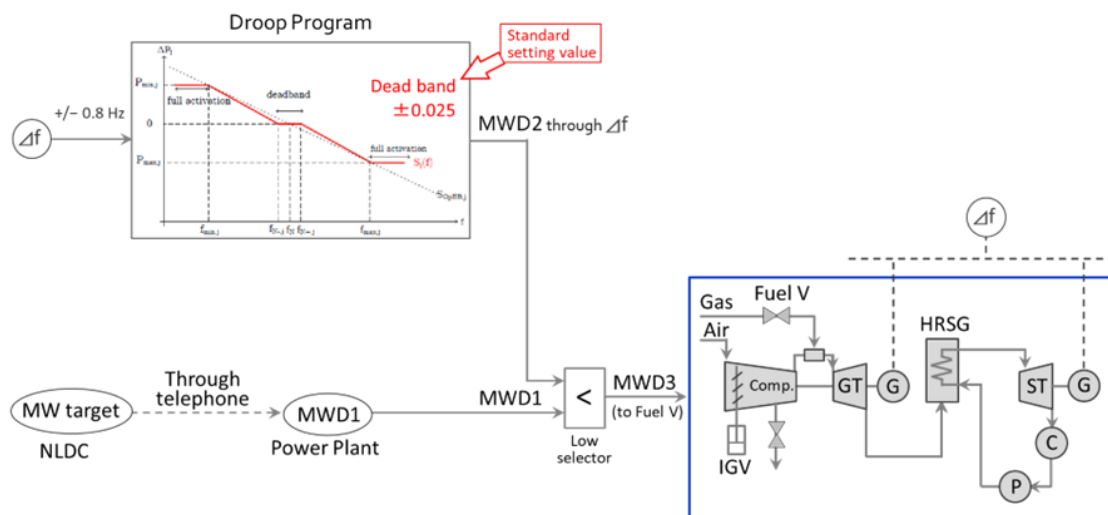
<Frequency control in Bangladesh>

Current frequency control has been confirmed in Bangladesh in this study. Figure 4-28 shows the frequency control function (Bangladesh) in coal-fired power control system and Figure 4-29 shows the frequency control (Bangladesh) in gas-fired power control system.



Source: Study Team

Figure 4-28 Frequency control function in coal-fired power control system (Bangladesh)



Source: Study Team

Figure 4-29 Frequency control function in gas-fired power control system (Bangladesh)

In Bangladesh, NLDC (National Load Dispatching Center) calls each power plant by telephone for Target MW and the operator in each plant input Target MW as MWD from control panel and

control generator output.

Figure 4-28 and Figure 4-29 shows the frequency control with FGMO function by Droop program.

In Japan, the frequency is controlled by the MWD1 signal (EDC + LFC signal) from the central load dispatch center under normal condition, and only when there is a large frequency deviation, the correction signal from the Droop program is added to the signal from the central load dispatch center.

4.3 The Current Status of Frequency Fluctuations in Bangladesh

Frequency fluctuations in Bangladesh have been surveyed from Oct 2022 to May 2023. The characteristic patterns of frequency fluctuations for the period are shown in Table 4-6.

Table 4-6 Table of frequency fluctuation trend

Date	Season	Daily average frequency (Hz)	Frequency fluctuation range (Hz)	Characteristics of frequency fluctuations
Feb. 20, 2023	Winter	50.3	+51.0 -49.4 1.6Hz	Early in the morning, the frequency was turned back down to 50.1 Hz over 5 hours.
Oct. 25, 2022	Autumn	50.5	+51.4 -49.0 2.4Hz	Large frequency fluctuation and quickly increasing and decreasing in during night time.
Nov. 01, 2022	Autumn	50.3	+51.0 -49.2 1.8Hz	Frequency fluctuation is small in the night time. Large and quickly increasing and decreasing in during day time.
Nov. 23, 2022	Autumn	50.5	+51.3 -49.2 2.1Hz	Large frequency fluctuation and quickly increasing and decreasing in during night time and day time.
Dec. 27, 2022	Winter	50.5 → 50.1	+51.4 -49.3 2.1Hz	Large frequency fluctuation and quickly increasing and decreasing in during night time. Frequency average level change from 50.5Hz to 50.1Hz.
Mar. 14, 2023	Spring	50.5	+51.2 -49.7 1.5Hz	Frequency fluctuation is not so large less than plus minus 0.5Hz all day long.
May 09, 2023	Summer	50.2	+51.3 -49.2 2.1Hz	Frequency fluctuation is very small in the night time. Average frequency level is almost 50Hz all day long.

Source: Study Team

The characteristics can be summarized as follows:

<Characteristics of frequency fluctuations>

- The average frequency (a day) is 50.5 Hz, which is high as a whole.
- The frequency fluctuation is 2.4 Hz at maximum and 1.5 Hz at minimum. The extracted average frequency fluctuation (a week) is 1.9 Hz.
- Characterized by steep and large frequency fluctuations
- The example of the case (20 February 2023) shows that the frequency is reduced from 50.5 Hz to 49.4 Hz over 5 hours as the power demand increases from the early morning.

- In the example case (1 Nov 2022), frequency fluctuations during the night are controlled between 50.2 Hz and 50.5 Hz, which means a fluctuation range of 0.3 Hz.

<Possible cause of frequency fluctuation>

Based on the results of interviews with NLDC experts, the following causes can be considered.

- Units that apply the FGMO function are limited. In addition, in the current situation where the spinning reserve including the primary control reserve is not sufficient, it is necessary to operate the frequency at a high level in consideration of the frequency drop due to large load fluctuations.
- There are cases in which the output cannot be lowered due to restrictions imposed by the minimum operational output of thermal power plants.
- During the operation of Abul Khair Steel Products Ltd. (hereafter AKSPL: Abul Khair Steel Products Ltd.), there is a tendency for the frequency to fluctuate due to sudden fluctuations in demand due to arc furnaces.
- On May 9, 2023, AKSPL's arc furnace was out of operation all day, and the frequency fluctuation was maintained within a relatively small range.

<Possible measures to reduce frequency fluctuation>

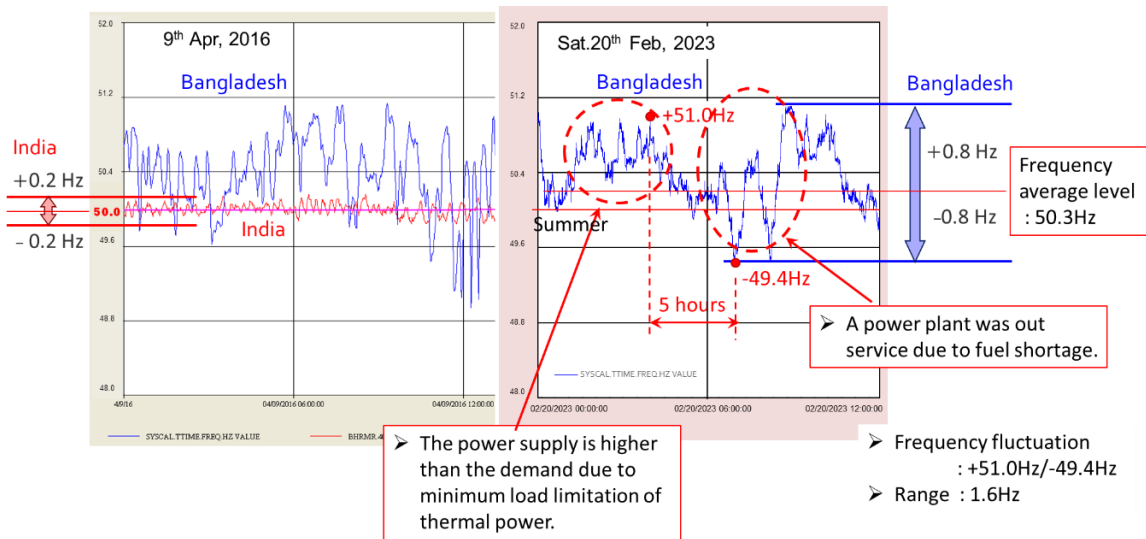
Measures relatively in early stage of actualization:

- Increase units utilizing FGMO function.
Start utilizing FGMO function from applicable units.
All of units will be utilized FGMO function in the future.
- Reduced the minimum output and increase ramp rate of thermal power plant.
For units whose minimum output can be reduced by remodeling, if unit is available to do so.
Test to confirm ramp rate and increase ramp rate as much as possible.

Medium to long-term measures

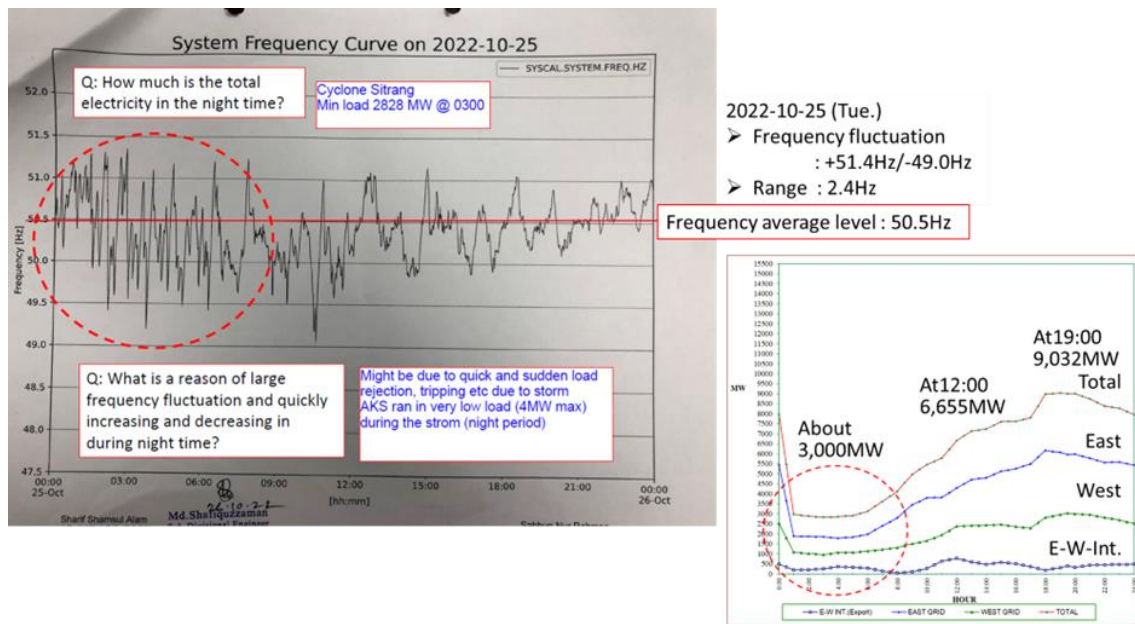
- Introduction of AGC (LFC + EDC) as soon as possible after establishing a communication system between NLDC and power plants
- Take measures of arc furnace in AKSPL
- Introduce new furnace having less impact to power system, consider additional flywheel installation.

The following shows the extracted characteristic frequency fluctuations.



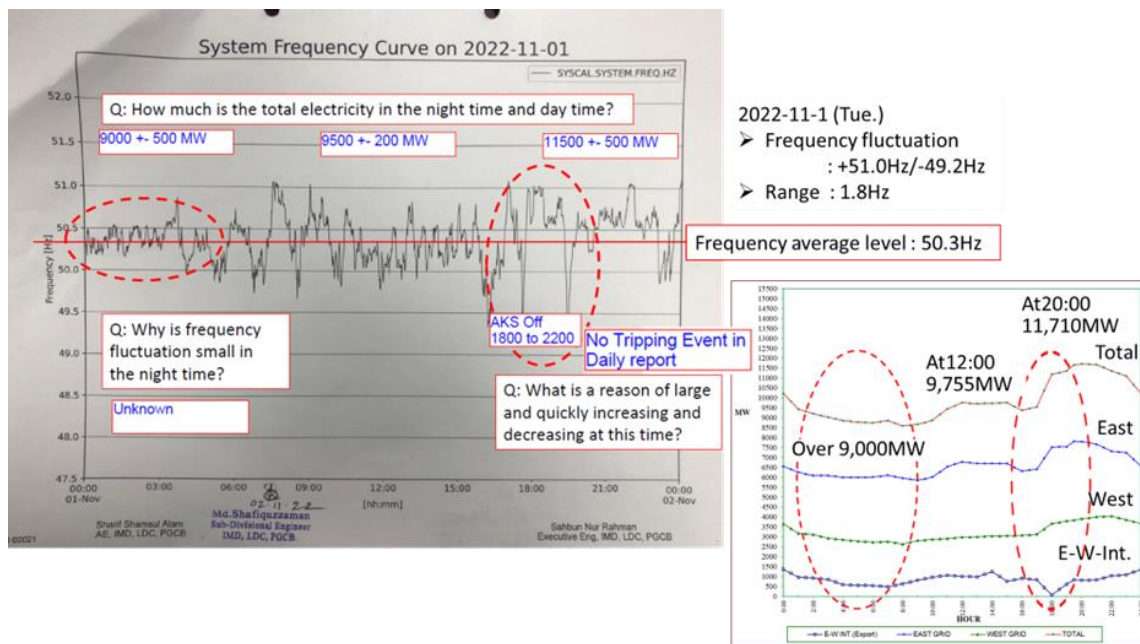
Source: Study Team (Based on NLDC data)

Figure 4-30 Trend of frequency (20 Feb, 2023)



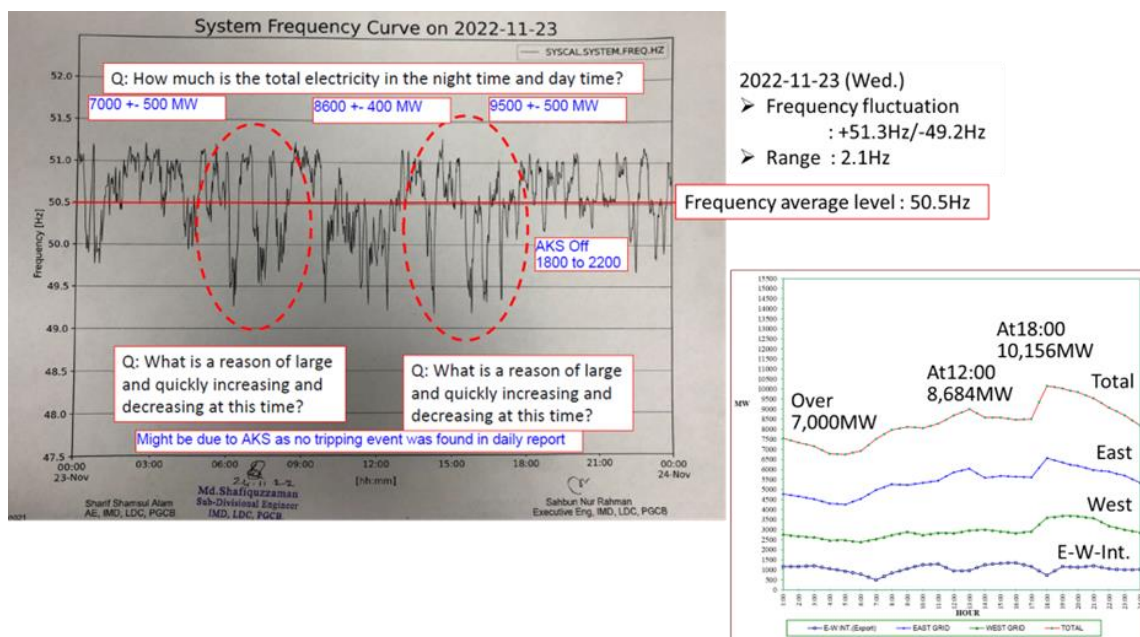
Source: Study Team (Based on NLDC data)

Figure 4-31 Trend of frequency (25 Oct, 2023)



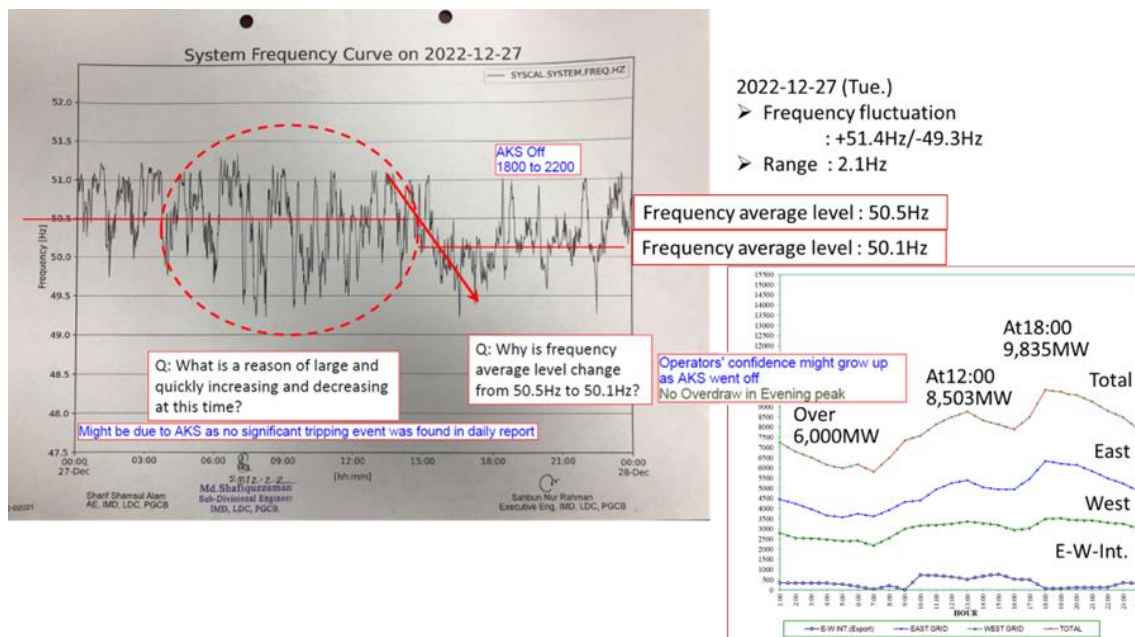
Source: Study Team (Based on NLDC data)

Figure 4-32 Trend of frequency (1 Nov, 2023)



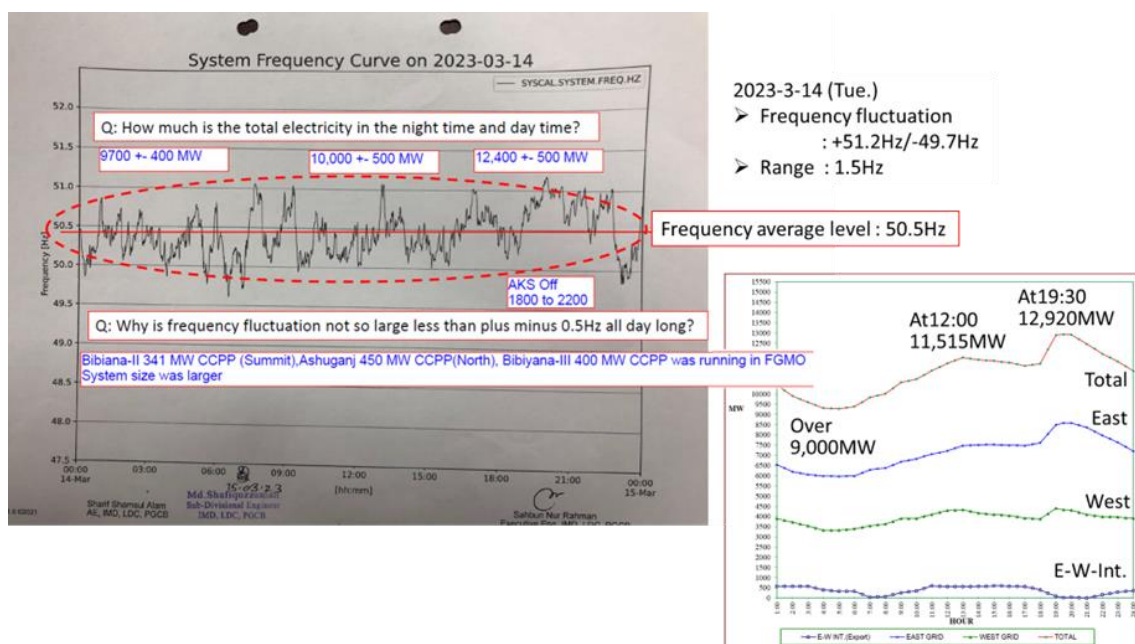
Source: Study Team (Based on NLDC data)

Figure 4-33 Trend of frequency (23 Nov, 2023)



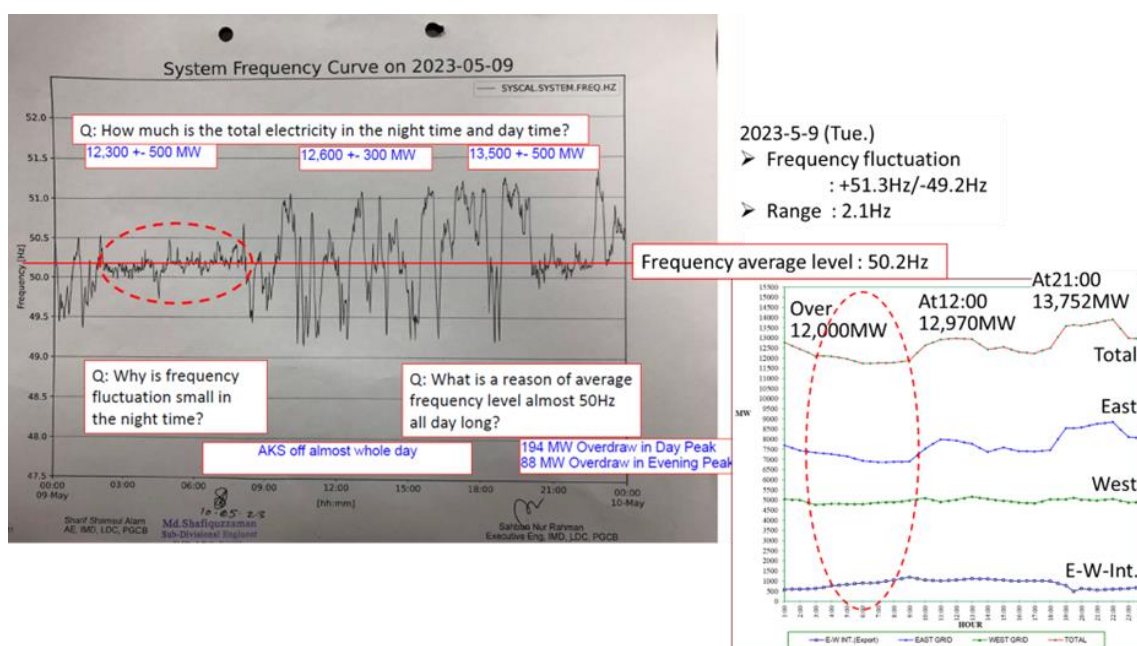
Source: Study Team (Based on NLDC data)

Figure 4-34 Trend of frequency (27 Dec, 2023)



Source: Study Team (Based on NLDC data)

Figure 4-35 Trend of frequency (14 Mar, 2023)



Source: Study Team (Based on NLDC data)

Figure 4-36 Trend of frequency (9 May, 2023)

4.4 Status of NLDC's instructions related to supply-demand and frequency controls

The current frequency fluctuation situation in Bangladesh is as shown in 4.3. The study team collected information on NLDC's instructions related to supply-demand and frequency control in relation to frequency fluctuations. Power dispatch orders from NLDC are given over the telephone based on Merit Orders from BPDB, taking into consideration the dispatch order response time. Table 4-7 shows the number of instructions on May 12 (weekend) and May 16 (weekday), 2023.

Table 4-7 NLDC commands on 12 May (Weekend) & 16 May (Weekday), 2023

	12 May, 2023 (Weekend)	16 May, 2023 (Weekday)
Phone commands	1069	1627
Demand placed	500	649
SCADA operations	143	198
Total	1712	2474

Source: NLDC

“Phone commands” means the number of output change instructions issued by the NLDC to each power plant for supply-demand and frequency control, by phone. More than 1,600 instructions are issued on weekdays, and more than 1,000 on weekends.

“Demand placed” means the instruction provided by the NLDC operator to the power plant. It includes instructions of generator start-up and the reason why power plants cannot meet the NLDC’s demand (the rated output instruction). “SCADA operation” means the number of restorations by the NLDC through SCADA after load shedding.

From the above results, it is quite clear that the NLDC operators have issued numerous instructions for supply-demand and frequency control. The phone commands will increase along with power demand increase and generator additions, so it is desirable to introduce online commands through EMS/SCADA in the near future. Additionally, in order to ensure fairness among power generation companies, NLDC gives instructions for controlling the output based on the economic merit order.

4.5 Application Status of Free Governor Mode Operation

Figure 4-37 shows the FGMO operation status as of May 3 to 9 , 2024. The FGMO is possibly applied to 29 generator units, but only 11 units are actually operating in FGMO.

Additionally, the results from the meeting with BPDB, 32 units from all of 150 thermal power facilities have soundness of FGMO. It is desirable to start early operation with FGMO function as soon as possible.

Power Grid Company Of Bangladesh Ltd.									
NLDC, Aftabnagar, Dhaka.									
Weekly Status of Free Governor Mode of Operation (FGMO) Power Plants from 3 May' 2024 to 9 May' 2024									
SL	Plant Name	Owner	Installed capacity (MW)	Active FGMO capacity (MW)	Max Gen. (MW)	Min Gen. (MW)	SR at 50 Hz	Capability Status	Remarks
1	Bibiana-II 341 MW CCPP (Summit)	IPP	341	340	340	250	45	Capable	Running in FGMO.
2	Shahjibazar GTPP Unit 8 & 9	BPDB	70					Capable	Not running in FGMO due to problem with IGV
3	Sirajgonj 400 MW CCPP Unit-4	IPP	414	380	380	320	30	Capable	Running in FGMO.
4	Sirajgonj 225 MW CCPP Unit-3	NWPG	220	220	220	180	20	Capable	Running in FGMO.
5	Sirajgonj 225 MW CCPP Unit-2	NWPG	220	220	220	180	20	Capable	Running in FGMO.
6	Meghnaghat CCPP (Summit)	IPP	305	310	310	240	35	Capable	Running in FGMO.
7	Ashuganj 450 MW CCPP (North)	APSCL	360	340	340	260	30	Capable	Running in FGMO.
8	Ashuganj 225 MW CCPP	APSCL	221					Capable	Running with fixed load due to gas shortage
9	Bheramara 410 MW CCPP	NWPG	410	410	405	345	30	Capable	Running in FGMO.
10	Haripur 412 MW CCPP	EGCB	412					Capable	Running with fixed load due to gas control vlv problem
11	Fenchuganj CCPP Phase-1	BPDB	97	32	32	28	2	Capable	GT-2 running in FGMO & GT-1 under maint.
12	Chandpur 150 MW CCPP	BPDB	163					Capable	Under shutdown
13	Siddhirganj 2x120 MW GTPP	EGCB	240					Capable	Shutdown due to gas shortage
14	Shikabaha 225 MW CCPP	BPDB	225					Capable	Not running in FGMO due to problem with GBC
15	Shikabaha Peaking GT	BPDB	150					Capable	Under shut down for turbine shaft maintenance.
16	Shahjibazar 330 MW CCPP	BPDB	330					Capable	Under shut down for maintenance
17	Ashuganj 450 MW CCPP (South)	APSCL	360					Capable	Not running in FGMO due to gas shortage
18	Fenchuganj CCPP Phase-2	BPDB	104	64	64	56	4	Capable	GT-3 & GT-4 running in FGMO
19	Bhola 225 MW CCPP	BPDB	194					Capable	GT-1 & GT-2 running with fixed load & ST under maint.
20	Ghorasal 365 MW CCPP Unit-7	BPDB	365					Capable	Under shut down for Maint.
21	Sirajgonj 225 MW CCPP Unit-1	NWPG	210					Capable	Shutdown due to gas shortage
22	Siddhirganj 335 MW CCPP	EGCB	335					Capable but not tested recently	Running with fixed load
23	Bibiana-II 400 MW CCPP	BPDB	400	380	380	320	30	Capable	Running in FGMO.
24	Sylhet 225 MW CCPP	BPDB	231					Capable	Running with fixed load (ST not capable to run in FGMO)
25	RPCL 210 MW CCPP	IPP	210					Capable but not tested recently	Running with fixed load due to gas shortage
26	Khulna 225 MW CCPP	NWPG	230					Capable but not tested recently	Under shut down due to fuel shortage
27	a) Baghabari 71 MW GTTP	BPDB	71					Not Capable but feasible	Under Shut down due to gas shortage
	b) Baghabari 100 MW GTTP	BPDB	100					Not Capable but feasible	Under Shut down due to gas shortage
28	Karnaphuli Hydro PP Unit: 1	BPDB	40					Capable	Running with fixed load due to low water level
	Karnaphuli Hydro PP Unit: 2	BPDB	40					Capable	Under shut down due to low water level
	Karnaphuli Hydro PP Unit: 3	BPDB	50					Capable	Under shut down due to low water level
	Karnaphuli Hydro PP Unit: 4	BPDB	50					Not Capable but feasible	Under shut down due to low water level
	Karnaphuli Hydro PP Unit: 5	BPDB	50					Not Capable but feasible	Under shut down due to low water level
29	a) Goranabari Repowered CCPP Unit	BPDB	416					Not Capable but feasible	FGMO will be available after maint work.
	b) Goranabari Repowered CCPP Unit	BPDB	410					Not Capable but feasible	Shutdown due to gas shortage
30	Bibiana South 400 MW CCPP	BPDB	383	380	380	320	30	Capable	Running in FGMO
31	Barapokuria 275 MW TFP Unit-3	BPDB	274					Not Capable but feasible	Design needs to be modified
32	Shahbaz 100 MW IPP	BPDB	100					Not Capable but feasible	Under shutdown
33	Pagra 1320 MW Unit-1	BCPCL	622					Capable	Running with fixed load
34	Kushira 163 MW CCPP (KP)	IPP	163					Not Capable but feasible	Running with fixed load
35	Bhola Nuran Bidur	IPP	220					Capable	Running with fixed load
36	Haripur 360 MW CCPP (HPL)	IPP	360					Not Capable but feasible	
37	Meghnaghat 450 MW CCPP (MPL)	IPP	450					Not Capable but feasible	Contract expired
Total Number of Plants Running on FGMO			Total Installed capacity	Total Active FGMO capacity	Total Spinning				
11			10586	3076	276				
Abbreviations		List of Plant/Unit (s)		Summary of Unit's Capability		Number of Units			
SR- Spinning Reserve		Total Plants in li		FGMO Capability		29			
DEM- Original Equipment Manufacturer		37		Status of different		3			
NOA- Notification of Awar		43		Units		0			
IGV- Inlet Guide Vane						0			
CI- Combustion Inspection						11			
						43			

Source: NLDC

Figure 4-37 FGMO Operation Status

4.6 Application status of LFC and EDC

Figure 4-38 shows the control status using LFC and EDC. This shows the trend of Super Critical pressure plant (SC) with a capacity of 1,000 MW in Japan. The blue line in the trend shows generator output (MW), which increases from 300 MW to 1,000 MW.

In Japan, the EDC signal is automatically distributed every 15 minutes and thermal power plants operate according to the instruction signal. The range of output change from LFC is set to $\pm 5\%$ (± 50 MW) and the frequency is controlled. The EDC load changing rate is 5%/min. (50 MW/min.), and the LFC load changing rate is 8 %/min. (80 MW/min.)

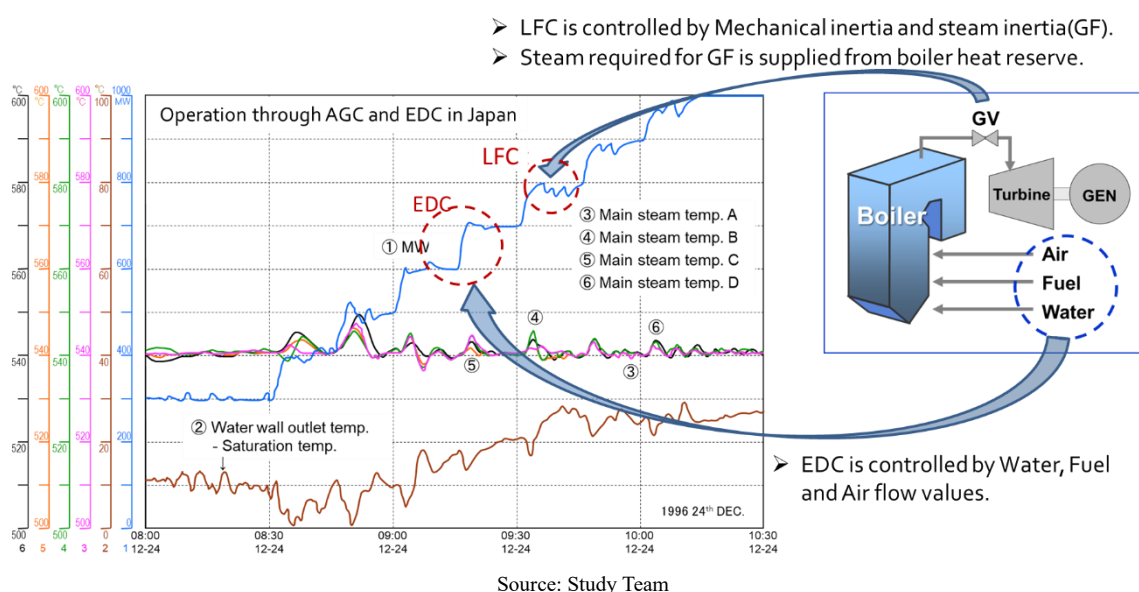


Figure 4-38 Control status using LFC and EDC in Japan

In this survey, the operation through EDC and LFC is confirmed in Haripur, Siddhirganj, Ghorasal and Ashuganj plants, and NLDC.

As a result, the instruction corresponding to EDC is provided by phone. The instruction is provided at 15-minute interval in principle but it depends on the day (e.g. 4 to 5 times or 20 times a day).

In Bangladesh, the frequency is actually controlled by Droop program (FGMO function) based on the output instruction provided from NLDC by phone.

Like the example in Japan, the frequency fluctuations can be improved in the future by structuring facilities to provide the EDC and LFC instructions automatically in communication and dispatching the instruction on a regular basis.

4.7 Optimization of Droop Program for GF operation

In this survey, the Study Team visited EGCB's Haripur, Siddhirganj 2x120 MW power stations and BPDB's Ghorasal power station to confirm the setting value of Droop program.

The following shows the Droop program used in Ghorasal power station. The setting value of the governor speed droop is set to 5% according to the grid code and it is a similar standard setting in Japan.

As mentioned in 3.2, the Droop Program is a system that does not operate under regular frequency fluctuations but operates in the event of dramatical frequency change to control frequency fluctuations. However, the frequency fluctuation ranges from 1.5 Hz to 2.4 Hz as shown in 3.3. Thus, the operation is continuously controlled by the Droop program. This seems not preferred situations because it greatly affects power generators.

On the other hand, the setting value of the governor speed droop is set to 10 % in Siddhirganj 2x120 MW power station in order to reduce the impact on power generators. This defines that frequency fluctuation increases from zero to maximum outputs if the frequency decreases by 10%. The sensitivity of power generators to frequency fluctuation is reduced, compared to the setting value of the governor speed droop set to 5%. Setting a bigger value of the governor speed droop reduces the sensitivity of power generators to frequency fluctuation. However, Siddhireani droop is on-line adjustable (variable droop from 4 to 20) and can be set according to the load demand from NLDC. As each GT of the Siddhirqani 2x120 MW Peaking Power Plant can provide around 105 MW. Therefore, if grid demanded for +10 MW variation (primary frequency response) from one GT, then it droops setting can be keeps at 10%. In other words, Siddhirgani droop can be set according to the demands of the grid.

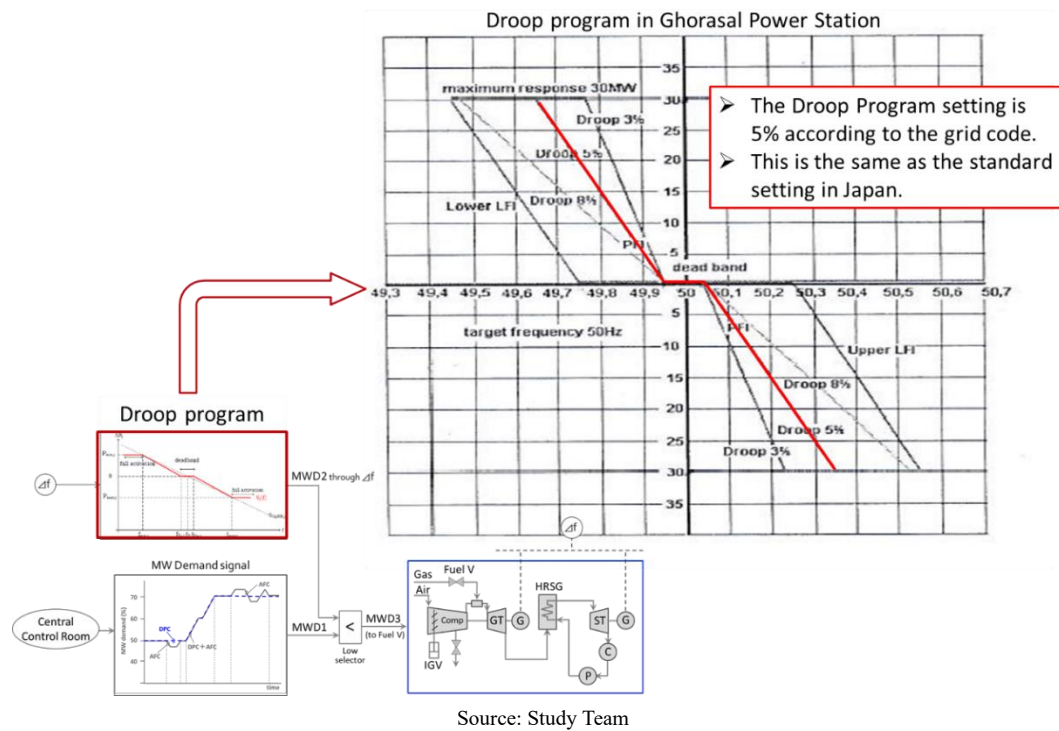


Figure 4-39 Droop program used in Ghorasal power plant

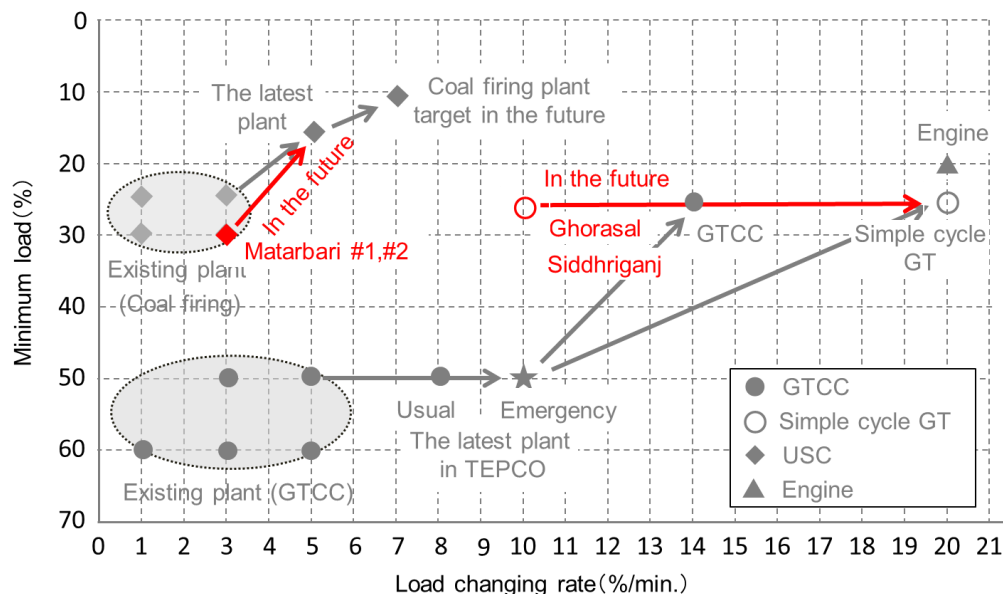
4.8 Improvement of the load changing rate and reduction of minimum load

Figure 4-40 shows the load changing rate and minimum load. This shows the data of power generation using coal-fired power (USC), gas turbine combined cycle (GTCC), and Engine in Japan. The data of the power plants in Bangladesh surveyed this time are added.

The Ghorasal power station is a gas turbine combined cycle (GTCC) power plant but currently it does not operate steam turbine. It operates as a simple cycle gas turbine.

In addition, the study team collected planned values for the rate of change in output and minimum output for Matarbari Units 1 and 2, which are coal-fired power plants currently under construction.

These values are added to the following figure.



【Source: TENPES Report in 2014 (Revised by TEPSCO in Feb.2022)】

Source: Study Team

Figure 4-40 The load changing rate and minimum load in thermal power plants

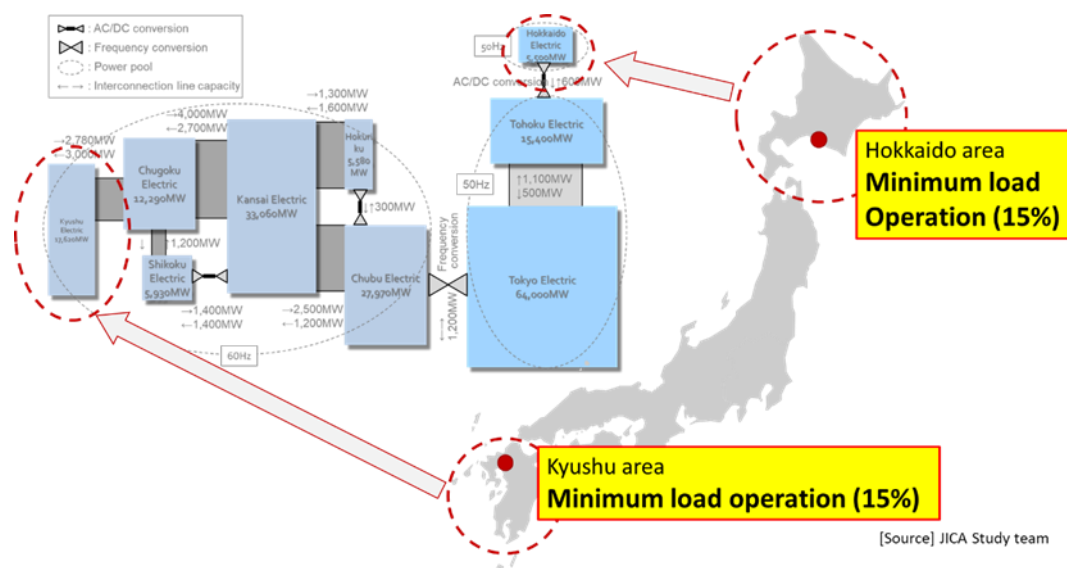
As shown in 3.3, the frequency fluctuates significantly in Bangladesh. One of the factors is that the output cannot be controlled because of constraint of minimum load of thermal power plants. The enhancement of the load change rate will help improve frequency fluctuations.

To improve the frequency fluctuations in Bangladesh, minimum load for the entire thermal power plants should be reduced and the load changing rate should be improved. In particular, when the total coal-fired power output will exceed 10 GW in 2041, the reduction of minimum load and enhancement of the load changing rate will play an important role in improving the frequency fluctuations.

<Example of minimum load operation in Japan>

Figure 4-41 shows the minimum load operation in Japan. Figure 4-41 shows power grid composed by Japan's major electric companies and an example of Kyushu Electric company and Hokkaido Electric Company, which operates with minimum load of 15%. Both electric companies are located at opposite ends of Japan's power grid.

For Example, Kyusyu Electric Company operates thermal power plant with minimum load of 15% because the generation amount increases drastically from solar power and wind power when the weather is in a good condition during daytime.

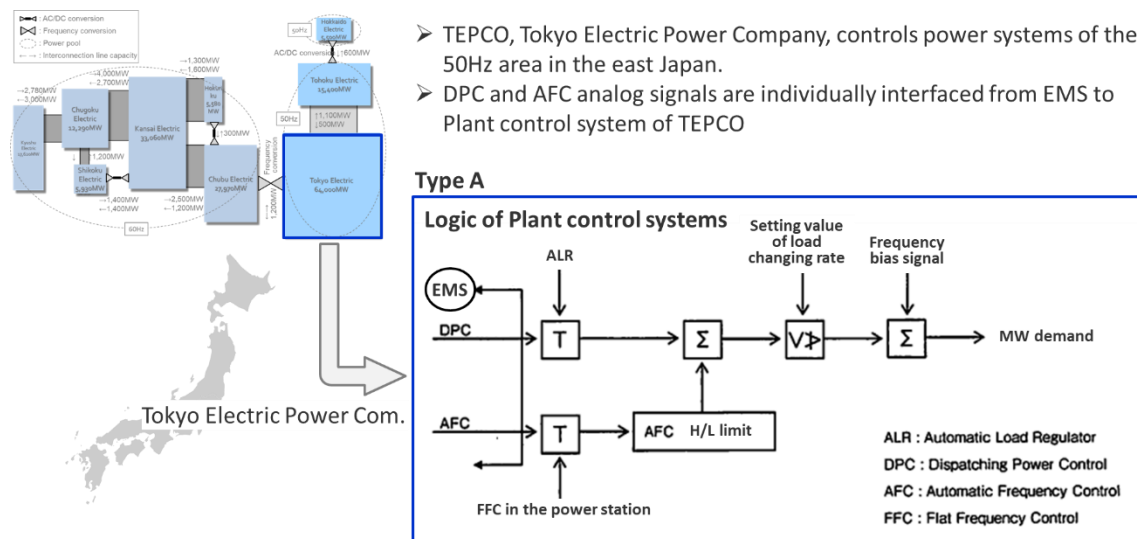


Source: Study Team

Figure 4-41 Example of minimum load operation in Japan

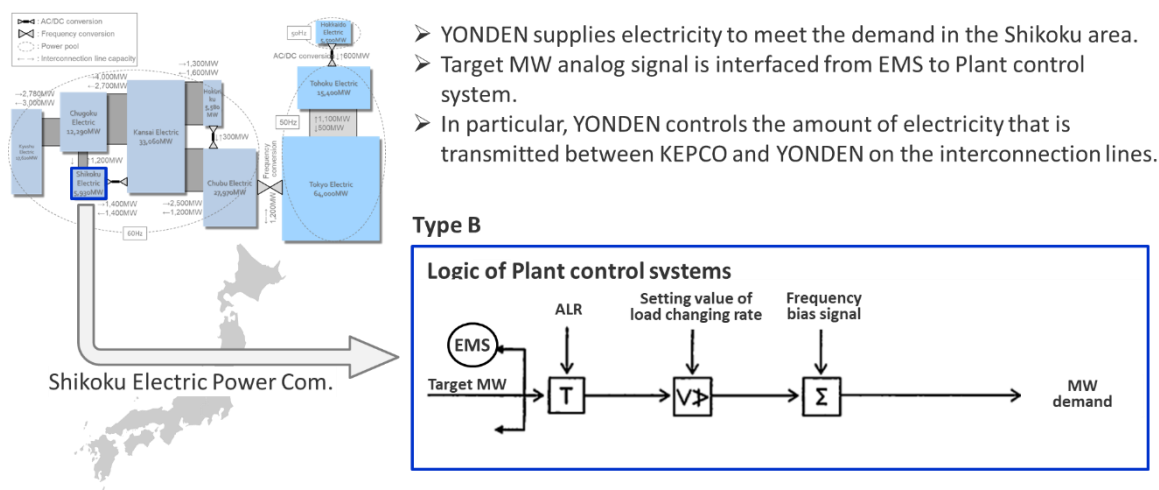
4.9 Interface between Central load dispatch center and the power plant

Figure 4-42 shows the Type-A interface between Central load dispatch center and the power plant and the Figure 4-43 shows the Type B interface between Central load dispatch center and the power plant.



Source: Study Team

Figure 4-42 The interface between Central load dispatch center and the power plant (Type A)



Source: Study Team

Figure 4-43 The interface between Central load dispatch center and the power plant (Type B)

Type A is the TEPCO's interface that sends two signals of DPC (Dispatching Power Control) and AFC (Automatic Frequency Control) to each power plant and controls frequency and generator output. In other words, the signal of DPC listed in the report is equivalent to EDC and AFC is equivalent to LFC.

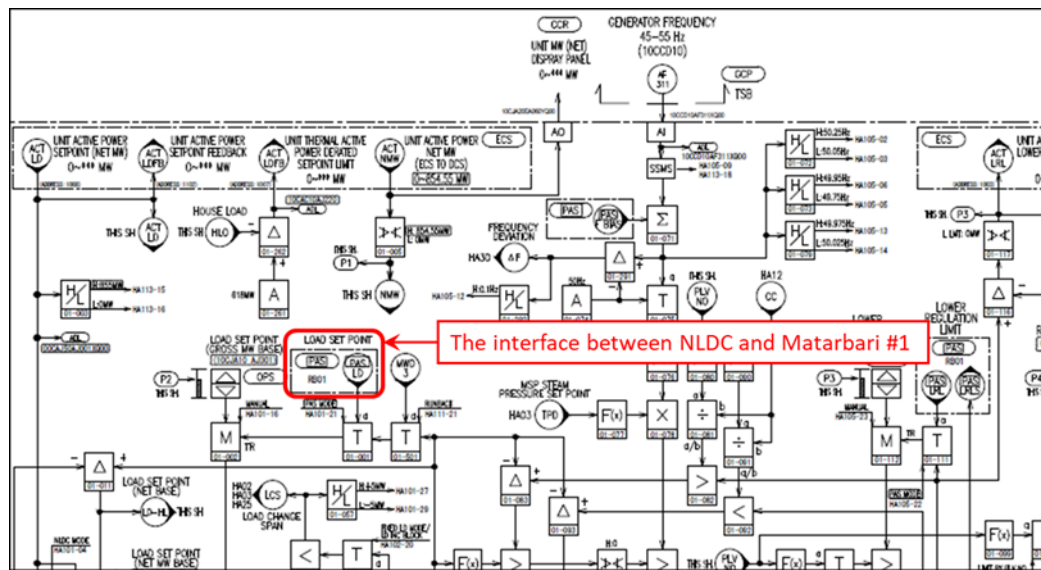
In Japan, electricity is controlled at 50 Hz in East area and at 60 Hz in West area.

Type B is the interface of Shikoku Electric Power Company (YONDEN) that sends one signal (Target MW) to each power plant and controls generator output. Shikoku Electric Power Company only operates with one interface (Target MW) and does not use FGMO function.

<Interface between NLDC and Matarbari No.1>

The Figure 4-44 shows one example of the result confirmed in this survey, which is regarding the interface between NLDC and Matarbari No.1 power plant.

NLDC and Matarbari No.1 is one signal (Target MW) interface. At the start of operations in 2024, the power plant is likely to operate with telephone commands as well as other power plants. However, in the future, the power plant should operate with Type A interface using 2 signals of EDC and LFC, just like TEPCO.



Source: Study Team

Figure 4-44 Interface between NLDC and Matarbari No.1

4.10 Efforts for improving grid frequency towards the introduction of nuclear power plants

<Schedule for construction and commissioning of the nuclear power plants>

The reactor of the Rooppur Nuclear Power Plant Unit 1 will start operation in Dec, 2024 before commissioning.

<Effects on frequency fluctuation caused by introduction of the nuclear power plants>

Voltage and frequency of the transmission power system at the connection point of a nuclear power plant shall not exceed the acceptable range in order to continue to provide a highly reliable electrical supply with nuclear power plants through the transmission power system even after a trip of a nuclear power plant unit. From the viewpoint of electricity users, a trip of a nuclear power unit shall not lead to load shedding, or to a high risk of system collapse or blackouts.

<Estimation of frequency fluctuation range improvements in case of increasing the number of FGMO applied generators>

Increasing the number of FGMO applied units will make faster recovery from frequency drop caused by a generator trip, improving the lowest frequency. Applying FGMO to many generators will decrease the frequency fluctuation range, reducing the stress on each power plant.

5. Improvement of Power System Operation and Rules

5.1 Supply-demand Operation Planning

5.1.1 Outline of Supply and Demand Operation Planning

Supply and demand operation planning is to clarify the supply and demand balance situation and operation status of each supply capacity by studying total operation of supply capacity with consideration for the wide-area operation in order to operate stable supply of electricity with economic operation of power source facility to respond to predicted power demand. For supply and demand balance under peak demand conditions, supply reserve capacity, which is a measure of the supply reliability, is calculated by comparing predicted maximum power demand and supply capacity in order to clarify supply and demand balance.

5.1.2 Current Work Flow Regarding Supply and Demand Operation Planning

After confirming the current supply and demand operation planning process on the basis of the discussion with stakeholders including NLDC, some distribution and generation companies, several issues that decrease the efficiency and accuracy of supply and demand operation planning are identified.

(1) Limited Scheduling Scope

The current practice only involves day-ahead scheduling, restricting the ability to respond to real-time changes effectively. Including planning supply and demand operation schedule shorter time intervals than the current per hour interval, and long-term planning (yearly, monthly, and weekly) will contribute to better optimization, supply and demand stability, and expanding introduction of renewable energy sources in the future.

(2) Types of Supply and Demand Operation Planning

Currently, NLDC is about to collect the day-ahead demand forecast from distribution companies through a web application and refines demand forecast using historical data and weather conditions. However, the demand forecasting is an hourly basis as specified in the existing grid code, preventing the granularity and accuracy of predictions. The intended targeting interval is 15 minutes. To achieve this, an amendment to the grid code is proposed by NLDC. This amendment aims to align the distribution and generation companies, enabling them to work towards the goal of achieving the desired demand forecast and generation schedule interval. By aligning the intervals and enhancing the accuracy of supply and demand operation scheduling, the power system can respond more effectively to real-time changes and optimize supply power resource utilization.

(3) Inadequate Information regarding Transmission Outage Schedules and Generation Maintenance Stop

To ensure accurate supply and demand coordination, various crucial pieces of information are required, including generator availability, distribution utility's demand forecast, previous demand trends, fuel availability, generator and transmission outage schedules. However, transmission outage schedules and generation schedules are not submitted to NLDC, leading to challenges in achieving precise demand and supply coordination. Additionally, the absence of proper provision for maintenance stop and scheduled outage plans further complicates supply and demand operation scheduling process. Furthermore, the recent increase in unscheduled shutdowns, prompted by instructions received from NLDC, has resulted in mechanical and economic damage to generation companies.

BPDB, a single buyer, may have generator operation information but NLDC confirms the operation and shutdown status with each power plant via phone calls the day before. Additionally, there are numerous cases where generators are unexpectedly disconnected due to reasons such as fuel shortages.

To break this detrimental cycle and improve the quality of supply and demand operation planning, it is crucial for both NLDC and generation companies to work closely together. Timely submission of transmission facility outage schedules, generation operation schedules, and provision of facility maintenance stop plans will enhance accuracy of supply and demand operation planning, minimize unscheduled generator outages, and reduce mechanical and economic damage. Collaborative efforts will foster a more efficient and reliable power supply that ultimately benefits all stakeholders involved.

(4) Implications for Supply Mismatch Caused by Over Forecasting

Distribution companies submit their demand forecast, which tends to be higher than the recorded data by NLDC. This is probably intent to secure more supply capability in their respective areas and may trigger mismatches between necessary supply capacity and actual demand. It is also possible that some of load information are not connected to SCADA in NLDC and distribution companies so NLDC may not manage the real time demand properly under emergency circumstance.

(5) Excel-Based Schedule Optimization

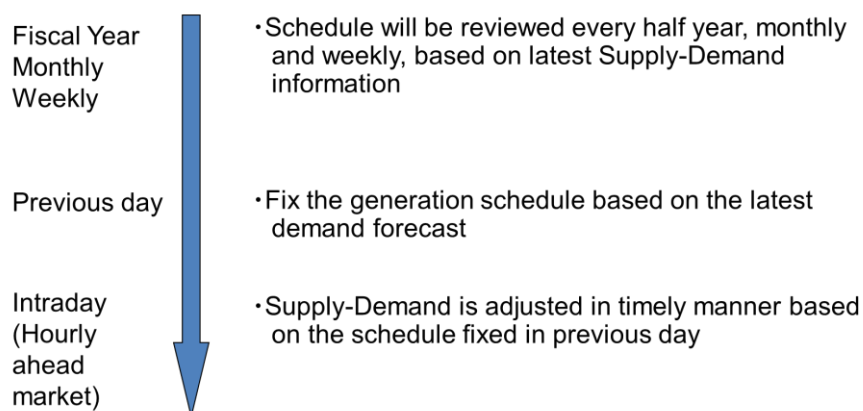
An Excel sheet is currently used for optimizing the schedule, allowing for checking the up and down range of generator output and creating the schedule in consideration of must-run power plants. In the future, it will be desirable to introduce a supply and demand scheduling system in order to improve the accuracy of schedules and reduce the workload.

(6) Cooperation with Fuel Planning Authority

Currently, NLDC has pointed out insufficient coordination between the related agencies including NLDC and the agencies that formulate long-term and short-term fuel plans. All parties need to work together to bring benefits to both lower fuel procurement costs and stabilization of supply and demand operations.

5.1.3 Work Flow

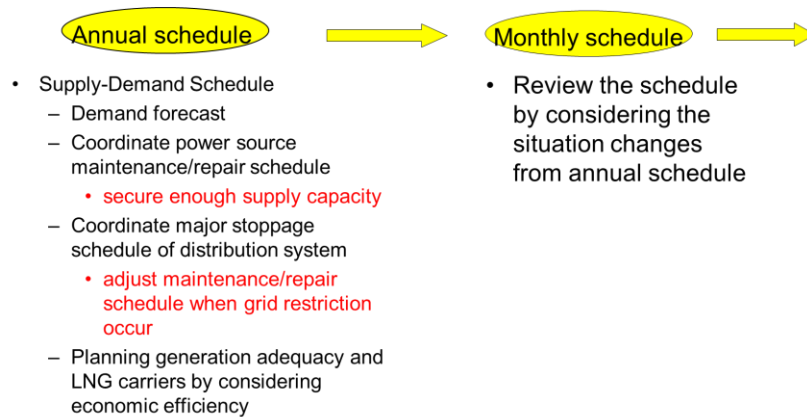
Figure 5-1 shows the overall flow of supply and demand operation planning. The formulated annual plan is reviewed in each phase (monthly and weekly plans) on the basis of the latest information. Additionally, power source operation status is decided based on most updated demand forecasts as of previous day. Time to time-based supply and demand adjustment on the intraday (hourly ahead market) is conducted on the basis of the previous day's plan.



Source: Study Team

Figure 5-1 Overall Picture of Supply and Demand Operation Planning

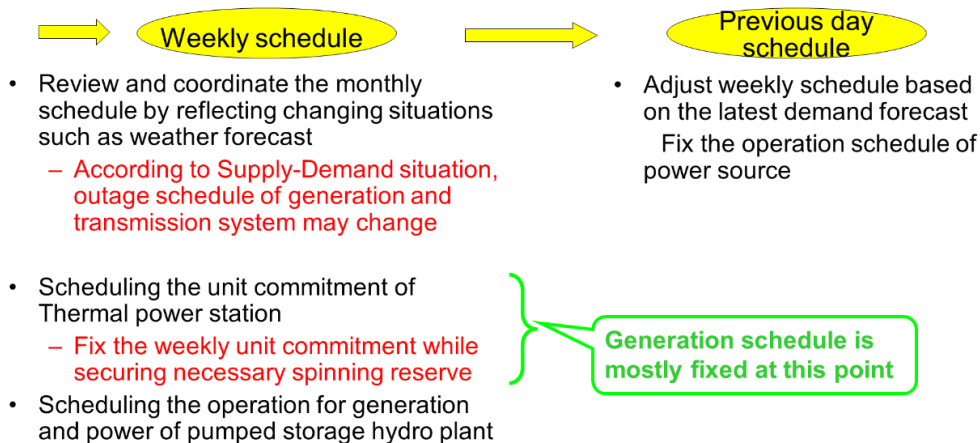
Supply and demand operation planning has been drastically changed in Japan after the electricity system reform, as well as under the vertically integrated system. Bangladesh has a single buyer system so the work flow under vertically integrated system in Japan can be a reference. Figure 5-2 and Figure 5-3 show the work flow under the vertically integrated system in Japan.



Source: Study Team

Figure 5-2 Workflow of Supply and Demand Operation Planning [Under the vertically integrated system] (Annual to monthly plans)

The annual plan coordinates the timing of planning power plant maintenance in order to secure enough supply capacity based on demand forecasts. If the power system constraints occur along with the coordination of long scheduled outage of transmission facilities, the timing of the power source maintenance planning is coordinated. The LNG shipping plan is formed by allocating power source capacity per supply capacity in consideration of economic efficiency. The supply and demand operation planning (monthly plan) is reconsidered in view of situation changes from the annual plan.



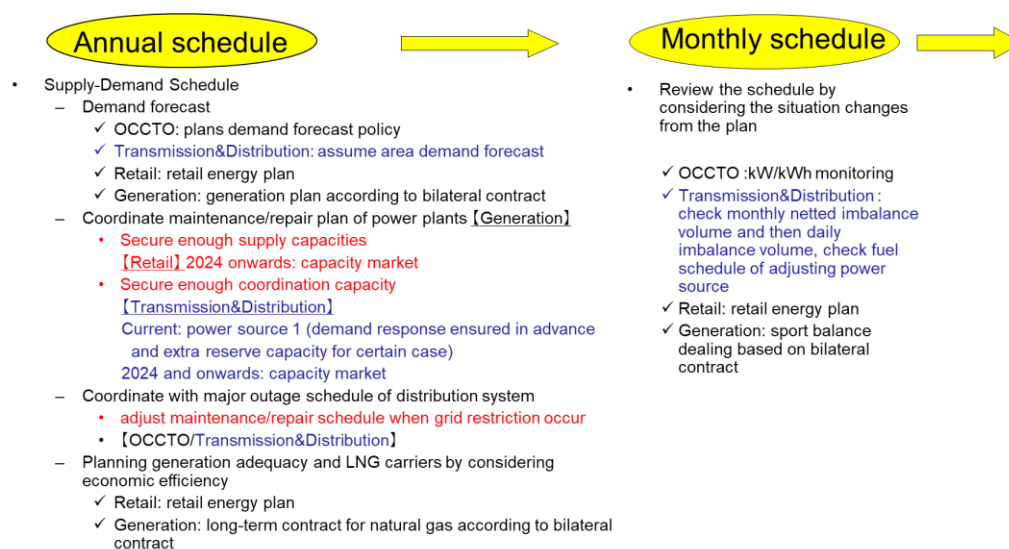
Source: Study Team

Figure 5-3 Work flow of Supply and Demand Operation Planning [Under the vertically integrated system] (Weekly to previous day plans)

The weekly plan includes most recent situation changes such as weather forecasts to review the monthly plan. The outage coordination plan of power source and transmission facilities may

change according to the supply and demand situation. Additionally, a weekly thermal plant unit commitment is formed and decided in order to secure necessary supplemental reserve. The pumped storage generation and pumping operation plan is also formed and the unit commitment is mostly determined at this point. The previous day plan is calibrated based on most updated demand forecasts, and the unit commitment is decided at this time.

Figure 5-4 and Figure 5-5 show the work flow after the electricity system reform.



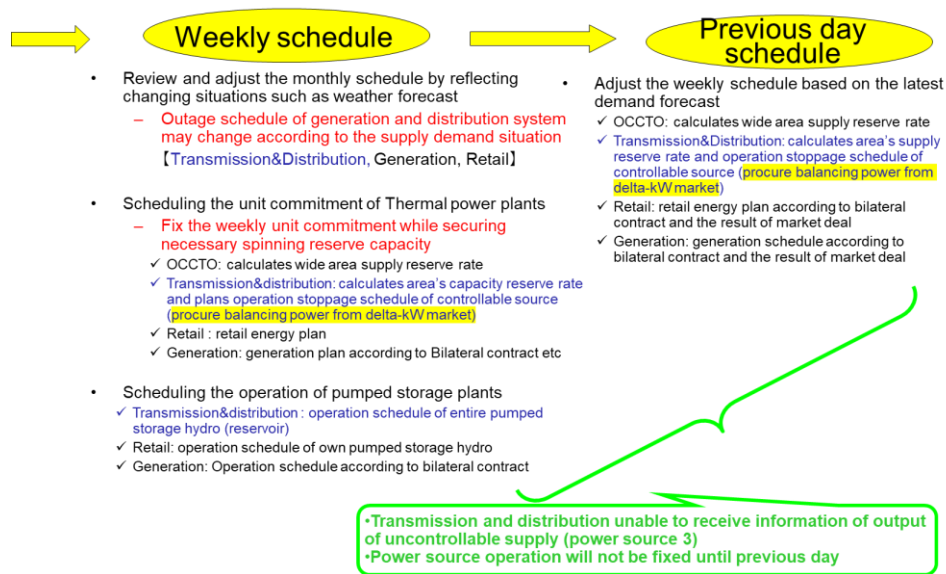
Source: Study Team

Figure 5-4 Work flow of Supply and Demand Operation Planning [After the electricity system reform] (Annual to monthly plans)

After the electricity system reform, the OCCTO forms the policy regarding demand forecasts for the annual plan, and the TSOs provide demand forecasts in corresponding areas.

Retailers form a sales plan and generation companies form a generation plan based on bilateral contracts. In order to secure enough supply capacity for coordination of the power source maintenance planning, the retailers will procure supply capacity at capacity market after 2024. Currently, the TSOs secure regulating power source called “power source I” but will secure the regulating reserve through balancing market after 2024. The retailers will form a sales plan and generation companies will form the long-term fuel plan based on bilateral contracts.

The monthly plan considers situation changes from the annual plan and reconsiders the supply and demand operation planning. At the monthly plan, the OCCTO monitors kw and kwh, and the TSOs divide monthly supply and demand balance to check every day’s balance, and schedule the fuel plan of regulating power source. The retailers form a sales plan and the generation companies procure fuel by the fuel spot contract on the basis of bilateral contracts.



Source: Study Team

Figure 5-5 Work flow of Supply and Demand Operation Planning [After the electric system reform] (Weekly to previous day plans)

The weekly plan includes most recent situation changes such as weather forecasts to review the monthly plan. Weekly unit commitment of thermal power generation is decided while necessary control reserve is secured. The OCCTO calculates the wide-area reserve ratio, and the TSOs calculate the area reserve ratio and forms the unit commitment of regulating reserve power source. Additionally, the TSOs procure regulating reserve from the wholesale electricity market. The retailers form the sales plan and the generation companies form the generation plan based on bilateral contracts. For forming the pumped storage power generation and pumping operation plan, the TSOs form the operation plan of overall pumping storage power generation, the retailers form the operation plan of contracted pumped storage power generation, and the generation companies form the operation plan on the basis of bilateral contracts.

The previous day plan is calibrated from the weekly plan based on most updated demand forecasts, and the power source unit commitment is decided at this time. The OCCTO calculates the wide-area reserve ratio, and the TSOs calculate the area reserve ratio and forms the unit commitment of regulating reserve power source. The retailers form the sales plan on the basis of bilateral contracts and the result of market deal. The generation companies form the generation plan on the basis of bilateral contracts and the result of market deal. It is hard for transmission and distribution operators to grab the information about non-reserve power source, which is power source III, so that the operation status of the power source cannot be decided until the previous day.

5.1.4 Planning Details and Required Days

Table 5-1 shows an example of the planning details and the required days to develop a supply and demand operation plan in Japan.

Table 5-1 Planning Details and Required Days

Target	Planning contents	Required human resource
Fiscal Year (next year, year after next)	➤ Maximum and minimum demand for each month (weekday/holiday) ➤ Supply capacity/Reserve capacity	➤ 1 MM x 12 months x 3 persons = 36 MM/year (3 persons in charge)
Monthly (next month, month after next)	➤ Maximum demand and minimum demand for each week(weekday/holiday) ➤ Supply capacity/Reserve capacity ➤ Amount of control reserve (Required/Secured)	➤ 0.25 MM x 12 months = 3 MM/year (1 person in charge)
Weekly (next week, week after next)	➤ Maximum demand and maximum PV output ➤ Supply capacity/Reserve capacity ➤ Amount of control reserve (Required/Secured) ➤ Study the demand for every 30 minutes (48 items per day) at the weekly planning stage.	➤ 0.05 MM x 9 persons x 52 weeks = 24 MM/year (9 man-days/week)
Intraday (the next day)	➤ Demand every 30 minutes (48 points per day) ➤ Supply capacity/Reserve capacity ➤ Amount of control reserve (Required/Secured)	➤ 1 man-month x 3 x 12 months x 2 persons = 72 MM/year (Three times the normal man-month due to 24-hour shift work)

Source: Study Team

The annual plan targets the next year and two years later, calculates maximum and minimum monthly demand on weekdays and weekends, and then calculates supply capacity and regulating reserve for each snapshot. Three people in charge engage in the annual plan for a year. The monthly plan targets the next month and two months later, calculates maximum and minimum weekly demand on weekdays and weekends, and then calculates supply capacity and reserve for each snapshot, along with necessary amount and secured amount of regulating reserve. One

person in charge engages in the monthly plan for approximately a week in a month, so it means approximately 3 people a month of workloads for a year. The weekly plan targets the next week and two weeks later and calculates supply capacity and reserve for the snapshots, which electricity and PV outputs are maximum. In actual situation, the demand every 30 minutes, supply capacity and reserve for 48 points per day are calculated in the weekly plan planning phase. Approximately nine people engage in the weekly plan for a day in a week, so it means approximately 24 people a month of workloads for a year. The intraday plan reflects most recent situation in the weekly plan and considers supply and demand schedule every 30 minutes. Two people on duty engage in the intraday plan for 24 hours so that it means approximately 72 people a month of workloads for a year.

5.2 Power System Operation Planning

5.2.1 Introduction

Short-term system operation planning is important for stable power supply. It helps optimize the use of available resources, including generating units and transmission lines, to minimize costs and maximize efficiency.

The report on short-term system operation planning covers several key topics. It will define what is meant by short-term system operation planning and explain its objectives. The report will discuss the various elements that affect short-term system operation planning, including demand forecasting, generation scheduling, unit commitment, regulating reserve management, and dispatching. It will also highlight the challenges faced in short-term system operation planning, such as uncertainty in demand forecasting and transparency in outage coordination, and the tools and techniques used to overcome these challenges. The report will emphasize the importance of effective short-term system operation planning in ensuring reliable and efficient operation of power systems and provide recommendations to meet with current Bangladesh system.

5.2.2 Bangladesh System Operation Planning

According to NLDC, the details of system operation planning currently conducted in Bangladesh are as follows:

(1) Analysis Tool

There is no offline simulation tool available in NLDC, such as voltage, voltage stability, synchronous stability, frequency stability, and short-circuit current calculation. Even though the contingency analysis and power flow calculation application are installed in SCADA/EMS, SCADA/EMS function cannot fulfill necessary calculation because some of online measurement data in power stations or substations are not send to the SCADA/EMS system in NLDC. In addition, short-circuit current calculation is not possible with the SCADA/EMS system.

(2) Various data necessary for considerations

Loads are measured once a month. Based on the ratio of total demand and individual load measurements, the total demand is allocated in substitutions. The total renewable energy facilities and output data on maximum demand snapshot can be calculated.

(3) Current considerations

In consideration of thermal capacity of transmission lines and transformers, overload transmission lines and transformers for which the N-1 contingency assumed in the previous-day phase are considered. However, the N-2 contingency is assumed for related networks in nuclear power stations. The PGCB planning section conducts long-term transmission system planning.

(4) Response for restrictions

(a) Measures for power flow restrictions

Generation adjustment, load shifting, topology change, bus-splitting, and load shedding.

(b) Measures for voltage restrictions

Changing the reactive power of generators, changing active power flow and the tap position of transformers, and shedding loads.

(c) Measures for short-circuit current restrictions

NLDC does not study short-circuit current but bus bars are split in some substations, which reduce the short circuit current.

(5) Current Analysis

There is a huge time lag between long-term power system operation planning conducted by PGCB and previous-day's planning considered by NLDC, and there are concerns that the actual situation may differ from that assumed in the long-term grid plan. It is considered essential to extract issues regarding actual system operation and consider the measures against the issues on an annual basis.

5.2.3 Definition of Short-Term System Operation Planning

(1) Definition of short-term system operation planning

Short-term system operation planning refers to the process of planning and managing the operation of a power system typically throughout the coming whole year. The main objective of short-term system operation planning is to ensure that the electricity supply meets the maximum and the minimum demand, while the operation procedure is optimized in order to cope with crisis situation in advance. Based on demand forecast, power development plan, and transmission system plan, power flow in both bulk and local systems, voltage, short-circuit current, transient stability, voltage stability, etc. are analyzed and considered along with the purpose of grasping the

system operation status during peak hours, off-peak hours, and large-scale construction. It helps identify potential issues in advance and reflect them in the facility upgrade plan to cope with them on operation level. Short-term system operation planning is conducted every year, and whenever any change is made on demand forecast or facilities plan, they are reconsidered. This involves a range of efforts, such as load forecasting, generation scheduling, unit commitment, reserve management, dispatching and countermeasures to meet target criteria, all of which are aimed at optimizing the use of available resources to ensure system stability and reliability. Short-term system operation planning is critical for maintaining the reliability and stability of the power system, particularly for responding to uncertainties and variability in demand and supply under extreme operation circumstance.

(2) Time horizon of short-term system operation planning

Short-term system operation planning involves planning and managing the power system over a whole year. The time horizon of short-term planning varies depending on the specific context and objectives of the planning process. In general, the time horizon of short-term planning can range from a few months to a few days, and sometimes even shorter, daily outage coordination management for example.

The time horizon of short-term system operation planning is explained as follows and the outage coordination management is explained in 5.3.

Short-term operation planning: It typically covers the whole year. During this period, the power system operators develop an annual operating plan that considers maximum and minimum forecast snapshot in supply and demand, transmission and substation facility maintenance schedules, and other factors, which may affect the power system operation throughout the year. Short-term system operation planning during this period focuses on developing detailed operating plans for the possible maximum and minimum demand snapshot.

(3) The objectives of short-term system operation planning

Short-term system operation planning is an indispensable process in power system operation, with the primary objective of ensuring the reliable, efficient, and safe operation of the power system. The following are some of the objectives of short-term system operation planning in power systems:

System operation under normal and contingency condition: One of the primary objectives of short-term system operation planning is to cope with contingency case caused by equipment failures, occasional system malfunction, and demand forecast errors. This involves a countermeasure to ensure that the system remains stable.

Ensuring system stability: Short-term system operation planning aims to ensure the stability of the power system by maintaining a balance between generation and demand. This involves

managing the frequency and voltage of the power system, as well as ensuring that there is enough regulating reserve available to handle unexpected changes in power system.

- Managing system emergency snapshot: Short-term system operation planning aims to ensure the supply-demand balance in peak and off-peak times. It reflects the demand for generation and plans while the system stability is ensured. In summary, the objectives of short-term system operation planning in power systems are to balance supply and demand in estimated peak and off-peak times, ensure system stability, and clarify countermeasures for emergencies. By achieving these objectives, short-term system operation planning helps to ensure the reliable and efficient operation of the power system.

5.2.4 Work Flow of Short-Term System Operation Planning

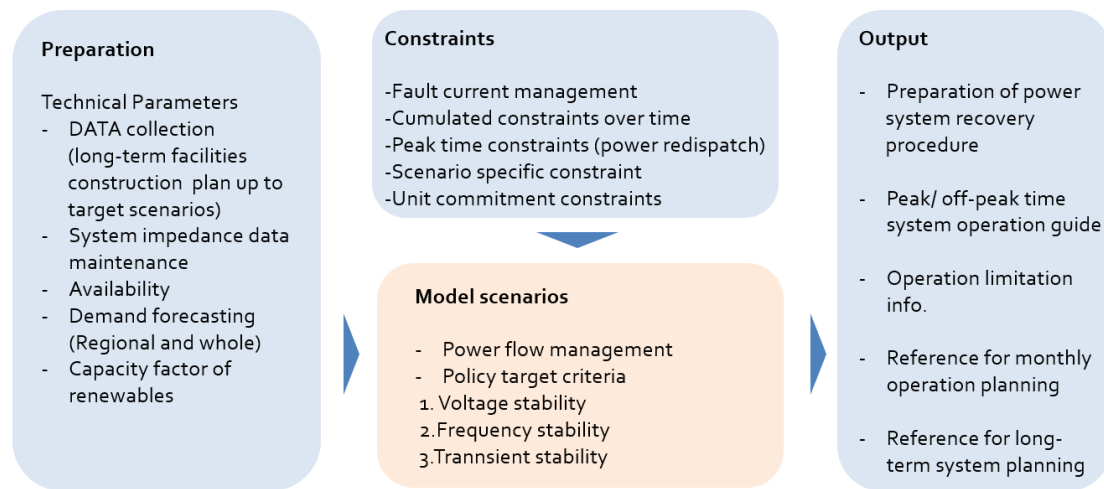
There are various stages involved in short-term system operation planning in power systems. The first stage is preparation, which includes collecting data on technical parameters, facilities availability, and demand forecasting. The data collected is used for long-term facilities planning and target snapshot development.

The second stage is constraints management, which involves managing fault currents, cumulated constraints on equipment over time, peak time constraints, snapshot-specific constraints, and unit commitment constraints.

The third stage is model scenarios development, which involves management to meet target criteria such as voltage, frequency, and transient stability.

The final stage is the outputs of short-term system operation planning, which contributes to the preparation of power system recovery procedures, peak/off-peak time system operation guides, operation limitation information, and reference materials for monthly and long-term system planning.

By following these stages, power system operators can ensure the efficient and reliable operation of the power systems, providing consumers with a reliable power supply.



Source: Study Team

Figure 5-6 Workflow of short-term system operation planning

(1) DATA collection

There are several important aspects of DATA collection.

- Demand record in previous year
(For calculation of load distribution ratio in each zone)
- Long-term facilities plan up to target snapshots
(Detailed technical parameter data is required.)
- System impedance data collection and maintenance
(Bulk system and local system)

(2) Demand forecasting (Regional and whole)

When it comes to power system operation planning, the demand forecast is a critical aspect that needs to be thoroughly considered. The demand forecast includes generally three steps. From the overall demand forecasting to the detailed forecasting, the forecasting area is progressively subdivided.

Firstly, demand forecasting is conducted for the whole system. This allows system operators to assess the overall demand for electricity across the entire system.

Secondly, regional load distribution studies are conducted based on past results. Normally the average demand over the past few years is used for each regional zone. By analyzing this data, system operators can make informed decisions about how to allocate resources to ensure that demand can be met effectively.

Thirdly, regional load forecasting studies are conducted to predict future demand of distribution substations and consumers connected to transmission lines in specific areas. This involves

collecting and analyzing data related to the load (P,Q) in distribution substations, including the forecasting of photovoltaic (PV) power.

The demand forecast is a critical component of power system operation planning, particularly in regional systems. By conducting demand forecasting and load distribution studies, system operators build highly effective, safe, reliable and cost-effective systems to maintain the stable supply.

(3) Source impedance data maintenance

- Source impedance calculation result
(Aggregation of system into a certain bus, e.g. 33kV bus in PGCB system model)
- Modification based on collected data above
(Neighboring area included, e.g. AC interconnection point)

(4) Facilities availability check

The operation status of transmission and substation facilities are confirmed by checking the operation status of generators during peak demand, which is scheduled in supply-demand operation planning, as well as availability of transmission and distribution facilities.

(5) Topology: fault current management

In order to ensure the reliable operation of a power system, there are several important factors that must be considered during the process of deciding system topology. These factors include the availability of generators and transmission facilities, the interrupting capability and short-time withstand current of circuit breakers, and the results of short circuit current calculations.

Firstly, it is essential to ensure that all available generators and transmission facilities are contained in the target snapshot for peak demand. This is to ensure that all generators that may be operated during the target period are in service and that the system is configured so that even if the maximum fault current flows, it will not exceed the allowable range.

Secondly, the bottlenecks of the interrupting capacity and short-term withstand currents must be identified for the facilities, including circuit breakers, disconnectors, arresters, and bus bars. This is necessary in order for the power system to operate within the capabilities of these facilities, even in the event of fault or other emergency situation.

Finally, a short circuit current calculation needs to be performed. In order to evaluate fault currents in solid grounding system, it is necessary to perform single line to ground fault current calculations in addition to three-phase short circuit current calculations.

By taking into consideration the availability of generators and transmission facilities, the interrupting capability and short-time withstand current of facilities, and short circuit current calculations, system operators can manage the fault current and ensure the safe and reliable

operation of the system.

(6) System model

Based on the long-term facilities plan that matches with target scenario snapshots, the system model is built while being modified in line with the collected data. (Detailed technical parameters are required).

Transmission system MAP data is also developed at this stage. (e.g. SLD file)

Long-term facilities plan includes:

- a. Transmission lines
- b. Generators
- c. Shunt equipment (Reactors and capacitors)
- d. Transformers
- e. Load (Consumers directly access to the transmission system)

(7) Updating the System Model

Based on the result of regional load (P,Q) forecasting study, the load data of the system model is determined. By conducting these studies, system planners can identify the load of transmission lines and transformers that is likely to be higher in the future and take action accordingly.

(8) Confirmation on the System Constraints

All the constrain in the power system should be taken care of, including:

- Fault current management
- Unit commitment constraints: output limitation affected by environment or Power Purchase Agreement (PPA)
- Snapshot-specific constraint
- Peak time constraints
- Cumulated constraints on equipment over time, etc.

(9) System reliability evaluation items

In order to ensure the reliability of the system, in the short-term system operation planning, various studies on the steady-state analysis, voltage stability, frequency stability, and transient stability are carried out, and measures are taken to satisfy the criteria.

The items of evaluating the system stability are as following:

System reliability evaluation: steady state

System reliability evaluation starts with the steady-state analysis, which includes power flow management for overload equipment. This mitigates the power flow overload by altering power system topology.

System reliability evaluation: Voltage management

Maintaining the voltage at all buses in the system within the allowable range is crucial for ensuring system stability and reliable operation. The voltage management procedure involves analyzing the voltage profile, taking corrective measures to address any deviations from the acceptable range, and adjusting generator voltage and sending voltage from substations.

System reliability evaluation: N-1 contingency study

It evaluates the system ability to continuously operate after the loss of a single component (a generator or transmission line). As measures to reduce the overload under N-1 contingency, restriction of generator output, load shifting, topology changing are considered.

System reliability evaluation: fault current management

The fault current management procedure involves rechecking the results of short-circuit calculations after the topology is changed to satisfy other criteria.

System reliability evaluation: N-2 contingency study

The N-2 contingency study involves analyzing the system's response to the loss of two elements, such as transmission lines or generators, to ensure that the system remains stable and can continue to meet the demand or minimize the area of blackouts. Bus-bar fault is included in N-2 contingency in some case.

The frequency stability evaluation involves analyzing the system's response to a maximum frequency deviation, which helps ensure that the system can maintain a stable frequency and avoid load shedding due to frequency drop. This is accomplished by ensuring a certain amount of generation capacity.

The transient stability evaluation involves analyzing the system's response to a disturbance or fault, such as a sudden loss of generation or a short circuit. This helps ensure that the system can maintain stable operation during transient events and avoid wide-area blackouts. Contingency case studies are performed to confirm the system's transient stability limitations and ensure that sufficient resources are available to maintain stable operation.

Overall, these evaluations are critical to ensuring the reliability and stability of the power system, especially during contingencies and disturbances.

(10) Human resources required for annual system operation planning

As an example of the required human resources for annual system operation planning in Japan, one team leader and two team members (two members for backup) are likely to be required if the project team conducts the annual system operation planning.

5.3 Outage coordination Planning

5.3.1 Purpose

Power plants, substations, and transmission lines, which are connected to power systems, sometimes require outages in association with inspection for facility maintenance, repairs, renovations, or facility expansion. Such outages may have a large effect on supply-demand balancing and system stability. In some cases, they cause blackouts, affecting consumers. Therefore, outage planning needs to be conducted while being coordinated through the entire system. For that reasons, the periods and outage areas are determined after the outages of power plants, substations and transmission lines are coordinated with related departments.

Recent power demand diversification, city's urban functions, and spread of home appliances are creating more difficult situations for scheduled outages. Thus, precise and detailed planning and coordination are essential for scheduled outages.

5.3.2 Current Work flow of Scheduled Outage Coordination in Bangladesh

This part focuses on identifying facts in scheduled outage coordination. JICA Study Team collects information on the current scheduled outage coordination process after discussion with NLDC. It highlights several issues that decrease the efficiency and accuracy of scheduled outage coordination.

(1) Period covered by scheduled outage coordination

Currently, there are only annual and daily plans for scheduled outage coordination. Daily scheduled outage requests are submitted two days before the scheduled outage, while annual scheduled outage requests are submitted at least 15 days before the scheduled outage. Emergency outage requests are submitted instantly through a web application, and all requests are compiled in a single file.

(2) Demand forecast

NLDC collects 15 days ahead hourly demand forecast from distribution companies.

(3) Scheduled Outage requests

An Excel file format is used to submit outage requests, including information such as date and time, facilities to be stopped, working part, reasons for the outage.

(4) Criteria for acceptance of scheduled outage

The criteria used for acceptance of scheduled outage includes avoiding overloading, ensuring

regulating reserve in consideration of N-1 contingency, minimizing load shedding, and maintaining network stability.

(5) Calculation of necessary reduction of power output due to transmission system constraints

The amount of necessary reduction of power output due to transmission system constraints is calculated manually based on past experiences and a systematic and automated approach is not available.

(6) Grid code

The Operating Committee is established to strengthen scheduled outage coordination. Grid code specifies that the operating committee regularly holds the meeting, but currently the committee does not function.

Grid code specifies that the annual outage plan is notified on 31 May every year. However, the annual outage plan is submitted by facility maintenance division at least 15 days before the outage date. In other words, the grid code is not strictly followed.

5.3.3 Basic Item

(1) The purpose of sharing information about an outage coordination plan and its importance

In order to ensure long-term predictability and transparency and to facilitate consideration of work plans and consistency with the generator maintenance work plan, the “Draft of outage coordination plan for transmission facilities that require power generation constraints” for the third year is shared with the generation companies that are subject to generation curtailment.

Disclosing the scheduled outage coordination results to the relevant parties ensures transparency. Higher transparency leads to well-planned action and builds a trusting relationship with the power system operator. The disclosed results enable to accelerate communications between relevant parties. Sharing the information promotes more efficient cooperation and encourages the operator to conduct the scheduled outage as planned. These well relationships will minimize repeating the scheduled outages.

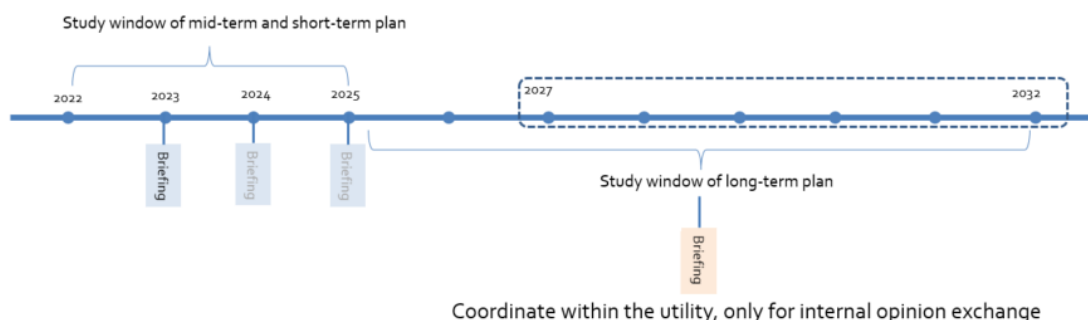
However, wrong predictability may trigger generation company’s confusion so the information (objective, duration, reason for the outage, etc.) on scheduled outage plan which have a high probability of implementation is shared with the generation companies. The outage coordination plan with power curtailment may take some time for coordination. Thus, the power system operator provides the first response deadline for the coordination requirement of the plan. Power generation companies that are subject to generation curtailment will contact transmission companies as soon as possible with their requests for adjustments, etc., and begin discussions to coordinate the scheduled outage plans.

Sharing the outage coordination plan will strengthen handling capability in emergency situation.

Relevant parties can understand the impact occurred by the planned outages in advance and can take smooth and appropriate measures.

(2) Forming schedule of the outage coordination plan

Figure 5-7 shows the schedule of the outage coordination plan.



Source: Study Team

Figure 5-7 Schedule of forming the Outage Coordination Plan

The long-term scheduled outage coordination plan is conducted every year, for a year span. The annual scheduled outage coordination is conducted by collecting a 3-year ahead plan and analyzed, then the briefing is hold every year.

(3) Types of Scheduled Outage Coordination Works, Target Period and Mutual Relevance

(a) Relevance of outage coordination plans

The long-term plan basically becomes a foundation for developing a short-term plan. All types of outage plans are subjected to the evaluation in terms of the necessity and amount of capacity curtailed by transmission constraints for all requests of scheduled outages

Target Period

(b) The period to be considered

- Long-term scheduled outage coordination Plan (4 years to 10 years)
The long-term scheduled outage coordination plan is formed to estimate future supply-demand balance of power systems and to secure long-term stability of the power systems. The long-term scheduled outage coordination plan consists of the demand and supply capacity prediction, facilities maintenance and enhancement plan. The long-term plan is essential for developing the annual outage coordination plan, monthly outage plan, and daily outage coordination plan.
- Annual scheduled outage coordination plan
The plan covers the next three years. For the second and the third-year scheduled outage coordination plan, update, addition, modification and elimination of power stations are

identified in accordance with the future demand forecast. Pre-coordination is conducted for facilities that require some time to coordinate the outage or are difficult to coordinate outage. Prior information necessary for determining the first-year outage coordination plan is provided.

As for the first-year outage period, scheduled outage is coordinated to respond to the demand forecast as well as not to affect stable supply of electricity in consideration of the status of power demand and supply capacity for each scheduled outage duration annually. The plan is coordinated in consideration of changes in maintenance, inspection, and repair plans of generation and transmission facilities from the previous year plan. Prior information necessary for determining the monthly outage coordination plan is provided

- Monthly scheduled outage coordination plan
In view of the status of demand forecast and supply capacity during the period of the monthly outage, operation constraints of power stations are coordinated if necessary. The outage is coordinated in consideration of the latest operation plan of the power stations. The necessary information for implementing outages is provided.
- Daily scheduled outage coordination
In the view of the status of supply capacity and demand forecast on the day, power station operation is coordinated if necessary. Emergency stop such as sudden accident and failure of equipment is handled.

(4) Types of scheduled outage coordination plans

The types of scheduled outage coordination plan for each period, which are planned by coordinating the timing of scheduled outages requested by the transmission system users are classified on Table 5-2.

Table 5-2 Types of scheduled outage coordination plans

【Types of plans (cycle)】 《Outage correspondent》	Period	Details
Power source outage coordination plan 【Annual plan】 《Power source plan》	One year	Outage coordination plan that coordinates the outage plan (periodical and general repairs) of power source facilities.

Long-term outage coordination plan 【Long term plan】 《Bulk system 1 to 4 years plan》 《Bulk system 5 to 9 years plan》	4th year 5th to 10th year	4th year To improve the accuracy of the scheduled outage plan and achieve construction work volume leveling at an early stage, only scheduled outage with high likelihood, for which detailed review has been completed, are coordinated and planned. 5th year and onwards To ensure the implementation of important matters such as long-term asset planning and long-term maintenance planning, and to promote consistency with other scheduled outage, the scheduled outages that take 10 days or more are coordinated and planned. (For scheduled outages that are likely to be realized after detailed consideration, scheduled outages to take about less than 10 days are also targeted.)
Annual outage coordination plan 【Annual plan】 《Bulk system 1 to 4 years plan》 《Local system plan》	three years	A three-year outage plan was prepared and coordinated regarding the timing and period of the scheduled outage plan of transmission and distribution facilities. Preliminary countermeasures on each and every perspective of system operation, facility operation and work implementation, which scheduled outage is implemented smoothly, are established. If needed, the countermeasures are reflected in the facilities plan. Scheduled outage coordination plan is matched with the facility capex (investment) and the cost plan.
Monthly outage coordination plan (Power source/system) 【Monthly plan】 《Bulk system plan》 《Local system plan》 《Facility management》	One month	All scheduled outage coordination plans for the following month (two months ahead) that have been reviewed and coordinated regarding the timing and period of the outage, which is for telemetering information directly affecting power source facilities and demand-supply control, circuit breaker information, and transmission and substation equipment.

Source: Study Team

(5) Concept of Scheduled Outage Coordination

On the premise of securing worker's safety and facility maintenance in the event of the facility outage, smooth and reasonable implementation of scheduled outage, supply and demand balance during the scheduled outage period, and securing supply reliability are considered to select appropriate outage timing. Table 5-3 shows the consideration items for developing the outage coordination plan.

Table 5-3 Consideration items for developing the outage coordination plan

Consideration Items	Main Consideration Items
Work details	Necessity of outage works, scope of outages, work method, work duration, work amount, securing workers, etc.
Safety	Safety of workers and facilities (short-circuit and ground fault current, thermal capacity), etc.
Power quality	Maintaining regulated frequency (supply-demand balance, securing regulating reserves) maintaining regulated voltage, harmonic, flicker, etc.
Supply reliability	Frequency of power outage, amount of power outage, outage duration, outage facilities, system stability, voltage stability, etc.
Efficiency	Transmission loss, etc.
Environment	Local support, impact to fishery and tourism, downstream water supply, etc.
Direct impact to the consumer	Power outage, agreement on main and backup lines, operation, work plan, etc.

Source: Study Team

(6) Overview of the scheduled outage coordination plan

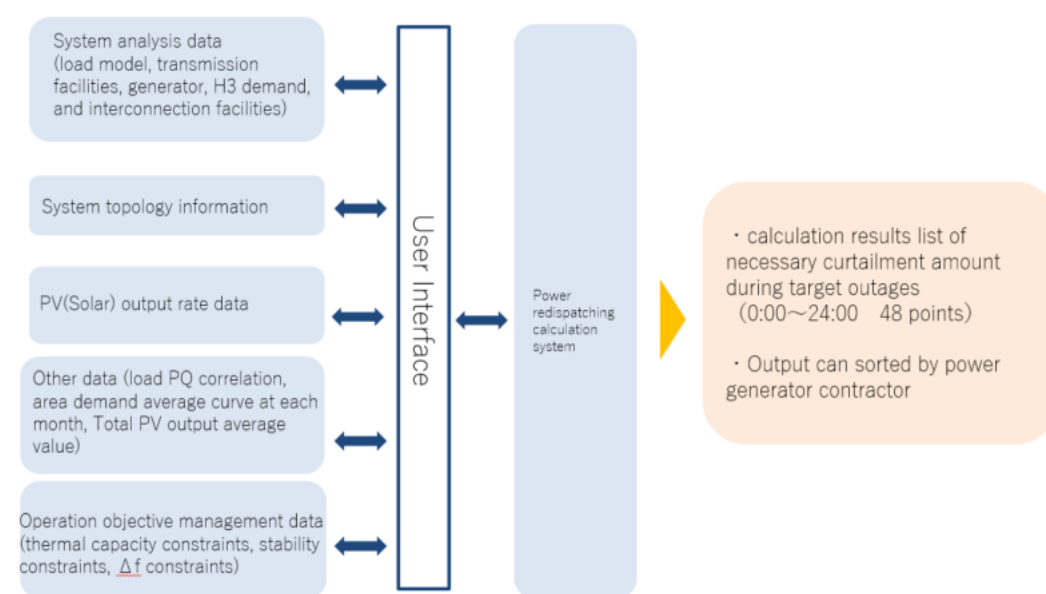
After the drafted plan regarding outage facilities and duration is provided from generation companies and facilities management department, the departments in charge of scheduled outage coordination develop the plan.

The system configuration topology during outage is considered and the thermal capacity, stability, and frequency stability are carefully confirmed to decide the possible outage period.

(7) Approach of the coordination of the scheduled outage plan associated with transmission system constraints

The coordination of the scheduled outage plan associated with power generation curtailment are based on the following: the department in charge of scheduled outage coordination provides the outage coordination plan in advance to the generation company (power generation plan provider), (shares the information on the next three year's outage coordination plan), and encourages the generation company to reflect the scheduled outage of generation facilities on the outage coordination plan of the transmission facilities.

The proposed annual outage coordination plan for both transmission and generation facilities (for two years later) is submitted. The department adjusts the plan while considering the minimization of power generation curtailments through reflection of the outage on the plan in order to reduce the power generation and avoid outages as much as possible if there are some options for the timing of the maintenance of transmission facilities. For promoting the work efficiently, the calculation system for generation curtailment is used to calculate the amount of generation curtailment. Figure 5-8 shows the conceptual diagram of the calculation system.



Source: Study Team

Figure 5-8 Conceptual diagram of Calculation System for generation curtailment due to transmission constraints

(8) Human resources necessary to implement scheduled outage coordination

The following shows an example of necessary human resources to implement scheduled outage coordination by the departments in charge of scheduled outage coordination .

Annual scheduled outage coordination plan: 4 people

Monthly scheduled outage coordination plan: 6 people (including members for update of weekly scheduled outage plan and the team leader of monthly scheduled outage coordination team)

5.4 Measures in Case of Supply-demand Emergency

5.4.1 Operation under supply-demand emergency

The generation company, transmission company and distribution company determine the operation details and coordinate with mutual goodwill to respond to power shortage quickly and accurately. System operators maintain reserve capacity while closely monitoring the demand

trend (degree of demand increase) and weather changes for ensuring supply-demand balance in the case where power shortage occurs or power shortage is expected because of shortage of reserve capacity due to high demand. The system operators check the implementation status of supply-demand emergency measures as needed and promptly implement usable measures.

5.4.2 Emergency notification advisory

When the reserve capacity ratio is anticipated to be less than 5% even though additional measures for improving supply capacity are taken, the transmission company issues an emergency notification advisory to give consumers alert. The advisory is issued by 6:00 p.m. on 2 days before the target day in order to inform the consumers that the power shortage may be caused. The issued information is to show the prospective reserve margin for two days later and notify consumers of the situation. By doing so, the consumers can prepare to save energy. Concrete actions for saving energy is not required in the phase.

5.4.3 First Stage Countermeasures: Reserve Margin Less Than 8%

When the reserve margin is less than 8%, the situation is considered as 1st stage. In the stage, necessary reserve margin may not be maintained. The system operator declares an energy emergency alert 1 if the above condition is met. The system operator requests transmission system users to take action against it without any delay.

Actions to be taken including:

- Thermal power plant output increase (Over power operation)
- Combined cycle thermal power plant output increase by peak mode operation (within annual maximum hours based on agreement)

5.4.4 Second Stage Countermeasures: Reserve Margin Less Than 8% After 1st Stage Countermeasures Are Taken

When reserve margin is still less than 8% after all necessary actions are taken for the first energy emergency, the situation is considered as 2nd stage. The system operator requests transmission system users to provide emergency supply capacity from all power sources.

Actions to be taken including:

- Request of increasing power generation outputs that cannot be controlled by the central load dispatching center.
- Request of increasing in-house power generation outputs

5.4.5 Third stage countermeasures

(1) Emergency notifications warning: Reserve margin is between 3% - 5%:

When the anticipated reserve margin is still less than 3% to 5% after all additional measures for improving supply capacity are taken, the government issues an “Emergency notifications

warning” by 4:00 p.m. a day prior to the target day. The warning is issued in terms of widely notifying consumers of the power shortage possibility in advance even if the wide area reserve margin is more than 3%, which is a basis of issuing the warning. It requests energy saving in accordance with the anticipated reserve margin for the next day and the urgency of power shortage.

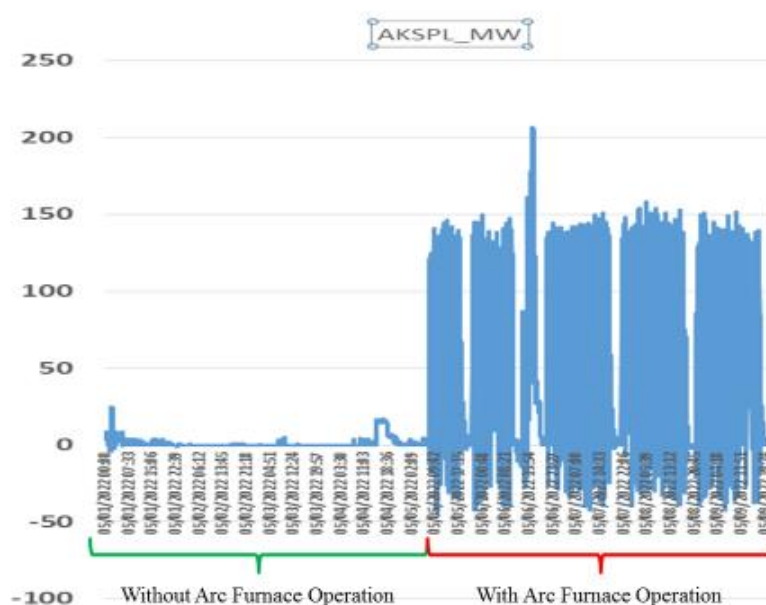
(2) Emergency notifications alert: Reserve margin is less than 3%

When those available countermeasures have been applied and reserve margin is still less than 3%, the government issues the Emergency notifications alert by 16:00 prior to the target day. If the supply-demand situation is not improved from the previous day and is updated, the situation is anticipated to be more severe, and the reserve margin is less than 3%, the government issues an alert (continuing). When the risk of power shortage is judged to be eliminated, the alert is cancelled. If the demand is unlikely to be met with the supply capacity as of about 2 hours prior to real-time supply-demand operation, the implementation of rolling blackouts is announced.

6. Measures for Flicker

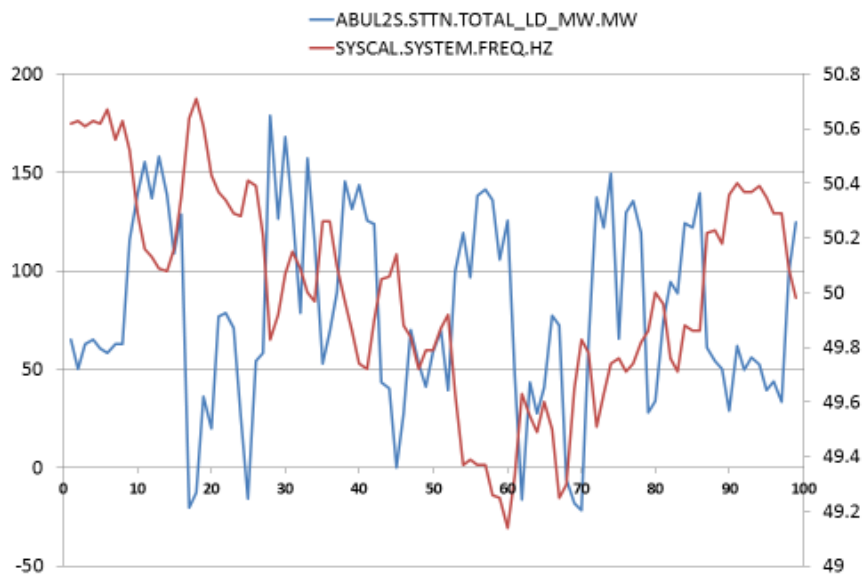
6.1 Current issues

There is an issue that a sudden demand fluctuation triggered by arc furnaces, etc. occurs, resulting in large impact on the entire frequency and other consumers when the multiple arc furnaces connected to the distribution substations of BPDZ are being operated by Abul Khair Steel Products Ltd. (AKSPL).



Source: NLDC

Figure 6-1 Demand fluctuations with or without arc furnace operation by AKSPL



Source: NLDC

Figure 6-2 The actual situation of demand and frequency fluctuation in the case of operation by AKSPL

According to NLDC and BPDB, the situation is as follows.

- ✓ Significant fluctuation is caused especially in the three plants (No.10, 12, and 13) among 14 plants in AKSPL.
- ✓ A total 13 load shedding were caused due to underfrequency relay operation at 8 a.m. to 12 p.m. in 3 July in 2021.
- ✓ Fluctuation range is about 200 MW and fluctuation cycle is about 2 sec. at minimum.
- ✓ Current grid codes have been revised in 2017 in accordance with the grid codes in the UK. However, the contract with AKSPL was agreed in 2016 before the revision was not completed.
- ✓ The TSO controls system operation to maintain higher frequency bands at all the time to respond to frequency fluctuation during AKSPL's operation.
- ✓ There is a situation where a few Primary Reserves (generators using governor-free) in the system are used to respond to the issue.
- ✓ In addition to frequency, there are issues on voltage fluctuation in surrounding systems but it does not have significant effects as much as frequency.
- ✓ The fluctuation gives stress on generators in many systems.

The NLDC has following measures even though the solutions are not applied.

- ✓ The batteries, etc., which can absorb energy comes from devices, are installed by AKSPL.

- ✓ The fluctuation range is reduced by adjusting the time zones of load fluctuations in each arc furnace.
- ✓ The types of arc furnaces are changed to continuous arc furnaces, induction furnaces, etc.

Table 6-1 Flicker load list provided by BPDB (S/N 10, 12, and 13 are the most affected)

S.N	Consumer Name & Address	Voltage level (KV)	Connected transmission line	The substation which sends the power to the customer usually	Actual demand (MW)	Contract Demand (MW)	Industry type	Furnace type for steel industry	Furnace capacity for steel industry	Measures on facilities are present or not	Measures on facilities (SVC, etc.)
1	Bangladesh Steel Re-Rolling Mills Ltd., Khulshi, Ctg.	132	Khulshi Grid to BSRM 132 kV Line	Khulshi 132/33 kV Grid -132kV Bus	50	60	Steel Mill	Induction Furnace	54 MW	Present	Capacitor with 6% detuned Reactor
2	T.K. Chemical Complex Ltd., Boaldhali, Kalurghat, Ctg.	132	Modonghat to Sikolbaha 132 kV Line	Modonghat 132/33 kV S/S	10	15	Paper Mill	NA	NA	Present	Harmonic Filter with Auto Control PFI
3	132 KV Modern Steel Ltd., Bayezid Road, Ctg.	132	Bakulia to Khulshi-132 kV Line	LILO	Shut off	16	Steel Mill	Induction Furnace	15 MW	Present	PFI
4	Abul Khatir Steel Products Ltd., Madanbikhat, Ctg.	132	Baraula to Khulshi 132 kV Line	LILO	20	24	Steel Mill	Cold Rolling & Galvanising	NA	Present	Harmonic Filter with PFI
5	Simpur Auto Steel Mills Ltd., Simpura Ctg.	132	Khulshi to Hathazari 132 kV Line	Baraula 132/33 kV Grid S/S	15	23	Steel Mill & Re-rolling	Induction Arc Furnace	20 MW	Present	Harmonic Filter with Auto PFI
6	Rahim Steel Mills Co private Ltd, Haripur	132	Bhulta to Meghna ghat 132 kV Line	Haripur 132/33 kV S/S	40	40	Steel Mill	Induction Furnace	86 MW (Self sensation)	Present	Harmonic Filter with Auto PFI
7	Saundhara Indust. Complex Ltd, Madanpasi	132	Meghnaghat to Dhaka (s) 132 kV Line	Modongongang 132/33 kV S/S	15	25	Cement industry	NA	NA	Present	Harmonic Filter with Auto PFI
8	Kabir Steel Re-Rolling Mills Ltd. (KSRM), Baro Kurira, Sitakund, Chittagong	132	Hathazari to Baraula 132KV Line	Baraula 132/33 kV Grid S/S	65	96	Steel Mill	Induction Furnace	64 MW	Present	Harmonic Filter with Auto PFI
9	KYCR Coil Industries Limited, Sitakund, cte	132	Hathazari to Baraula	Baraula 132/33 kV Grid S/S	15	20	Coil, GI Plate	Induction Furnace	250KW	Present	Harmonic Filter with Auto PFI
10	230 KV BSRM Ltd., Mirsarai Chittagong	230	Cumilla to Hathazari 230 kV Line	LILO	100	150	Steel Mill	Induction Furnace	132 MW	Present	Capacitor Bank with 6% detuned Reactor
11	PHP Integrated Steel Mills Ltd., Nishkumara, Chittagong, Pasi.	132	Cumilla South to Baroirhat 132KV Line	Baroirhat 132/33 kV S/S	15	30	Steel Mill	Pre-heating Furnace	1.2 MW	Present	Harmonic Filter with Auto PFI
12	GPH Bapat Ltd., Sitakunda, Chittogram.	230	Cumilla to Chittogram 230 kV Line	LILO	80	80	Steel Mill	Electric Arc Furnace	60 MW	Present	Harmonic Filter with Auto PFI
13	Abul Khatir Steel Products Ltd., Choptogram	230	Hathazari to BSRM 230 kV Line	LILO	150	230	Steel Mill	Electric Arc Furnace	140 MW	Present	SVC 110 MVAR
14	Seven Circle (Bangladesh) Ltd, Kalijang, Gazipur	132	Ghorashal to Seven Circle 132KV Line	Ghorashal 230/132/33 kV Sub-Station	25	40	Cement, Packaging & Ship building	NA	NA	Present	Harmonic Filter with Auto PFI

Source: BPDB

6.2 Rules of current grid codes

The rule regarding flicker specified in Section 17.2.1 and 17.2.6 of the current grid code issued in 31 Dec, 2019 is shown below.

There are rules regarding voltage fluctuations but there are no rules regarding frequency fluctuations, which can be applied as a measure for consumer's device causing a flicker.

● Power Quality Problems: Section 17.2.1 of the grid code

For the purpose of this Section, Power Quality shall be defined as the quality of the voltage, including its frequency and the resulting current, that are measured in the Grid during normal conditions.

A Power Quality problem exists when at least one of the following conditions is present and significantly affects the normal operation of the system:

(a) The System Frequency has deviated from the nominal value of 50Hz;
(middle part omitted)

(f) Voltage Fluctuations cause Flicker that is outside the allowable Flicker Severity limits;

or

(later part omitted)

- **Voltage Fluctuation and Flicker Severity:** Section 17.2.6 of the grid code
 For the purpose of this Section, Voltage Fluctuations shall be defined as systematic variations of the voltage envelope or random amplitude changes where the RMS value of the voltage is between 90 percent and 110 percent of the nominal voltage.
 For the purpose of this Section, Flicker shall be defined as the impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.
 In the assessment of the disturbance caused by a Flicker source with a short duty cycle, the Short-Term Flicker Severity shall be computed over a 10-minute period.
 In the assessment of the disturbance caused by a Flicker source with a long and variable duty cycle, the Long-Term Flicker Severity shall be derived from the Short-Term Flicker Severity levels.
 The Voltage Fluctuation at any Connection Point with a fluctuating demand shall not exceed one percent (1%) of the nominal voltage for every step change, which may occur repetitively. Any large Voltage Fluctuation other than a step change may be allowed up to a level of three percent (3%) provided that this does not constitute a risk to the Grid or to the System of any User.
 The Flicker Severity at any Connection Point in the Grid shall not exceed the values given in Table 6-2.

Table 6-2 Maximum Flicker Severity

	Short Term	Long Term
132 kV and above	0.8 unit	0.6 unit
below 132 kV	1.0 unit	0.8 unit

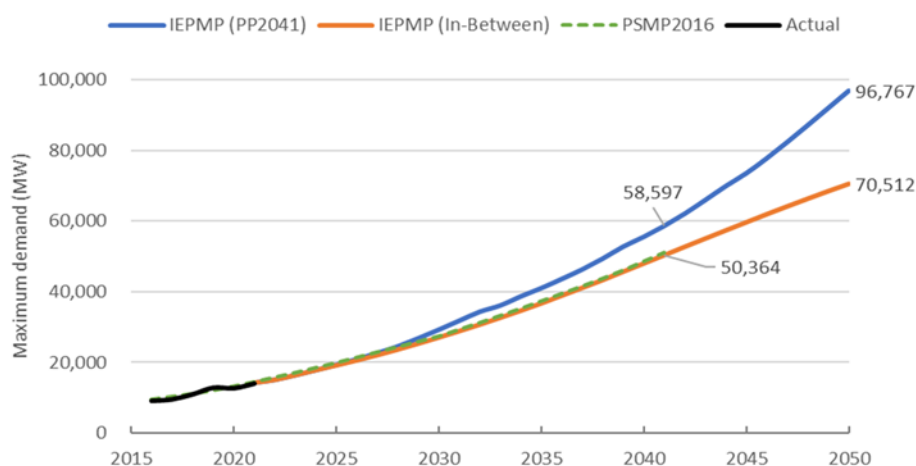
Source: Study Team (Based on the Bangladesh Grid Code)

6.3 Future Assumptions for Flicker Impact

In Chapter 4, frequency calculations were performed for the UFLS setting study, and the method was used to assume future flicker impacts. First, based on the results of the master plan study, the future maximum power demand assumptions are as follows.

Table 6-3 Future maximum power demand assumptions

	Maximum demand (MW)				Annual growth rate			
	2019	2030	2041	2050	'30/'19	'41/'30	'50/'41	'50/'19
PP2041	12,893	29,257	58,597	96,767	7.7%	6.5%	5.7%	6.7%
In-Between	12,893	27,087	50,364	70,512	7.0%	5.8%	3.8%	5.6%



Source: Study Team

Figure 6-3 Maximum demand forecast (from The Integrated Energy and Power Master Plan)

Future assumptions of flicker impact are calculated using the following methods.

- ✓ Identify future changes in frequency fluctuations when rapid demand changes of 200 MW occur.
- ✓ Assume that half of the maximum system demand is the minimum system demand as the case of flicker impact.
- ✓ Check the future change in frequency fluctuation when a sudden demand change of 200 MW occurs.
- ✓ In addition, as a frequency characteristic, it is assumed that the current value of about 2% MW/Hz will be 4% MW/Hz in 2030, with a certain degree of progress in measures to secure regulating power, and that improvements will progress year by year toward that value.

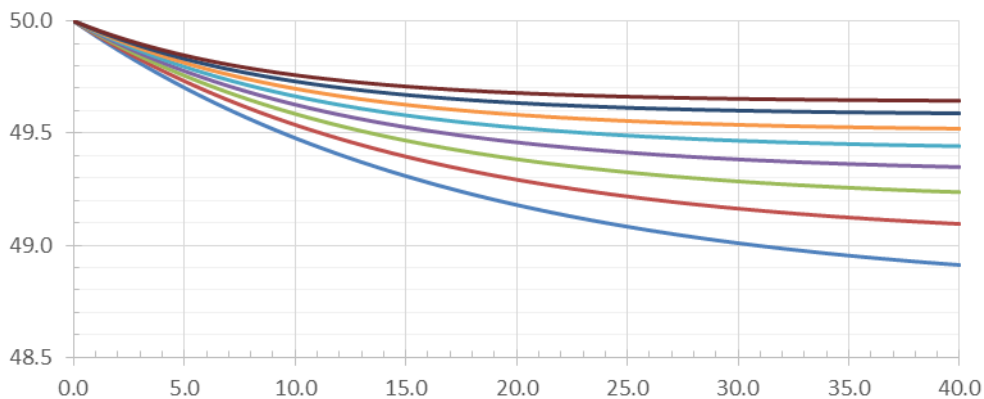
Therefore, the following are the parameters of the frequency calculations, and the results of the frequency calculations using these values are shown below.

The frequency calculation results show that the flicker effect improves year by year along with the growth of electricity demand. Although this is not an exact value due to the various factors involved, it can be considered as a guideline for a certain scale.

Table 6-4 Factors Related to Future Assumptions of Flicker Impact

	2023	2024	2025	2026	2027	2028	2029	2030
Maximum system demand [MW]	16418	17830	19218	20602	22106	23754	25728	27781
Minimum system demand [MW]	8209	8915	9609	10301	11053	11877	12864	13890
Rapid demand fluctuations, 200MW	200	200	200	200	200	200	200	200
Ratio of rapid demand fluctuations [%]	2.44	2.24	2.08	1.94	1.81	1.68	1.55	1.44
Assumption of frequency characteristic [%MW/Hz]	2.00	2.29	2.57	2.86	3.14	3.43	3.71	4.00

Source: Study Team



Source: Study Team

Figure 6-4 Assumption of future frequency fluctuations at 200 MW sudden load fluctuation in flicker load (assuming minimum demand)

6.4 Recommendations for consideration of countermeasures

(1) Improvement trend

The current adverse effects of frequency fluctuations due to flicker are expected to improve as a result of future developments in the power system.

The following three reasons can be considered.

- ① Increase in system demand
The peak demand of about 13 GW in 2019 is expected to increase rapidly to nearly 30 GW in 2030. While supply capacity and T&D system development issues are likely to emerge, significant improvements are expected in the impact of flicker load on frequency.
- ② Increase in reserve, especially spinning reserve
The current situation is described in detail in Chapter 3, but the introduction of FGMO, which is currently being expanded, is expected to increase in the near future.
- ③ Increase in large rotating machines
Based on the results of the study in Chapter 4, it is considered that the inertia force is currently small, not only due to the lack of reserve, but also due to the effect of the capacity of rotating machines in operation. In the future, it can be expected that the inertia force will increase as nuclear machines and other large generators are introduced.

(2) Cost burden issue

When the grid size increases beyond a certain level, the adverse effects of frequency fluctuations tend to be greatly improved. Therefore, in the grid codes of developed countries, there are generally no provisions that serve as constraints on frequency fluctuations on the customer side. With regard to flicker, the provisions are not about frequency, but about voltage. Considering this, we believe that it would be generally difficult to require the customer to pay for the measures.

(3) A countermeasure Flywheel energy storage

Among the various storage methods, flywheel energy storage are one of the most promising ways to reduce the frequency effects of flicker loads.

Flywheel energy storage store electrical energy by converting it into the physical energy of rotational motion, and generate electricity from the rotational motion when needed.

- Key features include:
 - Simple structure, long life, easy maintenance
 - Less performance degradation compared to rechargeable batteries that use chemical transformation
 - Easier to determine stored energy
- The main applications for power systems are as follows:
 - Spinning reserve
 - Countermeasure to rapid power fluctuation, flicker
 - Power leveling for renewable energy sources
- Major case examples are listed below.
 - Beacon Power, USA, installed a 5 MWh (20 MW x 15 min) facility with 200 units in Stephentown, NY in 2011, and a similar sized system in Hazle Township, PA in 2014.
 - Temporal Power of Canada installed a 0.5 MWh (2 MW x 15 min) facility in Minto Ontario in 2014.
 - A 58 kWh, 26.5 MVA facility was installed at Okinawa Electric Power Company's Nakagusukuwan substation as a countermeasure against grid frequency fluctuations caused by the start/stop operation of arc furnaces at nearby steel mills.

Considering the above case examples, the application to Bangladesh may not be appropriate in terms of scale and cost, and more detailed check will be required.

7. Recommendations

7.1 Detailed Countermeasures Aiming for Increasing Frequency Control Capability

7.1.1 Short-term Measures

(1) Review on demand forecast method and suggestion of improvement method

NLDC forecasts the annual, monthly, weekly, and the previous day's demand. NLDC develops the next-day's power station operation plan on the basis of the previous day's forecast and

dispatches the operation plan to power stations. Power stations coordinate outputs to maintain operation output dispatched in each timeframe in accordance with the order. Demand is changing every moment. However, if power stations operate in accordance with the highly precise demand forecast made beforehand and sudden demand fluctuations or generator failures do not occur, significant frequency fluctuations can be controlled even without any special order dispatched from NLDC.

(2) Systemized operation manual regarding the duties of supply-demand coordination

NLDC is responsible of formulating a supply-demand coordination plan, system operation plan, outage coordination plan, and supply-demand emergency countermeasures. These duties have correlations in each plan and plan details are varied so it requires developing a systemized manual. In addition, since these plans include complicated details, it would be important to adopt IT by introducing supply-demand schedule planning system.

(3) Development of grid codes and related rules

Power generation facilities having frequency control function basically conduct frequency control operation. If so, they need to operate while controlling outputs to a certain amount in order to respond to increased output. However, in the agreement with IPP, the payment is made, in proportion to the generation amount. Therefore, IPP tends to operate with maximum output. For this reason, it is necessary for the generation companies who wish to connect to the power system (except renewable energy) to incorporate the penalty clause into the rule of the system connection (interconnection guidelines) in the case where the generation companies cannot secure frequency control ability or cannot perform the necessary frequency control ability.

On the other hand, renewable energy generators, which are expected to be introduced more in the future, have no frequency control function. The NLDC/ISO needs to regulate frequency instead. Therefore, it is important to describe the clause in the rule of the system connection (interconnection guidelines, which specify that the fee for electricity quality stability services is charged).

(4) Review on current settings of under frequency load shedding and consideration/formulation of improvement plans

UFLS (Under Frequency Load Shedding) is the most efficient method to avoid total blackouts when frequency drops due to supply insufficiency in the event of generator equipment failure.

The UFLS is applied in Bangladesh as in Japan so it requires to minimize the range of power outages in consumer areas as much as possible and avoid total blackouts. In this study, current UFLS settings have been reviewed, improvements have been suggested, and the understanding from NLDC has been obtained. Currently, revision of the settings is ongoing according to the

suggestions.

Activating UFLS installed in each power station with the purpose of protecting generators will bring further supply capacity decrease when frequency drops. In order to avoid total blackouts, the value needs to be set to control the activation of UFLS. However, the setting is the voluntary obligation of each power station. Thus, it is necessary to have individual discussion with each power station when the setting value is changed.

(5) Additional frequency control function to existing AC-DC converters

AC-DC converters control the power flow easily so they stabilize frequency smoothly by installing control equipment that adds frequency control function to existing AC-DC converters. This means that power flow in interconnection lines always changes although Bangladesh side monitors the frequency and quickly controls the power flow in response to the deviation from standard value in order to control frequency.

In India, if the actual value deviates from the planned value of generation electricity for each time block (per 15 minutes), the amount that multiplied by settlement unit price according to system frequency for the time block is paid for the deviation. This is the Imbalance system called Deviation Settlement Mechanism (DSM). If power flow in interconnection lines always changes, a lot of penalty needs to be paid because of the DSM. In order to avoid this situation, it is recommended to control the actual value to the planned value per 15-minute. However, if frequency control capability is insufficient in Bangladesh, it is difficult to avoid the penalty. Therefore, to install the control equipment, the possible penalty needs to be assumed and whether the frequency control capability is effective in Bangladesh should be considered.

7.1.2 Mid-term Measures

(1) Enhancement of frequency control functions by generators

Synchronous generators applied in thermal power stations generally own the function to return to the standard value automatically while confirming the deviation from the standard value of system frequency according to the rotation speed of a generator rotor. Utilizing this function will make it possible to secure primary reserve (governor free). However, if this function would operate with high sensitivity, it will repeat output fluctuations within short-time period according to system frequency fluctuation. Therefore, deadband is generally set around the standard value to operate with lower sensitivity. Each power station is tasked with setting the deadband. The power generators with a larger deadband width seem not to perform the function of controlling primary reserves. Secondary reserve controls outputs according to the order from NLDC. However, if the order is not directly provided online from NLDC, the time lag will be generated between order delivery and actual operation and the necessary actions will not be taken at necessary timing. Based on these perspectives, mass introduction of power stations with Load Frequency Control (LFC) function, by which NLDC can send the order directly, is required.

(2) Introduction of new EMS and related systems

Introducing Energy Management System (EMS) in supply power system will directly connect between NLDC, power stations, and substations online to communicate and gather information automatically.

Developing communication networks between NLDC and substations and constructing database by collecting necessary information at all times will make possible to gather information necessary for the next day's demand forecasts with various correlations, such as day of week, each area's weather, temperature, humidity, and special events to be held. This will increase the precision of demand forecast and operation plan of power stations. In addition, developing communication networks between NLDC and power stations will enable NLDC to send orders directly, resulting in quick output control.

The Mass data obtained by EMS are used to automate the related system such as supply-demand coordination operation, enhancing the accuracy of the plan as well as NLDC's labor saving.

(3) AC interconnection with India

When AC interconnection with India is realized, frequencies in both systems become the same and frequency fluctuation drastically decreases, which is around 50 ± 0.1 Hz. However, if all frequencies are controlled by India's system, the power flow in the transmission lines between the two systems constantly fluctuates in order to adjust the amount of fluctuation caused in the Bangladesh system. As described in the previous clause, DSM system is introduced in India. When the power flow in the transmission lines always changes, a lot of penalties must be paid because of DSM. In order to avoid this situation, it is required to conduct Tie line load frequency Bias Control (TBC), which controls the power flow in interconnection lines to the planned value. TBC is a method that simultaneously detects the frequency changes and power flow changes in the interconnection lines and controls the generator outputs in the own system to keep the power flow in the interconnection lines at the planned value only when the changes in the own system are detected. This means that even if the frequency fluctuation drastically decreases after realization of AC interconnection with India, it is necessary to maintain the power flow in the interconnection lines at the planned value in order to avoid the penalties due to DSM. It is also essential to secure frequency control capability in Bangladesh.

7.1.3 Long-term Measures

(1) Development of ancillary service market

In Bangladesh, many thermal power stations are owned by IPP so that it is assumed that securing outputs only with thermal power stations owned by BPDB may become difficult. Considering this situation, one of the approaches is to establish ancillary service market to procure

frequency control providers in the market (or to provide the payment to IPPs for ancillary services). Specifically, system design regarding securement of regulating reserve (agreement types, schedules, how to calculate necessary amount, generator specifications), suggestions of tests for securing regulating reserve and monitoring methods, and incentive/penalty related suggestions are considered.

(2) Connecting hydro power stations in the neighboring country with Bangladesh systems using dedicated lines

Hydro power stations perform high-speed and wide-range frequency control capability. If the stations are connected with the Bangladesh systems using dedicated lines, large capacity of regulating reserve can be secured to contribute greatly to frequency stabilization. Therefore, in order to import the power generated by hydro power stations from the neighboring country, connecting the station with the Bangladesh system directly is one approach to secure the regulating reserve.

(3) Development of pumped-storage hydro power stations

As mentioned in the previous clause, development of hydro power stations will make a significant contribution to frequency stabilization in the Bangladesh system. However, since there is no potential of large-scale hydro power stations in Bangladesh, the development of pumped-storage hydro power stations must be considered. There are a few possible sites in Bangladesh where the economy is seemingly excellent for developing the pumped-storage hydro power stations. However, the feasibility of the station development is studied including the evaluation of regulating reserve in the possible sites suggested to IRPMP, and the development will be launched once the feasibility is confirmed.

7.2 Detailed Countermeasures Aiming for Improving Grid Operation Rules

This section describes suggestions regarding improvements of supply-demand coordination of NLDC. The contents are mainly based on the consideration listed in Chapter 5 and details of 7.1.1 Short-term measures (2) Systemized operation manual regarding the duties of supply-demand coordination.

7.2.1 Short-term Measures

(1) Enhanced supply-demand operation planning

The scope of supply-demand operation planning is expanded to include not only intraday scheduling but also shorter intervals (e.g., 15 minutes) and long-term planning (yearly, monthly, and weekly). This contributes to respond effectively to real-time changes in supply-demand operation, provide stable supply, optimize resource utilization, and introduce renewable energy sources.

(2) Formulation of annual system operation plans

NLDC confirms the overloaded transmission lines and transformers, which is caused by N-1 contingency at the previous-day phase, with contingency analysis and power flow applications. It is recommended to formulate a short-term operation plan and conduct various studies based on the assumption of annual peak demand. This aims to reduce the risk of which the issue continues until the effective measures against it are applied and to secure the time needed to consider the measures. In addition, mitigate measures for line and grid overloads need to be considered. The study requires the analysis by the offline simulation tools, so obtaining the tools, such as PSS®E, Power Factory, and XTAP, is recommended. If the power flow is calculated using the tools, the power flow under the N-1 contingency caused by system configuration changes associated with scheduled outage can be considered. This allows to secure the time needed to consider the measures during the period of the scheduled outage.

Another recommendation is to conduct voltage analysis in the short-term system operation planning using the offline simulation tools, in order to maintain optimal voltage prescribed by the Grid Code. Offline simulation allows to confirm whether optimal voltage can be maintained under the maximum use of transformer taps and reactive power control equipment. There is a time gap between the timing of study on reactive power compensation in the long-term plan and the timing of study in the short-term system operation plan, which may lead to a shortage of reactive power control equipment. It is necessary to consider the lead time required for the introduction of the equipment and select the timing of the study. To consider voltage, not only the data of active power in transmission lines, substations, consumers, and distribution substation, but also the data of reactive power is required.

Since growing demand, RES expansion, and new generator interconnections are expected, synchronous stability and voltage stability need to be considered. Since there is a gap in the demand forecast and power development plan between the snapshots considered in the long-term plan and the short-term plan, it is effective to consider the forecasted snapshot in the short-term plan in order to solve the actual power system problems. In addition, it is recommended to confirm whether the short-circuit or single line to ground fault current exceeds the withstand capability of the facility.

(3) Streamlining the outage coordination planning process

The process for daily outage requests is streamlined, ensuring timely submission. Communication and coordination between Facility Maintenance Division and System Operation Division are enhanced to manage the workload efficiently. Monthly and weekly plans are introduced to reduce the workload on the daily planning, enabling to respond to a request for outage due to a sudden accident or trouble on the day.

(4) Information sharing and timely submission

The collaboration between NLDC, distribution companies, and generation companies needs to be strengthened. The transmission outage schedules and outage coordination plans including generator maintenance schedules are recommended to be submitted to NLDC in a timely manner. The information-sharing process is enhanced to facilitate accurate demand forecasting, generator operation scheduling, and outage coordination planning. For example, it is recommended to expand the users of the web application for collecting demand forecasts to include generation companies, establish and implement a system where generator maintenance schedules and operation schedules owned by BPDB are submitted to NLDC directly.

(5) Enhancement of fuel plan information sharing

Information sharing needs to be enhanced among stakeholders, including NLDCs, generation companies, fuel suppliers, and regulatory agencies. Comprehensive long-term and short-term fuel plan information is required to be shared in order to ensure efficient fuel utilization, cost optimization and reliable supply and demand operations.

(6) Adding operational measures of supply and demand emergency to Grid Code

Operational measures of supply and demand emergency are added to the grid code in order to clarify the advance preparation and measures for reserve margin and define the roles of stakeholders, including NLDC, distribution companies, and generation companies. If stable supply may not be maintained due to tight supply and demand, it is expected to determine the measures quickly and appropriately and carry out them.

7.2.2 Mid-term Measures

(1) Capacity building and training

Training programs and capacity building initiatives are required for all stakeholders involved in the supply and demand scheduling, system operation planning, and outage coordination planning process. This will enhance their understanding of their roles, responsibilities, and the impact of their actions on the overall power system operation.

(2) Introduction of automated scheduling tools for supply-demand operation

Advanced scheduling tools beyond Excel spreadsheets are introduced to optimize the schedule more efficiently. These tools incorporate features such as checking the range of a generator output, reflecting must-run source, to improve the scheduling accuracy and flexibility.

7.2.3 Long-term Measures

(1) Establishing a system for continuous improvement and monitoring

A system for continuous improvement and monitoring of the supply and demand scheduling

process needs to be established. The effectiveness of implemented measures including error analysis is regularly assessed to identify areas for improvement, and adapt to the expanding power systems.

(2) Automation of calculation of necessary reduction of power output due to transmission system constraints and outage request management

The implementation of an automated calculation system for necessary reduction of power output due to transmission system is initiated to replace manual calculations based on experience. Transition from Excel-based record-keeping to a dedicated outage management system enables efficient tracking and analysis of outage requests.

(3) Introducing SCADA for distribution system

The SCADA systems for real-time monitoring and control of substations are introduced for distribution system. The information exchange between SCADA for distribution system and NLDC/SCAD enhanced, allowing for efficient control and timely and accurate response to tight supply and demand situation.

(4) Building the automated voltage control system

Currently, the voltage is controlled by operating a transformer tap or reactive power control equipment manually when the grid voltage deviates from the reference value. For the future, it is recommended to build an automated voltage control system in order to minimize transmission loss while changes in grid voltage due to demand fluctuations and renewable energy output fluctuations are appropriately responded.

7.2.4 Other idea

Creating a workshop involving all stakeholders can be one of the excellent approaches to enhance the scheduling process comprehensively, such as supply-demand operation planning, system operation planning, scheduled outage coordination planning. A workshop provides a platform for collaboration, knowledge sharing, and consensus building among the key participants, including NLDC, distribution companies, and generation companies. It is recommended to hold a workshop during the next project implementation period. Benefits of conducting a workshop include:

(1) Comprehensive work flow design

The workshop allows stakeholders to come together and collectively design a work flow that takes into account the specific requirements, roles, and responsibilities of participants. This collaborative effort ensures that all perspectives are considered, leading to a more comprehensive and effective work flow.

(2) Clear understanding of roles and impact

The workshop provides an opportunity for stakeholders to gain a clear understanding of their roles, duties, and the impact of their work on the overall scheduling process. This clarity promotes better coordination and cooperation among the participants, minimizing misunderstandings and ensuring smooth work flow execution.

(3) Knowledge exchange and learning

The workshop facilitates knowledge exchange among stakeholders. Participants can share their expertise, experiences, and best practices, enabling cross-learning and fostering a culture of continuous improvement. This exchange of knowledge contributes to the development of a more efficient and effective scheduling process.

(4) Alignment of goals and objectives

Through discussions and interactive sessions, the workshop helps align the goals and objectives of all stakeholders. It enables them to identify common interests, resolve conflicts, and establish a shared vision for the scheduling process. This alignment promotes collaboration and mutual support, leading to a more cohesive and harmonious work flow.

(5) Training and skill development

The workshop can include training sessions to enhance the skills and capabilities of the participants. This capacity-building aspect equips stakeholders with the necessary knowledge and tools to perform their roles effectively, ensuring the successful implementation of the scheduling process.

7.3 Issues expected to be addressed in the future

In order to improve power quality and operate the grid stably and efficiently, it is necessary to effectively utilize the ancillary service functions provided by generators, such as frequency control and voltage control. At present, generators are not paid special compensation for providing the ancillary service functions they possess, so there is little incentive for each generator to provide such functions. In the future, in order to effectively utilize the ancillary service functions possessed by generators, it will be necessary to consider the necessary and sufficient level of compensation, and to consider how to secure the compensation to be paid to the generators.

7.3.1 FGMO Provision

The power plants that are not obliged to provide FGMO provision according to PPA, but required FGMO support for maintaining the system, they may be provided Frequency Control

Ability Price (FCAP) and Loss of Opportunity Fee (LOOF), by amending the PPA.

7.3.2 Black Start Facility

Power plants having black start facility-

- need to ensure black start as contractual obligation and will not get any separate payment for this.
- need to arrange annual drill in presence of the representatives from BPDB & PGCB.
- need to be provided Grid Restoration Plan containing standard operating procedure for black start.
- If the country requires any black start zone in future, the PPA/tender document of the prospective plants to be installed in that region must include black start facility as mandatory requirement and technical criteria for this.

7.3.3 Grid Voltage Control

The following points need to be considered:

- Power plants need to maintain the voltage such that the pre-defined band of lagging power factor to leading power factor is ensured. The power plants will be obliged to maintain that voltage and no charges/incentives can be given to them.
- There might be "power factor adjustment fee" if power plants cannot ensure the pf range, or, "loss of opportunity fee" in case of operating any power plant outside that range, for system security.

II. Needs Survey of Human Resource Development in Power Sector

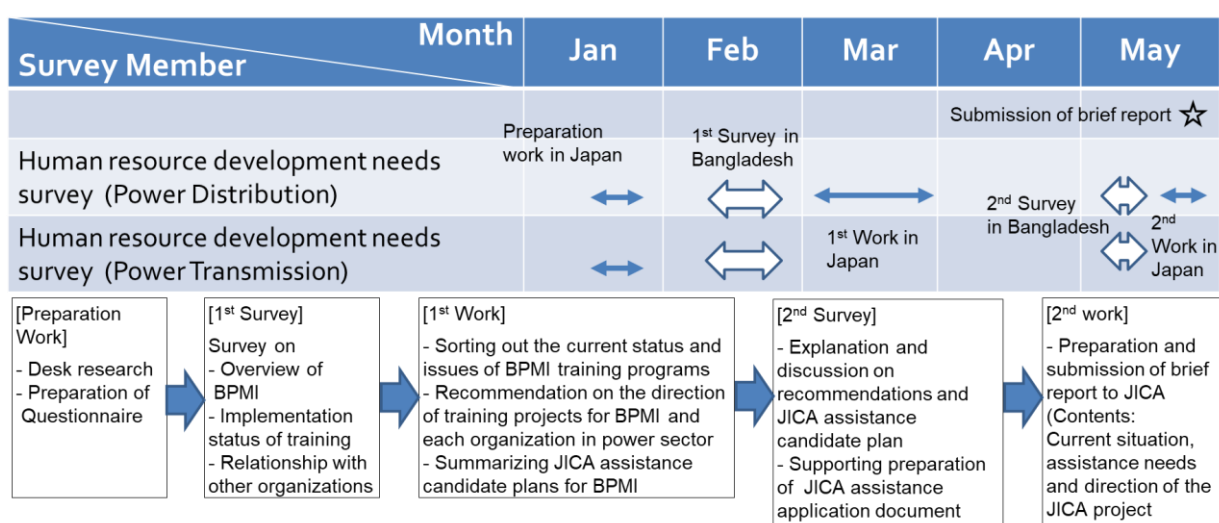
1. Outline of this Survey

1.1 Background

Ministry of Power, Energy and Mineral Resources (MoPEMR) and JICA has agreed to conduct a study on human resource development in power sector. This needs survey for human resource development support was targeted at summarizing recommendations and assistance plan for formulating cooperation project for human resource development in the power sector after reviewing the existing training facilities and curriculum, targeting the Bangladesh Power Management Institute (BPMI).

1.2 Survey Schedule

This survey was conducted for five months from January to May 2023. The survey schedule is shown in Figure 1-1.



Source: JICA survey team

Figure 1-1 Survey Schedule

1.3 Survey Team Member

This survey was conducted by Chubu Electric Power Co., Inc. that was subcontracted to and participated in the project members of the Institute of Energy Economics, Japan (IEEJ), which is entrusted by JICA to conduct the MP project.

2. Overview of BPMI

2.1 Background / Idea of the establishment

BPMI was established on June 8, 2017, by the Power Division of “Ministry of Energy and Mineral Resources” (hereinafter referred to as “MPEMR”) under the Society Registration Act, 1860 (Act No. XXI of 1860) with the aim of improving the quality of human resources employed in the power sector through the development of technical and managerial capabilities and training. BPMI began operations the following year in 2018. BPMI's Vision, Mission, and Function are disclosed on the website of BPMI as shown below.

Vision, Mission, and Functions Vision: Develop an international standard institution for providing appropriate training in developing manpower capable of providing quality electricity supply. Mission: To provide quality training to build a sufficiently skilled and dedicated workforce for balanced and integrated development of the power generation, transmission and distribution sectors. Strategic Objectives 1. Development of professional competence of power sector employees; 2. Increase the capacity of training of the Power Division; 3. Increase BPMI's infrastructure and training facilities; and 4. Human resource development through creative and innovative practices. Main Functions 1. Provide foundation training to the engineers and officers of the organisations/companies under Power Division; 2. Provide technical, managerial training to engineers and officers of organisations/companies under Power Division; 3. Training of the engineers and executives of private companies in the power sector to improve efficiency; 4. To advise the Power Division on training and skill development of the manpower; 5. Organizing national and international workshops, seminars, symposiums and conferences; and 6. Establish partnerships and increase networking with similar international organizations.

Source: Website of BPMI

Figure 2-1 BPMI's Vision, Mission, and Function

The “Memorandum of Association of Bangladesh Power Management Institute” (hereinafter referred to as “MoA”), which was created and approved in 2017, lists the following as the main roles played by BPMI.

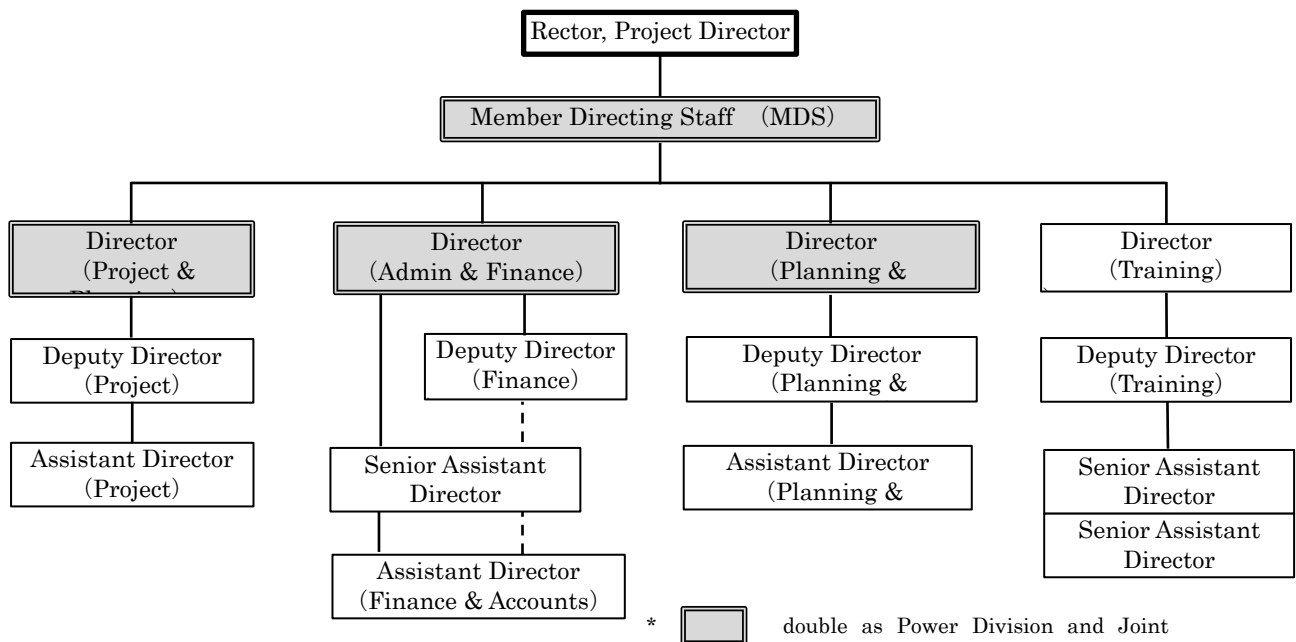
- ✓ To conduct human resource development in all fields such as power generation, power transmission, power distribution, renewable energy, and energy conservation for all utilities in the power sector and other ministries.
- ✓ To become an R/D organization involved in O&M and business operations in the fields of power generation, transmission, and distribution.
- ✓ Having the function of awarding academic degrees, master's degrees, etc.
- ✓ Equipped with training facilities that allow not only desk-based training but also direct practical experience.
- ✓ Conducting training on special advanced technologies such as IT.
- ✓ To become an organization that disseminates information by holding symposiums and seminars both domestically and internationally.

2.2 BPMI's Organizational Framework

The Governing Body of BPMI is stipulated in "VIII GOVERNING BODY" of the MoA. Unlike the original members of MoA, according to information on the BPMI website as of February 2023, the Governing Body consists of the following twelve (12) members (government officers, academic experts, heads of various power utilities, etc.).

- (1) Secretary, Power Division, MPEMR
- (2) Chairman, Bangladesh Power Development Board (BPDB)
- (3) Chairman, Bangladesh Rural Electrification Board (BREB)
- (4) Chief Executive Officer (CEO), North-West Power Generation Company Limited (NWPGCL)
- (5) Chairman, Sustainable & Renewable Energy Development Authority (SREDA)
- (6) Project Director and Rector, BPMI
- (7) Professor & Dean, Faculty of Electrical & Electronics Engineering, BUET (Bangladesh University of Engineering and Technology)
- (8) Managing Director, Power Grid Company Bangladesh (PGCB)
- (9) Managing Director, Dhaka Power Distribution Company Ltd. (DPDC)
- (10) Managing Director, Dhaka Electricity Supply Company Ltd. (DESCO)
- (11) Director General, Power Cell, Power Division
- (12) Member Directing Staff, BPMI and Joint Secretary, Power Division

Of these, officers (6) and (12) (underlined) concurrently serve as BPMI's executive officers. BPMI's executive structure is as follows.



Source: Prepared by JICA Survey Team based on interview with BPMI and information on BPMI's website

Figure 2-2 BPMI's Officers (as of February 2023)

The Rector is the only full-time person in charge of actual BPMI management. The role of the Rector is stipulated in “12.3 Rector of the Institute” of the MoA’s Annex “Rules and Regulations of the BPMI”. All of the officers other than the Power Division's Joint Secretary are seconded from power utilities and their salaries are paid by their original organization, so there are no BPMI-proper employees among the full-time employees. There are only part-time employees.

2.3 Facilities of BPMI

2.3.1 BPMI's existing office and lecture rooms

BPMI operates its business by renting an office space in the building of DESCO's Dakkhinkhan distribution substation as a temporary headquarters building. (Address: Plot #2, Road #104, Sector #4, Purbachal, Dhaka City Bypass, Dhaka, Bangladesh)

1F: DESCO substation control room

2nd, 3rd, 4th floor: BPMI training facility (3 rooms (capable of accommodating around 50 people)) and employee offices

5F: BPMI Chief Officer office and conference room



Figure 2-3 BPMI's Office

The lecture-based training courses organized by BPMI are held here. It also has lecture rooms equipped with desk top computers and a soundproof studio where the training course related to

Virtual Reality (VR) can be conducted. Before COVID-19, training was conducted on the basis of in a face-to-face lecture, but as of February 2023, lectures are mainly conducted by means of online (Google Meets). Since there is no accommodation facility, trainees must commute from Dhaka every day, and for this purpose BPMI has three microbuses for transportation.



(Left: Lecture room; Center: Lecture room equipped with Desk Top Computers; Right: Soundproof studio for the training course related to VR)

Source: JICA Survey Team, photographed on February 12, 2023

Figure 2-4 Lecture rooms / computer room in BPMI building

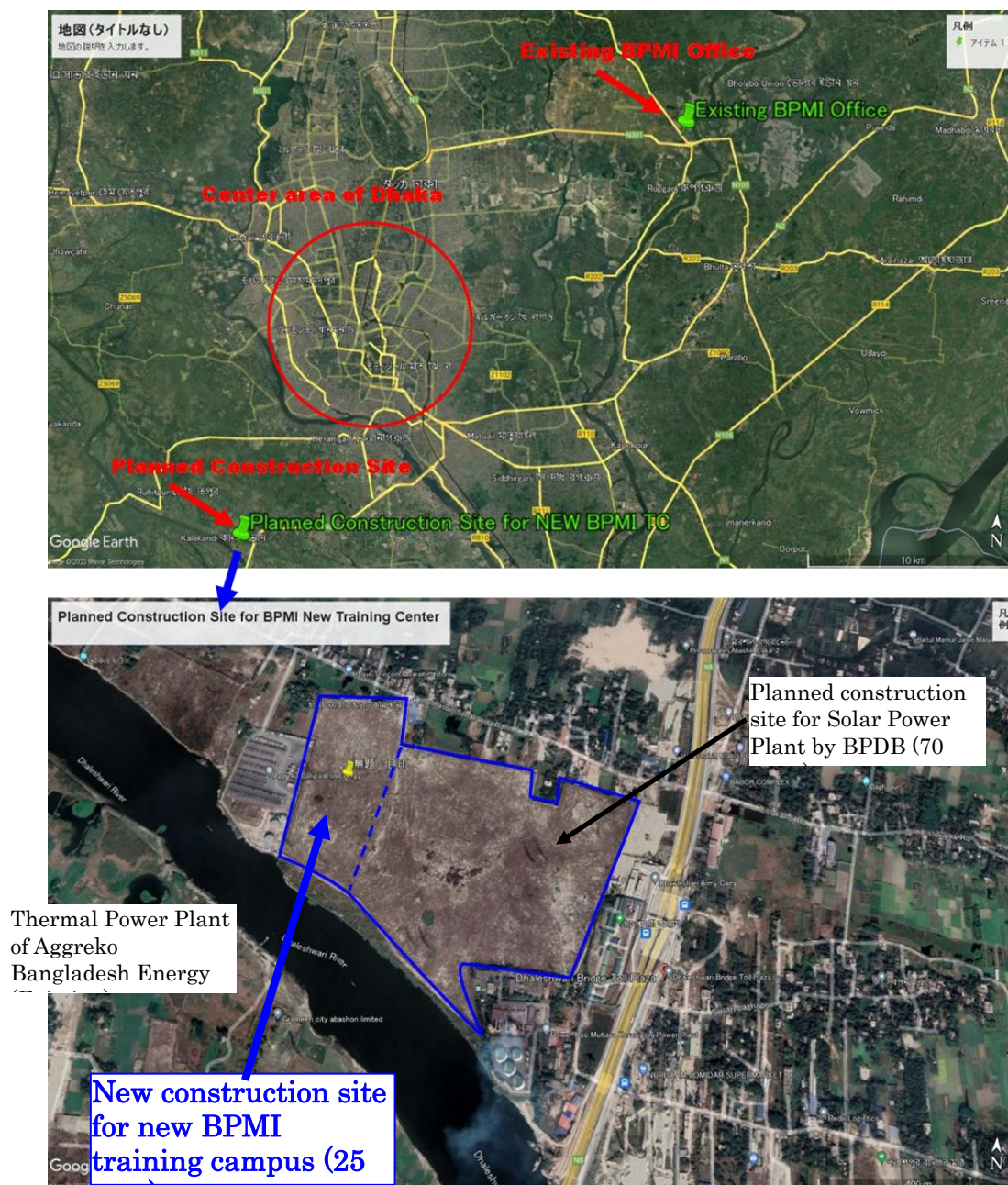
BPMI does not possess any training equipment such as power transmission, substation, power distribution simulation equipment or power plant simulators for conducting practical training. When BPMI hosts practical training using simulation training equipment, they borrow the training equipment owned by power utilities (power generation companies, power transmission companies, power distribution companies, etc.), and the trainers are also assigned from those power utilities. In these cases, BPMI does not share the training cost, and the training cost will be entirely borne by those power utilities.

2.3.2 Construction plan of new BPMI training campus

BPMI has a plan to construct a permanent campus (called “Training Academy”) for training purposes in the southwest of Dhaka (Keranigonj district, approximately 28 km from the city center, shown in Figure 2-5). Approximately 25 acres (equivalent to around 10 ha) of the land owned by BPDB has already been secured as a construction site for new BPMI training campus. The basic design of the training buildings has been already completed by a consultant (URBANA, Local Consultant in Bangladesh) at BPDB's expense. In addition to training facilities, there is a plan of constructing a research laboratory and a testing laboratory¹

¹ Aiming to conduct acceptance tests for electric power equipment and materials. Currently, there is no testing facility in Bangladesh, so testing is outsourced to KEMA (currently acquired by CESI). Since the cost of outsourcing is also high, there is a strong desire to own testing equipment in the country. Additionally, the aim is to increase the effectiveness of the training by having the trainees observe the sites where the tests are being conducted.

However, there is no funding for the construction costs of the training and accommodation buildings, which are said to be between 30 and 40 million USD and securing funds will be a critical issue in the future. It is said that the cost is so high that funding from the Bangladesh government cannot be expected.



Source: Prepared by JICA Survey Team based on interview with BPMI; Google Earth [March 2023]

Figure 2-5 Location map of the planned new construction site for the BPMI training campus



Source: JICA Survey Team, photographed on February 22, 2023

Figure 2-6 Photographs on the planned new construction site for the BPMI training campus

Although the land has been secured, it is physically impossible for BPMI to conduct on-the-job training mainly because the funds for constructing the building and arrangement of the training facilities are nowhere in sight. Before introducing training facilities for practical training (power transmission/ substation/ distribution simulation equipment, power plant simulators, etc.), it is first necessary to construct the buildings and prepare the grounds for the training campus.

3. Training implementation status

3.1 Target management related to training

Each power utility signs an Annual Performance Agreement (APA) with the Power Division every year, committing to a target of training hours per employee per year. The target value set by Power Division for 2022 is 60 hours / person / year. (However, there are power utilities that have set slightly higher numbers.) Each power utility reports monthly progress and achievement status

(** hours/person) to the Power Division and manages progress. Although each power utility conducts its own in-house training, it is difficult to meet the goal of 60 hours / person / year with just only in-house training courses. Each power utility has been somehow able to achieve this goal by having its employees participate training sponsored by BPMI, training sponsored by other domestic organizations, and overseas training². It should be noted that none of power utilities have developed long-term training / human resource development plans for training over multiple years, but only training plan for a single year each year.

3.2 Role sharing between BPMI and each power utility

At the beginning of each fiscal year, BPMI conducts a training needs assessment (TNA) of each power utility, and based on TNA, BPMI formulates an annual training plan and implements the training. (The fiscal year in Bangladesh is from July to June of the following year.) The power utilities under the administration of the Power Division are as follows.

Table 3-1 Power utilities under the administration of the Power Division

Category	Power Utility
Power Generation	BPDB , NWPGCL , EGCB ³ , APSC ⁴ , RPCL ⁵ , CPGCBL ⁶ , BIFPCL ⁷ , BR Powergen , BCPCL ⁸
Power Transmission	PGCB
Power Distribution	BPDB , BREB , DPDC , DESCO , WZPDCL ⁹ , NESCO ¹⁰
Renewable Energy	SREDA

***Bold letters** indicate the utility interviewed with during the 1st survey in Bangladesh

Source: Prepared by JICA Survey Team based on BPMI's information

Of the eight companies the JICA survey team visited during the 1st survey in Bangladesh, APSC, BPDB, BREB, DPDC, and DESCO have its own Training Academy (training building), and PGCB has a floor dedicated to training. In addition, WZPDCL also has a Training Academy. Other institutions said that they borrow training site from another utility or conduct training in their offices or actual sites. As mentioned above, BPMI training courses are determined each year based on the needs of each power utility. The general role sharing as for training implementation between BPMI and each power utility is as follows;

Fundamental course: Implemented by BPMI

² For example, in the case of DESCO, the annual training budget for 2022 was expected to be 30 million BDT for domestic training at DESCO, BPMI, etc., and 50 million BDT for training overseas. (However, due to the severe economic situation caused by COVID-19, the amount has been cut in half to 15 million BDT and 25 million BDT, respectively.) The cost of attending overseas training has become a huge burden.

³ Electricity Generation Company of Bangladesh

⁴ Ashuganj Power Station Company Limited

⁵ Rural Power Company Limited

⁶ Coal Power Generation Company Bangladesh Limited

⁷ Bangladesh-India Friendship Power Company Pvt. Limited

⁸ Bangladesh-China Power Company Pvt. Limited

⁹ West Zone Power Distribution Company Limited.

¹⁰ Northern Electricity Supply Company Limited

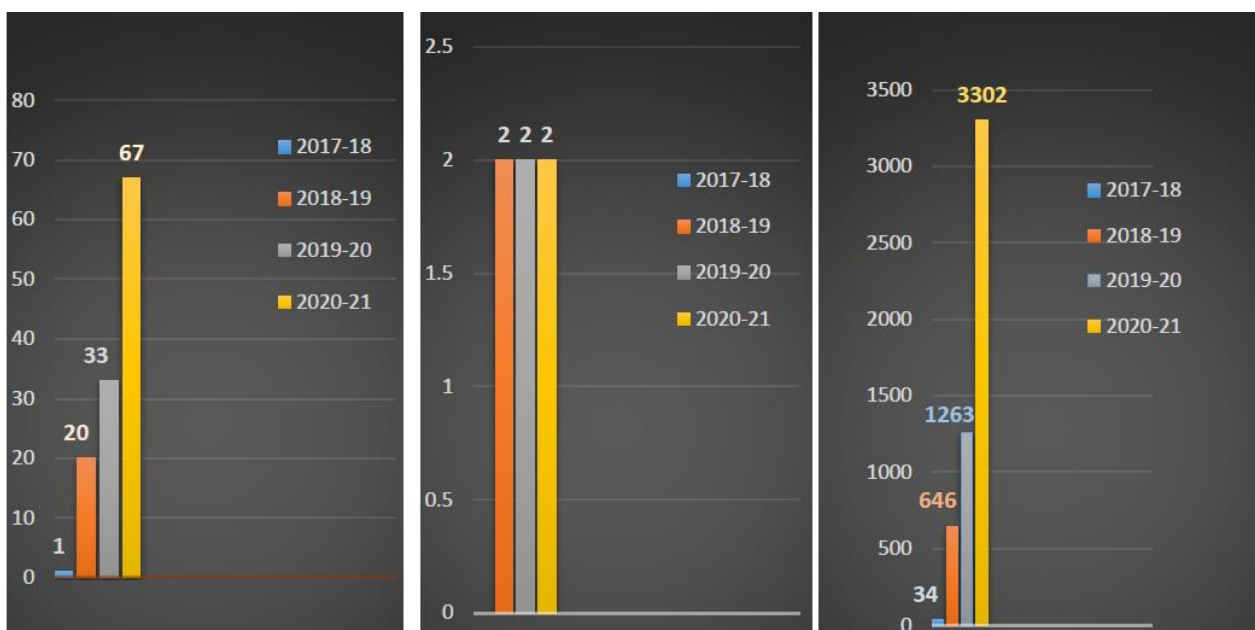
Professional course: BPMI conducts some basic matters, Matters related to practical equipment such as the unique equipment, business implementation of each power utility, and O&M are implemented by each utility.

Management course: Implemented by BPMI

3.3 Summary of the training conducted at BPMI

A summary of the training conducted at BPMI in the fiscal year 2020-2021 (July 2020-June 2021) is as follows.

- | | |
|--|--|
| (1) No. of training courses | : 67Nos. |
| (2) No. of workshops | : 2Nos. |
| (3) Accumulated No. of training participants | : 3,302 persons (Training : 3,133, Workshop : 169) |
| (4) Accumulated No. of training days | : 829 days |
| (5) Accumulated No. of person·day | : 40,234 |
| (6) Accumulated No. of person·time | : 3,180,972 |
| (7) Training hours per person | : 113.51 |



(Left: No. of Training Courses; Center: No. of Workshops; Right: Accumulated No. of training participants)

Source: BPMI Annual Report 2020-2021

Figure 3-1 Changes in scale of BPMI training held over the past four years

Table 3-2 BPMI training course list

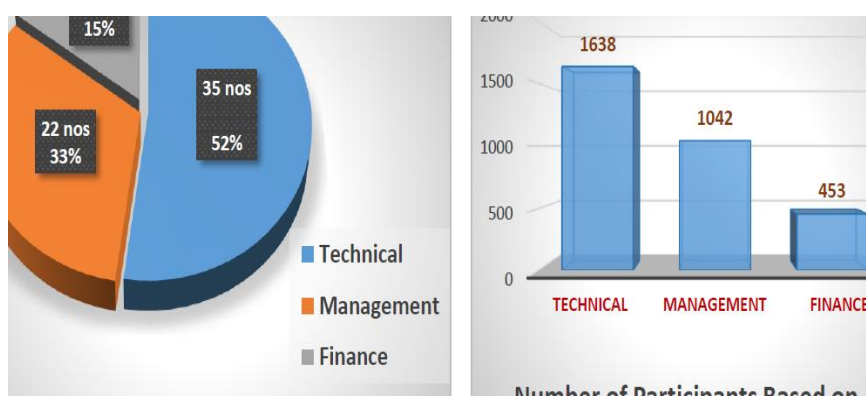
Area	Name of Training Course
Technical	✓ Generation Planning, Power Plant Project Formulation & Implementation ✓ Fundamental Components, Operations & Maintenance of Distribution Substation, Line and Related System ✓ Operation & Maintenance of Combined Cycle Gas Turbine Power Station ✓ Operation & Maintenance of GT Power Plant ✓ Distribution & Transmission Line ✓ Basic Training on GIS Mapping & SCADA ✓ Design, Manufacturing and Testing of Transformer ✓ Basic Training on Smart Pre-Payment Metering System & Smart Grid ✓ Design and Implementation of Solar Power Plant ✓ Operation, Maintenance and Protection of Electrical Substation ✓ Basic Training on Smart Pre-payment Metering System & ICT Activities ✓ Basic Training on Smart Pre-payment Metering System & Smart Grid ✓ Power System Protection ✓ Basic Training on ICT Management for Power Sector ✓ Refresher Course on Design, Manufacturing and Testing of Transformer ✓ Design, Construction, Testing & Maintenance of Power Transformer & Distribution Line ✓ O&M of Switch Gear, Circuit Breaker and Relay
General, financial and management	✓ Foundation Training ✓ Company Affairs ✓ Leadership Development Program for Power Sector Organization ✓ Project Formulation, Implementation, Monitoring and Evaluation ✓ Training of Trainers (ToT) ✓ Basic Management ✓ Audit and Financial Management ✓ Project Planning and Management ✓ Financial Management & Corporate Governance ✓ Fixed Asset Management & Inventory Control ✓ Coal Supply Chain & Coal Management ✓ Financial & Economic Analysis of Dev. Project ✓ Physical Security & Access Control of KPI ✓ Public Procurement for Power Sector ✓ Public Procurement for Power Sector's Top Level Management ✓ Public Procurement for Power Distribution Utilities ✓ Training on Company Act & Share listing of Power Sector Utilities
Future training will be provided	✓ Computer Hardware and Troubleshooting ✓ Strategic Leadership ✓ Supply Chain Management ✓ International Procurement and Supply Chain Management ✓ E-Governance & E-Commerce ✓ Fundamental Components, Operation & Maintenance of Coal Fired Thermal Power Station (5 Days)

Source: BPMI Annual Report 2020-2021

Table 3-3 Training hosted by BPMI in the fiscal year 2020-2021

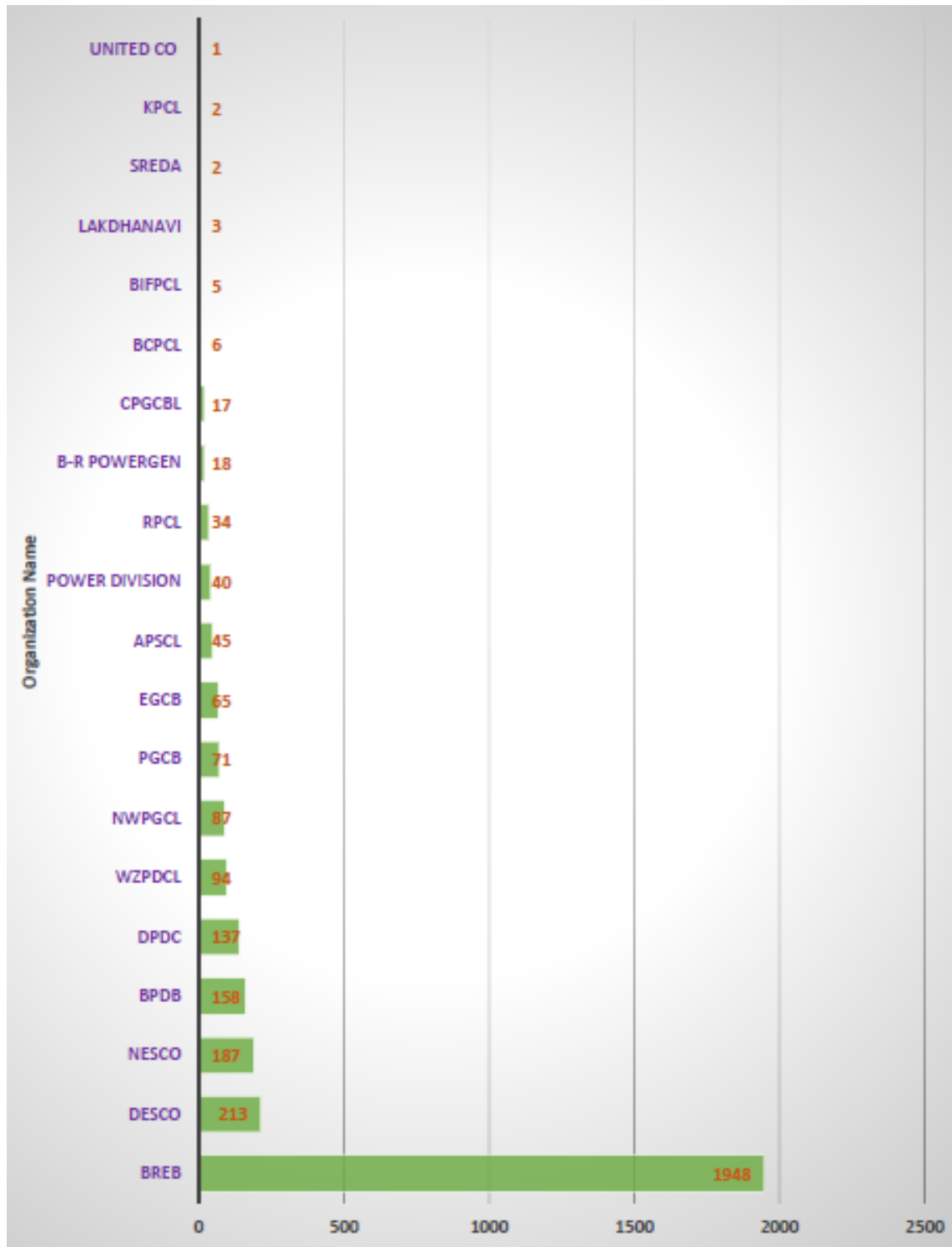
Category	Name of Training Course	No. of Batches
Technical	Basic Training on Smart Pre-Payment Metering System & Smart Grid	12
	Design and Implementation of Solar Power Plant	1
	Operation Maintenance and Protection of Electrical Sub-station	2
	O&M of Combined Cycle Gas Turbine Power Station	1
	Basic Training on GIS Mapping & SCADA	3
	Design, Manufacturing and Testing of Transformer	1
	Distribution & Transmission Line	6
	Basic Training on Smart Pre-Payment Metering System & ICT Activities	3
	Power System Protection	2
	Basic Training on Smart Pre-payment Metering System	1
	Power System Operation for BREB Engineers	1
	Basic Training on ICT for Power Sector	2
Management	Foundation Training Course	3
	Company Affairs	1
	Leadership Development Programme for Power Sector Organizations	11
	Project Formulation, Implementation, Monitoring and Evaluation (PIME)	1
	Training of Trainers	4
	Basic Management	1
	Project Planning and Management (PPM)	1
Financial	Public Procurement for Power Sector	3
	Audit and Financial Management	5
	Public Procurement of Power Sector's Top Level Management	1
	Public Procurement for Power Distribution Utilities	1

Source: BPMI Annual Report 2020-2021



Source: BPMI Annual Report 2020-2021

Figure 3-2 No. of training held and No. of participants by field (Technical, Management, Finance) (Fiscal year 2020-2021)



Source: BPMI Annual Report 2020-2021

Figure 3-3 No. of participants in training by power utility (Fiscal year 2020-2021)



Source: BPMP Annual Report 2020-2021

Figure 3-4 Practical training for participants in the training course “Power System Protection”

Table 3-4 BPMP's budget for the fiscal year 2020-2021

Expense Item	Amount (Lakh BDT)
Contingency spending	
Salary and Allowances	119,82
Administrative and other expenses	650,15
Repair and maintenance	18,00
(Total recurrent expenditure)	787,97
Capital Expenditure	
(Total capital expenditure)	232,00
Total Recurrent and Capital Expenditure	1,019.25

Source: BPMP Annual Report 2020-2021

In addition, in the power sector of Bangladesh, mutual cooperation in training is carried out with some neighboring countries. For example, training on Hydropower Generation is held in Nepal, with participation from Bangladesh as well. Conversely, training on Solar Power Generation is held in Bangladesh, with participation from Nepal as well. Such efforts are underway.

3.4 Training implementation status of each power utility

The following is specific information about the training implementation status of each power utility collected through questionnaires and interviews during the 1st survey in Bangladesh.

3.4.1 Power generation company

Interview survey was conducted with four power utilities: APSCL, NWPGL, EGCB, and BPDB. Both power utilities conduct power generation business that mainly involve thermal power generation, with some part of renewable energy power generation also involved. Thermal power generation equipment has different manufacturers and specifications depending on the power plant or unit, so training on the operation of these equipment is conducted individually by each company using the actual equipment or a simulator attached to the actual equipment. Furthermore, all of these utilities requested that BPML introduce simulators for training, cut-out models of equipment, etc. Additionally, information was collected from four power utilities: RPCL, CPGCL, BR Powergen, and BCPCL using questionnaires.

(1) APSCL

- APSCL has a training center in Ashuganj (90km away from Dhaka) and an accommodation facility that can accommodate 16 people.
- APSCL provides free training to university students and government officials as part of its CSR activities. IPP personnel are also allowed to attend lectures, but they have to pay the participation fee.
- As an example of a training plan, Table 3-5 shows an excerpt from the annual training plan for the fiscal year 2022-2023.
- As an example of monthly progress management, Table 3-6 shows APSCL's training results in January 2023.

(2) NWPGL

- NWPGL has a lecture room at the head office and they can conduct lecture-based training there, but OJT is conducted at each power plant.
(As an example, the monthly training schedule for BHERAMARA combined cycle thermal power plant (410MW) in 2018 is shown in Table 3-7.
- For the fiscal year 2021-2022, NWPGL achieved 81 hours/person against the training time target of 50 hours/person committed with Power Division (achievement rate 162%). As shown in Figure 3-5, the training results for FY2021-2022 are: 74% in-house training, 25% training at domestic institutions including BPML, and 1% overseas training.

Table 3-5 APSCL's annual training plan (Excerpt from the fiscal year 2022-2023)

Name of the Month	SL No.	Course Code	Course Name	Duration (Day)	No. of Participants	Target Group	Training period (DD/MM/YY)	
July 2022	1	OHS-2	Security, Firefighting, and Safety Procedure for security staff	2	12	Staff	20/7/2022	21/7/2022
	2	OJT-5	Power plant operation On-Job Training (400MW East Project)	42	38	Officer + Staff	23/7/2022	7/9/2022
	3	OM-6	E-Filing	1	12	Staff	27/7/2022	
August 2022	4	OPN-5	Operation of Power Plant Challenges and Mitigation	1	45	Officer	6/8/2022	
	5	IT-3	Cyber Security Awareness (Batch-1)	1	54	Officer /Staff	7/8/2022	
	6	PM-3	PPR-2008 & DFP-2017	1	25	Officer	28/8/2022	
	7	IT-3	Cyber Security Awareness (Batch-2)	1	77	Officer /Staff	31/8/2022	
September 2022	8	PM-4	PPR-2008 & Financial Analysis	1	25	Officer	11/9/2022	
	9	OM-11	National Integrity Strategy (NIS) Action Plan	1	40	Officer	24/9/2022	
	10	OM-8	E-governance and Innovation Action Plan	1	40	Officer	24/9/2022	
	11	OM-7	Grievance Redressal Management Action Plan	1	43	Officer	26/9/2022	
	12	OM-10	Right to Information Action Plan	1	43	Officer	26/9/2022	
	13	OM-9	Service Commitment Action Plan	1	40	Officer	27/9/2022	
October 2022	14	OPN-1	Power Plant Operation (Part 1: GT & HRSG)	2	15	Staff	10/10/2022	11/20/2022
	15	OM-6	E-Filing	1	12	Officer	16/10/2022	
	16	PM-3	PPR-2008 & DFP-2017	1	45	Officer	23/10/2022	
	17	MM-1	Mechanical Maintenance works of BFP, CEP, ACWP/OCWP, CCWP & CWP	2	20	Staff	24/10/2022	25/10/2022
	18	EM-1	Electrical Maintenance works of Generator, SFC, SEE & DC power system	2	20	Staff	29/10/2022	30/10/2022
November 2022	19	OM-7	Grievance Redressal Management Action Plan	1	25	Officer	5/11/2022	
	20	OM-9	Service Commitment Action Plan	1	25	Officer	5/11/2022	
	21	OM-10	Right to Information Action Plan	1	25	Officer	5/11/2022	
	22	OHS-1	Occupational Health, Safety & Environment, First Aid & Fire Fighting	2	25	Officer	8/11/2022	9/11/2022
	23	OHS-2	Security, Firefighting, and Safety Procedure for security staff	2	15	Staff	15/11/2022	16/11/2022
	24	OPN-2	Basic Operation Principle of Water Treatment Plant	2	20	Staff	27/11/2022	28/11/2022
	25	OM-6	E-Filing	1	12	Staff	29/11/2022	

Source: "Power Plant Training Centre (PPTC) Annual Training Plan 2022-2023" received from APSCL

Table 3-6 APSCL's training results in January 2023

SI NO.	Name of the Training Institute	Name of Training Course	Course Duration	No. of Trainees	No. of Participants	Hours/ men	Man-hours
1	PPTC, APSCL	Training Program on “On-Job Training” for APSCL’s Officer	01/1/2023 to 31/1/2023	4	4	216	864
2	BPMI, Purbachal, Narayanganj	Training Program on “Advance Training of Trainers (Batch-1)” for APSCL’s Officer	01/1/2023 to 09/1/2023	1	1	56	56
3	BPMI, Purbachal, Narayanganj	On line Training Program on “Advanced course on Oracle database 19C: automatic storage Management (ASM) and Real Application Cluster (RAC) (Batch-1)” for APSCL’s Officer	01/1/2023 to 04/1/2023	1	1	24	24
4	PPTC, APSCL	Training Program on “Addressing the Challenges of the 4th Industrial Revolution” for APSCL’s Officer	07/1/2023	51	41	4	164
5	PPTC, APSCL	Training Program on “Occupational Health, safety & Environment, First Aid & Fire Fighting (Batch-4)” for APSCL’s Staff	08/1/2023 to 09/1/2023	23	23	16	368
6	BPMI, Purbachal, Narayanganj	On line Training Program on “Design, Construction, Operation and Maintenance of Different Types of Boilers and turbines of Power Plant (Batch-1)” for APSCL’s Officer	08/1/2023 to 24/1/2023	1	1	88	88
7	PPTC, APSCL	Training Program on “Power Plant Operation, on Job Training” for APSCL’s Officers & Staffs	15/1/2023 to 31/1/2023	28	28	29.75	833
8	PPTC, APSCL	Training Program on “Power Plant Operation, on Job Training” for APSCL’s Officers & Staffs	15/1/2023 to 30/1/2023	24	24	28	672
9	PPTC, APSCL	Training Program on “Operation and Electrical Maintenance Works of Boiler Feed Pump, Circulating Water Pump, Condensate extraction Pump, Closed Cooling water Pump, Auxiliary Cooling Water Pump & instrument air Compressor (Batch-1)” for APSCL’s Officer	24/1/2023 to 25/1/2023	15	15	16	240
10	BPMI, Purbachal, Narayanganj	On line Training Program on “Public Procurement for Power Sector (Batch-5)” for APSCL’s Officer	22/1/2023 to 31/1/2023	1	1	64	64
11	BPMI, Purbachal, Narayanganj	On line Training Program on “Project formulation, Implementation, Monitoring	29/1/2023 to 31/1/2023	1	1	13.5	14

		& Evaluation (PIME) (Batch-7)” for APSCL’s Officer					
12	PPTC, APSCL	Training Program on “Power Plant Operation (Part:2 ST & BoP) (Batch-2) Public service)” for APSCL’s Staff	29/1/2023 to 30/1/2023	22	22	15.81	348
13	Siemens, Germany	Training Program on “Operator MMI & SIM Training)” for APSCL’s Officer	30/1/2023 to 31/1/2023	7	7	16	112
Total					169		3,847

Source: “MONTHLY TRAINING REPORT (January 2023)” received from APSCL

Table 3-7 Monthly training schedule of NWPGL’s BHERAMARA 410MW CCPP (fiscal year 2018)

SI NO.	Name of the Topic	Month	Duration (Session)	No. of Participants	Target Group	Expected Training Hours
1	An Overview on Occupational Health and Safety (OHS)	July/ 2018	02	25	Officers & Staffs	120
2	Transformer Protection System		02	25	Technical Officers & Staffs	60
3	Gas Turbine Inlet Air, Combustion and Exhaust Gas System	August/ 2018	02	25	Technical Officers & Staffs	60
4	Condenser Air Evacuation System		02	25	Technical Officers & Staffs	60
5	Introduction to Electrical Equipment in Power Plant		02	25	Technical Officers & Staffs	60
6	Overview of Power Transformer and its auxiliaries		02	25	Technical Officers & Staffs	60
7	E-filling		04	30	Officers	140
8	Procurement (PPR-) Regulations		02	25	Officers	60
9	GT & BOP firefighting system Maintenance		02	20	Technical Officers & Staffs	48
10	Head-to-Toe Training on PPE		02	20	Technical Officers & Staffs	45
11	Gas Turbine Cooling Air, Seal Air and Compressor Blade Washing System		02	20	Technical Officers & Staffs	45
12	Raw Water (River Water & Bore well Water) system and Water Pre-treatment		02	20	Technical Officers & Staffs	45
13	Condensate System	September/ 2018	02	20	Technical Officers & Staffs	45
14	Overview of Instrument Transformers		02	20	Technical Officers & Staffs	45
15	Overview of Generators and its auxiliaries		02	20	Technical Officers & Staffs	45
16	National Integrity Strategy		02	30	Officers & Staffs	72
17	Power cycle Water chemistry		02	20	Technical Officers & Staffs	48
18	Instrumentation and control of Gas Turbine Cooling Air, Seal Air and Compressor Blade Washing System		02	20	Technical Officers	48
19	Working at height		02	25	Technical Officers & Staffs	60
20	Gas Turbine Lube Oil and Control Oil System	October/ 2018	02	25	Technical Officers & Staffs	60
21	Fuel Gas System – (RMS to Gas Turbine)		02	20	Technical Officers & Staffs	48
22	Feed Water System		02	20	Technical Officers & Staffs	48

SI NO.	Name of the Topic	Month	Duration (Session)	No. of Participants	Target Group	Expected Training Hours
23	AVR and Excitation System		02	20	Technical Officers	48
24	SFC system		02	20	Technical Officers	48
25	Etiquette, Manner, Attitude and General conduct, Discipline		02	20	Staffs	144
26	Travelling and Dearness Allowance		02	30	Officers & Staffs	144
27	Operation and Maintenance of different type of Control Valves and actuators		02	20	Technical Officers & Staffs	48
28	Working in Confined Space		02	25	Technical Officers & Staffs	60
29	Fuel Oil and GT Water Injection System	November/ 2018	02	20	Technical Officers & Staffs	48
30	Industrial Gas Systems and Hazardous Area Classification		02	20	Technical Officers & Staffs	48
31	Auxiliary Steam System		02	20	Technical Officers & Staffs	48
32	HRSR Design and Combined Cycle Basic Rules		02	20	Technical Officers & Staffs	48
33	Switchgear Panels (.kV, /kV)		02	20	Technical Officers & Staffs	48
34	Bus Transfer System		02	20	Technical Officers & Staffs	48
35	Medical Bill Submission		02	20	Officers	48
36	Financial Rules of NWPGL		02	15	Officers	72
37	Gas Turbine, HRSR and Steam Turbine Maintenance	December/ 2018	02	15	Technical Officers & Staffs	36
38	All Chemical Dosing Systems		02	20	Technical Officers & Staffs	48
39	DM Water, Portable Water, Service Water and Waste Water Treatment System		02	20	Technical Officers & Staffs	48
40	Maintenance and Troubleshooting of Plant Circuit Breakers		02	20	Technical Staffs	48
41	Relay Coordination System		02	25	Technical Officers	48
42	Gas Turbine, HRSR and Steam Turbine Maintenance		02	15	Technical Officers & Staffs	61.8
43	Air conditioning and HVAC system	January/ 2019	02	20	Technical Officers & Staffs	48
44	Transformer basics and protection		02	15	Technical Officers	36
45	NWPGL Service Rules		02	25	Officers & Staffs	60
46	Basics of Controllers & HMIs		02	15	Technical Officers	36
47	Chemical Spillage		02	20	Technical Officers & Staffs	48
48	Fire Fighting System	February/ 2019	02	25	Technicians & Staffs	60
49	Air Cooling Water Systems (CW, ACW & CCW) and Induced Draft Cooling Tower		02	20	Technical Officers & Staffs	48
50	Compressed Air Systems (Instrument Air, Service Air & GT Purge Air)		02	20	Technical Officers & Staffs	48
51	HVAC Systems		02	20	Technical Officers & Staffs	48
52	HRSR General Description Drums.		02	30	Technical Officers & Staffs	48
53	HT/LT Motor		01	15	Technical Officers & Staffs	18
54	Cable Termination System	March/ 2019	01	15	Technical Staffs	48
55	Auxiliary Power Supply (UPS, DC)		02	20	Technical Officers & Staffs	48
56	Operation and Maintenance of DCS system and its network Architecture		02	40	Technical Officers & Staffs	48
57	Electrical Hazard and Safety		02	20	Technical Officers & Staffs	96

SI NO.	Name of the Topic	Month	Duration (Session)	No. of Participants	Target Group	Expected Training Hours
58	Heat Exchangers (GT Cooling Air Cooler with Fuel Gas Heater, GT and ST Lube Oil		02	20	Technical Officers & Staffs	48
59	Gas Turbine and Steam Turbine Generator Cooling, Lube Oil and Sealing System		02	20	Technical Officers & Staffs	48
60	Busbar and Busduct System		01	20	Technical Officers & Staffs	24
61	EDG System	April/ 2019	01	23	Technical Officers & Staffs	28
62	Generator basics and protection		02	15	Technical Staffs	36
63	Motor basics and protection		02	15	Technical Officers	36
64	Types of measurements and control strategies		02	20	Technical Officers & Staffs	48
65	Safe Lifting and Material Handling		02	20	Technical Officers & Staffs	48
66	Discussion on Steam Turbine & Combined Cycle Power Plant and MHPS SRT-.AX		02	20	Technical Officers & Staffs	48
67	Feed Water, Main Stream, Auxiliary Steam		02	25	Technical Officers & Staffs	60
68	System Description for Steam Turbine Oil and Steam System		May/ 2019	02	25	Technical Officers & Staffs
69	Lighting System	01		20	Technical Staffs	24
70	Commonly used electrical equipment for testing purpose	02		20	Technical Staffs	48
71	Troubleshooting instrumentation and control system	02		20	Technical Officers & Staffs	48
72	First Aid	02		30	Officers & Staffs	216
73	HRSG General Description, Operating Instructions and Steam Lines	02		25	Technical Officers & Staffs	60
74	Gas Turbine, HRSG and Steam Turbine Maintenance	02		25	Technical Officers & Staffs	120
75	Basic on Electrical Maintenance	June/ 2019		02	20	Technical Staffs
76	KPI Guideline and Security of KPI		02	25	Officers & Staffs	60
77	Performance Appraisal, Submission and Evaluation Process		02	25	Officers	60
Total			153			4410

Source: "TRAINING CALENDAR 2018-2019" received from NWPGCL



Source: BPMI Annual Report of NWPGCL 2022

Figure 3-5 NWPGCL's training results for the fiscal year 2021-2022

(3) EGCB

EGCB prepares a training calendar/plan and implements trainings at each power plant to achieve the number of hours committed with the Power Division. When one power plant creates a training plan, employees from other power plants may also participate in the training. (EGCB owns three power plants.) Although lecture-based training is conducted at the head office, there is no dedicated lecture room, and the training is conducted in a regular meeting room.

At EGCB, there are very few staff members who carry out human resource development and training full-time, and all of them concurrently carry out other duties.

TRAINING CALENDAR/PLAN (Year : July/2022-June/2023)

Document No. QF-HRD-05

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Month-wise plan For Siddhirganj 335 MW CCPP Office

Name of the office/PS	Total man-power	Yearly targeted total training manhour (60hr.xcolumn 2)=	4																			
1	2	3																				
Office	124	7440	July/2022			Aug./ 2022			Sept./2022			Oct./2022			Nov./2022			Dec./2022				
			Targeted monthly manhour = total (axb) =			Targeted monthly manhour = total (axb) =			Targeted monthly manhour = total (axb) =			Targeted monthly manhour = total (axb) =			Targeted monthly manhour = total (axb) =			Targeted monthly manhour = total (axb) =				
			a	b		a	b		a	b		a	b		a	b		a	b			
Features →			Course code	No. of participant	Training hour	Course code	No. of participant	Training hour	Course code	No. of participant	Training hour	Course code	No. of participant	Training hour	Course code	No. of participant	Training hour	Course code	No. of participant	Training hour		
Serial no.																						
1			O-1	20	7	O-10	20	7	O-6(M3)	25	7	O-10	20	7	O-16	20	7	O-15	20	7		
2			O-2	20	7	O-11	20	7	O-6(M4)	25	7	O-11	20	7	O-17	20	7	O-6(M1)	25	7		
3			O-6(M1)	25	7	O-14	20	7	O-6(M5)	25	7	O-14	25	7	O-19	20	7	O-6(M2)	25	7		
4			O-6(M2)	25	7	O-15	20	7	O-7	100	5	O-15	25	7	S-6	20	7	O-7	100	5		
Total Manhour=				630			560			1025			630			560			1025			

Course Code:

O-1	Accounts and Financial Management	O-6(M3)	Gas Turbine Overview	O-9	Total Quality Management (TQM)	S-4	Water Treatment
O-2	Basic Idea of Power Plants	O-6(M4)	Maintenance & Operation of Gas Turbine Auxiliaries	O-10	Project Management	O-8	Maintenance of Gas Turbine
O-3	Special Course	O-6(M5)	Detail study of life history of hot section components	O-11	General & advanced use of Computer, ICT, MIS, e-Governance and MS Excel	O-19	Public Procurement Rules (PPR)-2008, EGC Procurement Policy-2015
O-4	Occupational Health, Safety and Environment	O-6(M6)	Maintenance of Gas Boogier Compressor	O-13	Ethics, integrity and anti-corruption	S-6	Office Management/Administration
O-5	Selection of procurement method and tender documents preparation.	O-6(M7)	Operation & Maintenance of Instrument Air Compressor	O-14	Contracts and Agreement	S-7	Operation of staff
O-6(M1)	Start up procedure of GT	O-7	Fire Fighting and Safety Procedure	O-15	Elements of Gas Turbine Control System.	S-8	Safety Driving
O-6(M2)	Start up procedure of GBC	O-8	Human Resource Management	O-16	Distributed Control System (DCS).	STM	Auto and Protection of Turbo-shaft

Course Code:

O-1	Accounts and Financial Management	O-6(M3)	Gas Turbine Overview	O-9	Total Quality Management (TQM)	S-4	Water Treatment
O-2	Basic Idea of Power Plants	O-6(M4)	Maintenance & Operation of Gas Turbine Auxiliaries	O-10	Project Management	O-18	Maintenance of Gas Turbine
O-3	Special Course	O-6(M5)	Detail study of life history of hot section components	O-11	General & advanced use of Computer, ICT, MIS, e-Governance and MS Excel	O-19	Public Procurement Rules (PPR)-2008, EGCB Procurement Policy-2015
O-4	Occupational Health, Safety and Environment	O-6(M6)	Maintenance of Gas Booster Compressor	O-13	Ethics, integrity and anti-corruption	S-6	Office Management/Administration
O-5	Selection of procurement method and tender document preparation	O-6(M7)	Operation & Maintenance of Instrument Air Compressor	O-14	Contracts and Agreement	S-7	Operation of staff
O-6(M1)	Start up procedure of GT	O-7	Fire Fighting and Safety Procedure	O-15	Elements of Gas Turbine Control System	S-8	Safe Driving
O-6(M2)	Start up procedure of GRC	O-8	Human Resource Management	O-16	Distributed Control System (DCS)	S-10	Autism and Parkinson's Disease

Legend: md = module

2019
06.2022

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Source: Document received from EGCB

Figure 3-6 Excerpt from EGCB's Training Calendar 2023-2023

(4) BPDB

BPDB is a power generation company (with a total of 26,700 MW of power generation facilities including coal, LNG, hydro, solar and wind power) as well as a power distribution business in four districts: Mymensingh, Chattogram, Cumilla and Sylhet. BPDB has the following seven training facilities, each with dedicated staff assigned to the training activities. The 9th floor of the BPDB headquarters building in Dhaka is a lecture-based training facility. Additionally, six training facilities other than Dhaka have mock training facilities for power distribution.

Table 3-8 Training facilities owned by BPDB

Training Academy, Center	Officer	Remarks (Facilities, Training courses etc.)
Directorate of Training & Career Development, BPDB, Dhaka	Director Deputy Director (Executive Engineer) -1 Deputy Director (Executive Engineer) -2 Deputy Director (Executive Engineer) -3 Deputy Director (Executive Engineer) -4	- Well-furnished seminar room with a seating capacity for 40 persons - Classroom with a seating capacity for 30 persons. - Well-furnished computer lab. - Need-based training courses on Coal based power plant, Communicative English, e-GP, e-filing, ERP, Project Management, Innovation Initiative, APA & KPI, etc.
Engineering Academy BPDB, Kaptai, Rangamati	Director Joint Director (Superintendent Engineer) Deputy Director (Admin) -1 Deputy Director (Executive Engineer) – Civil Deputy Director (Admin) -2 Deputy Director (Executive Engineer) -3 Deputy Director (Executive Engineer) -4	Conducting training for creating skilled manpower in Water & Power Development Board. Training is conducted in 2:1 ratio in respect of Power & Water Development Board since WAPDA is divided into two organizations as BPDB & BWDB. But the Administration of the Academy is controlled by BPDB.
Training Academy BPDB, Cox's Bazar	Director Deputy Director (Executive Engineer) Deputy Director (Admin)	The main objective is to impart training with a view to improve the professional skill of the BPDB's Personnel and to make them able to carry out their relevant functions effectively and efficiently.
Training Academy BPDB, Khulshi, Chattogram	Director Deputy Director (Executive Engineer) Deputy Director (Admin)	- Conduct different training courses for both technical and non-technical officers - Focusing the objectives of SDGs of 2030 - Well-equipped for super critical and ultra super critical thermal power plant - Installation of power plant simulator is planned - Conducting various distribution field related courses - Regular Electrical Trade Courses
Training Academy BPDB, Ghorashal, Narsingdi	Director Deputy Director (Executive Engineer) Deputy Director (Admin)	- Specialized for Power generation & general affairs training programme - High capacity Power plant simulator lab. - Training courses related to National Integrity Strategy, Professional Ethics, Anti- Corruption, ERP, e-filing etc.
Training Academy, BPDB, Rajshahi	Director Deputy Director (Executive Engineer) Deputy Director (Admin) Deputy Director (Accounts)	- Air-conditioned classroom, related laboratories, a gorgeous- conference room with multimedia and digital conferencing system - Training on distribution, office management and administration, e-GP& e-Filing and ERP, financial procedure, power plant etc.
Training Academy, BPDB, Tongi	Deputy Director (Executive Engineer) * under Director of Directorate of Training & Career Development, BPDB, Dhaka	- Adjacent to Dhaka, Central Equipment Repair Shop & Central Stores depot - 4 (Four) air-conditioned classrooms equipped with multimedia projectors & audio sound system

* Officer as of February 2023

Source: "Annual Training Program 2022-2023" and "Organogram of Training Wing of BPDB" received from BPDB

Table 3-9 Training programs of BPDB

Category	Training Program
Foundation Training	1. Foundation Training for Assistant Engineers 2. Foundation Training for Sub-Assistant Engineers 3. Foundation Training for Assistant Directors 4. Foundation Training for Store/Purchase Officers 5. Foundation Training for Accountants 6. Foundation Training for Chemists 7. Foundation Training for Doctors 8. Foundation Training for Security Officers
Training on Management	1. Effective Managerial Communication Skills, Inter-Personal & Intra-Personal Communication Skill Development & Motivating People at the Workplace 2. Short Course on Managerial Change for Better Public Service Delivery: South & South East Asia Experience 3. Corporate Management of BPDB 4. Leadership, Good Governance, Citizen Charter and SDGs 5. Advanced Management & Decision Making Skill 6. Strategic Human Resource Management and Office Administration for Senior Officers 7. Improving the Quality of Service and Skills of the Employees through the Implementation of IMS in BPDB 8. Stores Purchase and Online Store Management 9. Environmental Management System: Global aspect and ISO Standard 10. Professional ethics, anti-corruption and customer service excellence 11. Professional practice of Engineering Ethics and Interaction of Engineers with society
Accounts and Finance Related	1. Basic Training Course on Audit Management & Monitoring System 2.0 (AMMS-2) web based software operation and Implementation Procedure in BPDB 3. Foreign Financing 4. Foreign Payment Procedure 5. Financial Statement Analysis 6. Preparation of Budget and Financial Strategy 7. Account & Financial Management 8. Auditing and Settlement of Audit Objections 9. Basic Idea on TAX, AIT, CD-VAT and other Financial Activities 10. Tariff Rule, COP and Electricity Act 2018 and Rules 2020 11. Smart Pre-payment Metering, Computerized Billing System and Customer Service Excellence
Administrative Course	1. History, Society, Culture of Bangladesh and Strategic implementation spirit of Liberation War Philosophy of the Father of National Bangabandhu Sheikh Mujibur Rahman 2. National Integrity Strategy (NIS), Anti-Corruption, Etiquette & Manner, Professional Ethics & Organizational Behavior 3. Basic Management & Human Resource Management (HRM) / Human Resource Development (HRD) (for Senior Level) 4. Soft Skills, Etiquette and Grooming 5. Lifestyle, Motivation and Relaxation of Mental Stress 6. Office Administration, Personnel Management and File Management as per Secretariat Instruction 2014 7. Customer Service Excellence & Office Etiquette 8. Inquiry Procedure & Report Writing, Punishment and Appeal According to the Service Rules of BPDB 9. Constitution and Other Legal Provisions Relating to Public Services and Public Service Delivery 10. Next Generation Information and Knowledge Dissemination to Realize the Agenda 2030 for Sustainable Development 11. Bangabandhu as a visionary and charismatic leader and his roles for the independence of Bangladesh 12. Social Engineering and Social Media Offence, Defense and 4th Industrial Revolution

Category	Training Program
Information Technology Related Training	1. ERP (Enterprise Resource Planning) and Salary Automation through ERP, e-filing and APA 2. Ethical hacking & cyber security in power sector, Policy an Operational Perspective 3. Advanced course on 3D modeling software (Auto-CAD, Sketch Up & Lumion) 4. Training on Digital Platform (E-Payment System, Prepayment Metering System, Smart Metering, Snapshot Meter Reading System, Online Store Management) in BPDB 5. Smart Grid and GIS Mapping 6. Electronic Government Procurement (e-GP), APA and Delegation of Financial Power-2018 7. e-Filing, File Management for Development of Work Procedure & Services as per Secretariat Instruction 2014 8. Computer Training on Internet Security, Cyber security, Cloud Storage System and Use of Virtual or online platform 9. Basic Idea on Computer Software, Software Installation & Troubleshooting
Power Generation/ Supply Related Training	1. Basic and Brief Introduction, Analysis, and Troubleshooting of Different Distributed Control Systems and Programmable Logic Controllers 2. Basic and Brief Introduction, Analysis, and Troubleshooting of Mark VI and Vie Control System and Related Generator Excitation System 3. Basic and Brief Introduction, Analysis, and Troubleshooting of S7-200 PLC, S7-300 PLC, S7-400 PLC, PCS7 DCS, S7-1500 PLC System, S7-200 Smart, etc. 4. Idea About Coal Power Plant, coal handling, environmental risk / challenge's, Ultra Super Critical Boiler, Coal ash handling procedure and NOx/Sox Minimization procedure 5. Power Plant Fuel Diversity, Necessity of Fuel Diversity and Fuel Management System of Power Plants (Coal, Liquid Fuel, Natural Gas, LNG) 6. Power System Reliability. Load Forecasting and Economic Dispatch of Power Plants 7. Implementation of Integrated Solid Waste Management and Conversion of Waste into Energy: Economic and Technical issues 8. Solid Fuel Coal; Types, Properties, Composition, Coal Management and Sub-Critical, Critical, Super Critical, Ultra-Super Critical Point of a Coal based Thermal Power Plant 9. Operation and Maintenance of (GT, STG, Engine bases power plant and its auxiliaries) 10. Schedule maintenance (CI, HGPI and MI) of Gas Turbine, selection of schedule maintenance spares, planning for schedule maintenance procurement and refurbishment of capital spares 11. Power system protection (Generator protection, turbine protection, transformer protection, transmission line protection, etc.) 12. Relay & protection of power transmission and distribution system 13. FGMO operation for reliable/ stable power system 14. SCADA operation for coordination for power supply system 16. Operation of Power System Simulator (CCPP) 17. Operation of Power System Simulator (Gas Turbine) 18. Waste to Energy and it's Environmental Impact
Project Related Training	1. SWOT Analysis for Project Formulation, Implementation, Monitoring, Reporting, Evaluation and Closure 2. Project Management (For PD Pool of BPDB) 3. Training on Project Formulation, Processing, Approval & Revision Guideline-2022 for the Development Vision 2041 & Development of Power Sector – a Critical Analysis on Financial Aspect (For Senior Officers of BPDB) 4. Company Law 5. Power purchase agreements (PPA), Risk identification and mitigation procedure of PPA, Case study 6. Global Electricity Trading Scenario, Cross Border Electricity Trade (CBET) between Bangladesh and South Asian Region: Current Status, Future Prospects, risk and mitigation procedure
Training on Health, Security, KPI	1. Training for Doctors of BPDB for Professional Development 2. Occupational Health Safety Environment and First Aid 3. Security of KPI, Firefighting and safety procedure 4. Training for Medical Staff of BPDB 5. Training for Security Guard of BPDB 6. Driving Risks, Awareness, Vehicle Act, Road Safety & Traffic Management 7. Awareness Creation for some common diseases

Category	Training Program
Others	1. Power System Planning of BPDB 2. Ensuring Sustainable Power Sector through Energy Efficiency Development and Energy Conservation 3. Preparation of Tender Documents (Local international, EOI & RFP), Contract Document 4. Public Procurement Rules (PPR)-2008, PPA-2006 & delegation of Financial Power-2018 of BPDB 5. Pre-shipment Inspection and Post Landing Inspection, Factory Witness and Acceptance Test 6. Training on Civil Engineering & Architecture 7. Enhancing Academic and Professional Development for School Teachers

Source: "Overview of Training Activities of BPDB" received from BPDB

(5) RPCL

RPCL owns four thermal power plants and sells electricity to BPDB and others. RPCL has training facilities at its own Mymensingh 210 MW Combined Cycle Power Station and Gazipur 52 MW Dual Fuel Power Plant and conducts training there. In addition, training is conducted using the training center of Bangladesh Power Equipment Manufacturing Company Ltd. (BPEMC). In addition, like NWPGL and others, in addition to BPML, RPCL utilizes training courses provided by external organizations such as BIM, BIAM, and NAPD. RPCL also has the training system where the employees can travel to foreign countries to receive training. Table 3-10 shows RPCL's annual training plan for the fiscal year 2022-2023.

Table 3-10 RPCL's annual training plan (in-house trainings, fiscal year 2022-2023)

<Technical Training Plan>

S.N.	Course Name	No. of Course	Duration (Days)	Course Hour on per Person	Participants per Course	Target Group (Grade Wise)	Total Participants	Total Man Hour
1	Project preparation, Approval and Monitoring System	1	2	6	25	4-8	25	300
2	Public Procurement Management/Public Procurement Rule-2008 and Acts-2006	1	2	6	25	4-10	25	300
3	Black Start and Dead Bus Synchronization of a Power Plant	1	2	6	25	4-10	20	120
4	Operation and Maintenance of Combined Cycle Gas Turbine Power Plants and its auxiliaries	1	2	6	30	6-13	30	360
5	Operation and Maintenance of HFO Engine Based Power Plant and its auxiliaries	1	2	6	30	6-13	30	360
6	Control and Protection System of Power Plant	1	1	6	30	5-13	30	180
7	Preparation of Power Purchase Agreement (PPA) and Tariff structure of Power Plant	1	2	6	25	5-10	25	300
8	Accident and Safety Management of Power Plant	1	1	6	30	5-20	30	180
9	Programmable Logic Controller (PLC)	1	1	6	30	5-10	30	180

10	Maintenance of Alternator, Circuit breaker, Step up Transformer and Switch-gear	1	1	6	30	6-10	30	180
11	Importance of Different alarm and Imitativeness (HFO Engine based Power Plant)	1	1	6	30	5-10	30	180
12	Importance of Different alarm and Imitativeness (Combined Cycle Power Plant)		1	6	30	6-12	30	180
13	Inventory Control (Technical)	1	1	6	25	8-15	25	150
Total Man Hour:								2970

<General Training Plan>

S.N.	Course Name	No. of Course	Duration (Days)	Course Hour on per Person	Participants per Course	Target Group (Grade Wise)	Total Participants	Total Man Hour
1	KPI Based Performance Management	1	1	6	20	6-10	20	120
2	Leadership Development Program	1	2	6	20	5-8	40	240
3	Training on IMS	1	2	6	20	5-10	40	240
4	RPCL Employee Service Rules-2016	1	1	6	30	6-14	30	180
5	Fire Fighting, Fire Prevention, Rescue and First Aid Training	1	2	6	20	8-20	40	240
6	Orientation Training	1	2	6	30	8-10	60	360
7	Office Management and Record Keeping	1	1	6	25	6-10	25	150
8	Land Management	1	1	6	20	6-10	20	120
9	Etiquette and Manners	2	1	4	25	10-20	50	200
10	Traffic Laws, Regulations and Vehicle Management	1	1	6	30	8-15	30	180
11	Good Governance	1	1	4	25	5-12	25	100
12	National Integrity Strategy	2	1	3	50	5-12	100	300
13	Thematic Workshop to meet the challenges of the 4th industrial revolution	2	1	3	25	5-10	50	150
14	Training on e-government and innovation	4	1	4	20	5-10	80	320
15	Workshop on Service Commitment / Training	2	1	3	25	6-14	50	150
16	Grievance Redressal Mechanism and GIS Software Training	2	1	3	25	6-15	50	150
17	Right to Information Act-2009	3	1	3	25	5-16	75	225
Total Man Hour:								3425

<Financial Training Plan>

S.N.	Course Name	No. of Course	Duration (Days)	Course Hour on per Person	Participants per Course	Target Group (Grade Wise)	Total Participants	Total Man Hour
1	Project Financing and Financial Modeling	1	2	6	30	6-12	30	360

S.N.	Course Name	No. of Course	Duration (Days)	Course Hour on per Person	Participants per Course	Target Group (Grade Wise)	Total Participants	Total Man Hour
2	Banking and Commercial Activities	1	1	6	25	6-10	25	150
3	Income Tax, VAT and Customs	1	1	6	30	5-10	30	180
4	Audit (Internal and External) Financial Management	1	1	6	25	5-10	25	150
5	Basic Course on Accounting Principles	1	1	6	15	6-12	15	90
6	Power Sector integrated ERP Implementation	1	1	6	30	5-10	30	180
7	Petty Cash and Impress Fund Management	1	1	6	30	5-12	30	180
Total Man Hour:								1290

Source: "Training Calendar 2022-2023" received from RPCL

(6) CPGCBL

CPGCBL is a power generation company that is promoting the Japanese ODA loan project "Matarbari coal-fired power generation project" on the Bangladeshi side, and its main business is coal-fired power generation. However, as it has not yet started operation, actual operation and maintenance work has not yet been carried out. Therefore, as shown in Table3-11, the company only has the Corporate Office and Matarbari Site Office and does not have a training institute.

Table 3-11 Composition of CPGCBL's employees

Description	FY 2020-2021			FY 2021-2022		
	Corporate Office	Matarbari Site Office	Total	Corporate Office	Matarbari Site Office	Total
Officers	52	24	76	36	49	85
Staffs	37	17	54	27	25	62
Total =	89	41	130	63	74	147

Source: document received from CPGCBL

Although CPGCBL does not carry out practical work, like other power utilities, training activities are being conducted for employees as shown in Table 3-12, and the target values have been achieved.

Table 3-12 CPGCBL's training results (Fiscal year 2020-2021 and 2021-2022)

Type of Training	FY 2020-2021	FY 2021-2022
	No/Man-Hour	No/Man-Hour
Number of employees	130	147
Local Training (Man-hour)	8,822	6,657
Foreign Training (Man-hour)	0	5,760
Total Training (Man-hour)	8,822	12,417
Average Training – Man-hour (Local)	68	45

Average Training – Man-hour (Foreign)	0	39
Average Training – Man-hour (Total)	68	84

Source: document received from CPGCBL

(7) BR-Powergen

B-R Powergen Ltd. was established in 2010 by BPDB and RPCL under the Power Division and is a power generation company in which Power Division (63.2%), BPDB (18.4%) and RPCL (18.4%) have invested. BR-Powergen owns Kodda 150 MW Dual Fuel Power Plant and conducts power generation business. Additionally, the Mirsarai 150 ($\pm 10\%$) MW Dual Fuel Power Plant Project and the Sreepur 150 ($\pm 10\%$) MW HFO Based Power Plant Project are currently underway, and its power generation capacity is expected to be increased in the near future. Also, in 2022, the Madargonj 100 ($\pm 10\%$) MW Solar Power Plant Project was started. The number of employees is 209 (as of 2021).

BR Powergen does not have a dedicated training facility and uses the Corporate Office conference room (capacity 40 people) and the Kodda Power Plant conference room as a training room. Also, like NWPGL and RPCL, in addition to BPML, BR utilizes training courses provided by external organizations such as BIM, BIAM, and NAPD and has the training system where the employees can travel to foreign countries to receive training. Table 3-13 shows the training results for the fiscal year 2021-2022.

Table 3-13 BR-Powergen's training results (Fiscal year 2021-2022)

No.	Type of Training	Total Achievement (Man-Hour)	Percentage
1	In House Training	2,254	21.62%
2	Training by other organizations e.g. BPML, Techvision, Ministry etc.	2,986	28.63%
3	On the Job Training	5,111	49%
4	Workshop, Seminar etc.	79	0.75%
5	Foreign Training	-	-
Total		10,430	100%

Source: "Training Calendar 2022-23" received from BR-Powergen

Table 3-14 shows BR-Powergen's annual training plan for the fiscal year 2022-2023.

Table 3-14 BR-Powergen's annual training plan (Fiscal year 2022-2023)

<General Training Plan of Corporate Office>

S.N.	Course Name	No. of Course	No. of Days in Each Course	Course Hour per Person in Each Day	Participants in Each Day	Total Man Hour
1	Bangladesh Public Procurement Rules (PPR)	1	2	6	15	180
2	BRPL Employee Service Rules	2	1	6	20	240
3	Office Management	1	1	6	20	120
4	Effective Communication Skill & Organizational Behavior	1	2	6	15	180
5	Company Affairs	1	1	6	15	90
6	Leadership Development Program	1	2	6	15	180
7	Human Resource Management (HRM)	1	2	6	10	120
8	Effective Inventory and Warehousing Management / Store Management	1	1	6	15	90
9	Vehicle Management & Road Transport Act	1	1	6	20	120
10	National Integrity Strategy	2	1	5	30	300
11	Workshop on Fourth Industrial Revolution	2	1	6	30	360
12	E-Governance & Innovation	4	1	4	30	480
13	Citizen Charter	2	1	5	30	300
14	Right to Information (RTI)	3	1	4	30	360
15	Grievance Redress System	2	1	4	30	240
16	Integrated Management System	2	3	4	20	480
17	Fire Fighting, Fire Prevention, Rescue and First Aid Training	1	1	4	20	80
18	Communicative English	1	1	4	15	60
Total Man Hour:						3,980

<Technical Training Plan of Corporate Office>

S.N.	Course Name	No. of Course	No. of Days in Each Course	Course Hour per Person in Each Day	Participants in Each Day	Total Man Hour
1	Operation And Maintenance of Gas Turbine Power Plant	1	2	6	20	240
2	Programmable Logic Controller (PLC), Distributed Control System (DCS) and SCADA	1	2	6	15	180
3	Project Formulation, Implementation, Monitoring & Evaluation (PIME)	1	2	6	15	180
4	Power Generation & System Planning	1	2	6	15	180
5	Alignment Technology of Rotating Machines	1	2	5	15	150
6	Design and Implementation of Solar Power Plant	1	2	6	15	180
7	Operation & Maintenance of Transformer	1	2	6	20	240
8	Relay and Protection	1	2	6	15	180
9	Boiler Operation & Maintenance	1	2	6	10	120
10	Power System Protection	2	3	6	10	360
11	Design Manufacturing and Testing of Transformer	1	2	6	15	180
12	Operation & Maintenance of Combined Cycle Gas Turbine (CCGT) Power Station	1	2	6	20	240
13	Basic Training on ICT for Power Sector Professionals	1	2	6	10	120
14	Instrumentation & Control System in Power Station	1	2	6	15	180

15	Maintenance of Bearing, Selection & Proper use of Lubricants, Seals, Paints & Protective Coatings	1	1	5	20	100
Total Man Hour:						2,830

<Financial Training Plan of Corporate Office>

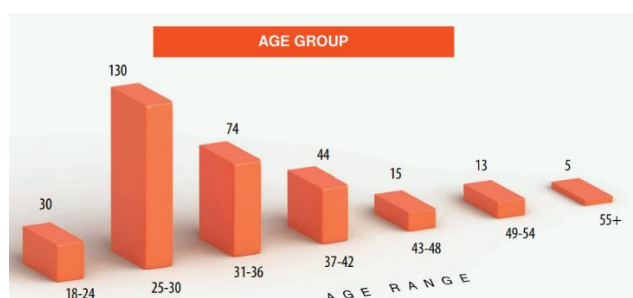
S.N.	Course Name	No. of Course	No. of Days in Each Course	Course Hour per Person in Each Day	Participants in Each Day	Total Man Hour
1	Internal Audit & Compliance	1	2	6	10	120
2	Imprest Fund Management	1	1	4	20	80
3	Fixed Asset Management & Maintenance	1	1	6	15	90
4	VAT & Tax Regulations	1	1	5	20	100
5	Management of Provident Fund, Workers Profit Participation Fund and Gratuity Fund	1	1	6	15	90
6	International Financial Reporting Standards (IFRS)	1	3	6	10	180
7	iBass++	2	1	6	10	120
8	Finance for Non-Finance Professionals	1	3	6	10	180
Total Man Hour:						960

Source: "Training Calendar 2022-23" received from BR-Powergen

(8) BCPCL

BCPCL is a company established in October 2014 through a Joint Venture Agreement (JVA) between NWPGL and China National Machinery Import & Export Corporation, and currently owns the Payra 1320 MW Thermal Power Plant. (two 660MW coal-fired power plants). Additionally, the Payra 1320 MW Thermal Power Plant Project (2nd Phase), a coal-fired power plant, is also underway.

BCPCL is a relatively new company and plans to expand its business in the future, so it hired 58 new employees in the fiscal year 2021-2022 to strengthen human resources (22 officers, 36 staff). As shown in Figure 3-7, most of the employees are in their late 20s to early 30s, and the importance of human resource development, such as improving practical skills related to coal-fired power generation, is very high.



Source: Annual Report 2022 of BCPCL

Figure 3-7 BCPCL staff composition by age (fiscal year 2021-2022)

In addition to conducting training at the Corporate Office and Payra 1320MW Thermal Power Plant, BCPCL also utilizes training from external organizations such as BIM, BIAM, and NAPD in addition to BPML, like NWPGL and RPCL. Among the in-house training, the training (monthly schedule) conducted at Payra 1320MW Thermal Power Plant is shown in Table 3-15.

Table 3-15 Monthly training schedule of BCPCL's Payra 1320MW Thermal Power Plant
(fiscal year 2022-2023)

SI NO.	Name of the Topic	Month	Duration (Session)	No. of Participants	Target Group	Expected Training Hours
1	Overview of O&M Contract	July - 2022	6	50	Officers (AE & Above) of Mechanical Maintenance Division	300
2	Performance Management System (Goal Setting & Key Performance Indicator – KPI) and Annual Performance Agreement (APA)		2	65	Technical & Non-Technical Officers	130
3	Performance Purchase Agreement (PPA)		3	50	Technical Officers (AE & Above)	150
4	Awareness on common disease (communicable and non-communicable disease)		2	60	Staff	120
5	Awareness on common disease (communicable and non-communicable disease)		2	50	Staff	100
6	Food & Beverage Service		8	10	OSS	80
7	Performance Management System (Goal Setting & Key Performance Indicator – KPI) and Annual Performance Agreement (APA)	August - 2022	2	90	Staff	180
8	Public Procurement (PPR & e-GP) Regulations		5	20	Officers	250
9	Delegation of Administrative Power		2	50	Technical & Non-Technical Officers	100
10	Fire Detection and Firefighting system of Payra 1320MW TPP		5	58	Officers	290
11	Fire Detection and Firefighting system of Payra 1320MW TPP		2	60	Staff	120
12	Labor Law & Company Act	September - 2022	2	50	Technical & Non-Technical Officers	100
13	Basic Safety norms for operation and maintenance (Incident, Accident, Near Miss, Effective use of PPE and Mechanical Maintenance & Maintenance Safety)		6	40	Officers (Operation Division)	240
14	Boiler Operation and Emergency Handling		10	35	Technical Officers (Operation & Boiler Maintenance Division)	350
15	Turbine Operation and Emergency Handling		12	35	Technical Officers (Operation & Turbine Division)	420
16	Delegation of Financial Power		2	50	Technical & Non-Technical Officers	100
17	Generator, Excitation system, Electrical Switchgear operation and NCS system Operation and Emergency Handlings	October - 2022	12	35	Technical Officers (Operation & Electrical Maintenance 1&2 Division)	420
18	FGD & ESP system operation and emergency handlings		12	50	Technical Officers	600
19	Awareness on common disease (communicable and non-communicable disease)		2	50	Officers	100

SI NO.	Name of the Topic	Month	Duration (Session)	No. of Participants	Target Group	Expected Training Hours
20	Awareness on common disease (communicable and non-communicable disease)		2	50	Officers	100
21	Recruitment & Promotion (As per Service Rule of BCPCL)		2	50	Officers	100
22	HVAC system operation and emergency handlings		4	40	Technical Officers	160
23	Basic Power System Engineering for Mechanical Engineers	November - 2022	3	15	Mechanical Engineers	45
24	Leave Procedure		2	100	Officers	200
26	Annual Performance Appraisal Submission and Evaluation Process		2	60	Technical & Non-Technical Officers	120
27	Power Plant O&M Basic Operational Concept of Power Plant		2	50	Officers	100
28	First Aid training including Management of Burn Injury, Electrocution, Snake Bite, Choking		2	60	Technical & Non-Technical Officers	120
29	First Aid training including Management of Burn Injury, Electrocution, Snake Bite, Choking		2	60	Staff	120
30	BOP Operation and emergency handlings	December - 2022	6	10	Officers (Chemical & Chemical Maintenance)	60
31	Hydrogen Plant Operation and Emergency Handlings and Safety		3	10	Officers (Chemical Dept. & Relevant Officers)	30
32	Leave Procedure		2	119	Officers	238
33	Travelling Allowance / Daily Allowance (As per the Service Rules of BCPCL)		2	60	Technical & Non-Technical Officers	120
34	Chemical Lab Equipment Handlings (Oil, Coal, Water)		3	15	Officers (CHP, I&C Chemical Dept. & Relevant Officers)	45
35	Sodium Hypochlorite Generating plant operation		3	10	Officers (Chemical Dept. & Relevant Officers)	30
36	Fire Detection and Firefighting system of Payra 1320MW TPP	January - 2023	5	60	Technical & Non-Technical Officers	300
37	Fire Detection and Firefighting system of Payra 1320MW TPP		2	60	Staff	120
38	Basic Electricity and Electronics		3	30	Staff	90
39	Basic DCS System, NCCS		8	40	Technical Officers (I&C, Operation)	320
40	Etiquette, Manner, Attitude and General Conduct, Discipline	February -2023	2	50	Officers	100
41	All Benefits including Medical Reimbursement & Fringe Benefits		2	60	Technical & Non-Technical Officers	120
42	Fundamental of Computer Applications (MS Word, Excel), Internet and Networking		6	30	WA/OA/SS	180
43	Basic Instrumentation of 400kV GIS for SF ₆ Gas (Pressure Transmitter, Pressure Switch, Density Analyzer, Moisture Analyzer and SF ₆ Gas Detector)		6	40	Technical Officers (Electrical Maintenance, I&C and Relevant Officers)	240
44	Protection Scheme used for Dry type Transformers and MV motors		4	15	Technical Officers (Electrical Maintenance and Relevant Officers)	60
45	Etiquette, Manner, Attitude and General Conduct, Discipline	March - 2023	2	100	Staff	200
46	Training on Hazard Identification and Risk Assessment and Documentation		4	20	Officers (EHS & ISO Audit Relevant Officers)	80
47	Retirement & Gratuity (as per the Service Rules of BCPCL)		2	60	Technical & Non-Technical Officers	120
48	Training on Coal Sourcing, Procuring, Supplying, Vessel Nomination & Transportation system and Billing of Coal Purchasing		6	30	Technical Officers (CHP & Relevant Officers)	180

SI NO.	Name of the Topic	Month	Duration (Session)	No. of Participants	Target Group	Expected Training Hours
49	First Aid training including Management of Burn Injury, Electrocution, Snake Bite, Choking	April - 2023	2	50	Technical & Non-Technical Officers	100
50	First Aid training including Management of Burn Injury, Electrocution, Snake Bite, Choking		2	60	Staff	120
51	Training on Coal Supply Agreement (CSA) and Coal Transportation Agreement (CTA)		8	30	Technical Officers (CHP & Relevant Officers)	240
52	Furnace safeguard supervisory system (FSSS) & SIL3 control system & Boiler Protection System		3	15	Technical Officers (I&C and Boiler)	45
53	Fundamental of Computer Applications (MS Word, Excel), Internet and Networking		4	30	Staff	120
54	Water System of Payra 1320 MW Thermal Power Plant	April - 2023	2	40	Technical Officers (Turbine Maintenance, Operation and Chemical)	80
55	CHP Operation and Maintenance (Fly ash, Bottom ash and Gypsum Handling System & Coal Jetty)		24	15	Technical Officers (CHP & Relevant Officers)	360
56	Retirement & Gratuity (as per the Service Rules of BCPCL)		2	50	Staff	100
57	Evolution System of Performance Management System (PMS)	May -2023	2	60	Technical & Non-Technical Officers	120
58	Familiarization with DC system and UPS of Main Power Block		4	50	Electrical Maintenance & Operation Division	200
59	415V Motor Controlling scheme		2	15	Electrical Maintenance Division-1	30
60	Familiarization with Power Station Spare Parts Management & Tools Handling		6	10	Boiler Maintenance, Store & Workshop	60
61	Inventory & Store Management	June -2023	2	30	Staff	60
62	Housekeeping & Cleaning		2	20	Staff	40
63	Training for Physical Fitness		2	38	Security Supervisors and Guards	76
64	KPI Security Policy-2013		2	115	Officers	230
Total						9,829

Source: "TRAINING CALENDAR 2022-2023" received from BCPCL

3.4.2 Power transmission company

The power transmission business in Bangladesh is operated by a single company, PGCB.

PGCB, like other power utilities, utilizes training programs of BPMI for management and financial training and technical basic training, and conducts in-house training courses for specific content on power transmission skills and technologies (troubleshooting of power transmission equipment, etc.). The annual training plan is formulated from April to June after listening to the needs of each department and is implemented the following year. PGCB does not have a training center dedicated to training. PGCB has established the following training policy and training implementation strategy regarding training/human resource development.

<Policy on training/ human resource development>

- (1) Competent personnel will execute, supervise, inspect and verify various functions of PGCB, The Managing Director will oversee and provide guidance to ensure and maintain competency of its personnel in discharging such functions. Training will be carried out as a

significant activity to develop competency of personnel working in PGCB. All training courses will be carried out in the interest of PGCB.

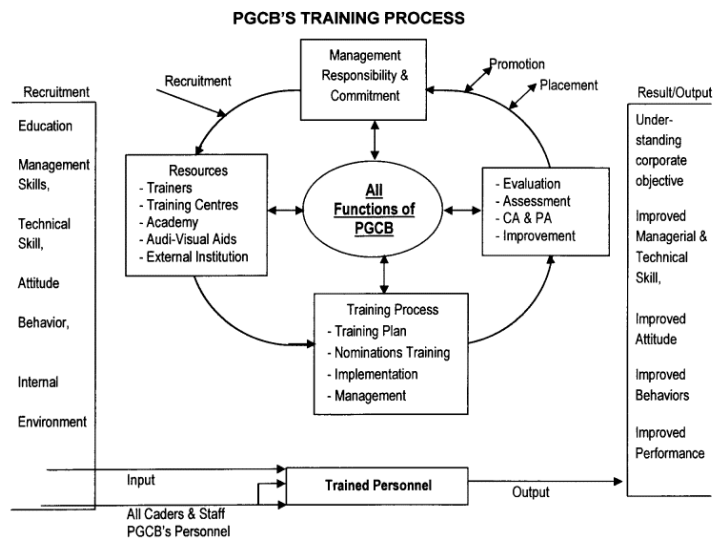
- (2) All training programs will be aimed at achieving the objectives stated above.
- (3) Training will be a planned activity. There will be long-term plan (5 years) and an annual short-term plan for implementing training programs in PGCB
- (4) All personnel and functions in PGCB will be included in the training plan. It will be the responsibility of all functional heads (GM, DGM, Manager) to ensure that all personnel under his/her control are included in the relevant plan.
- (5) A person shall undertake at least 3 days (18 contact hours) training in every year in his/her field of work in order to maintain competency. Functional heads will ensure that all personnel under his/her control fulfill this minimum requirement.
- (6) To fulfill the need for human resource development PGCB may utilize the training facilities of BPDB and other power sector utilities on payment. PGCB can alternately buildup its own training institutions. Besides, other facilities such as follows may also be utilized:
 - A. External training institutions in Bangladesh
 - B. Foreign training facilities
- (7) Training organised by PGCB shall be need based & goal oriented to improve desired competency.
- (8) PGCB will utilise training programs organised by other agencies only if the said program fulfils the need and goal of PGCB in competency building of its personnel.
- (9) Training outcomes will be measured by applying suitable methodology. Connective and preventive measures will be initiated accordingly.
- (10) PGCB will evaluate the continuing suitability of this policy and take necessary measures for its effectiveness.
- (11) PGCB will update the training courses suiting to the need of the changed environment/conditions.

< Training implementation strategy >

- (1) Training will be carried out off-job (at training institutions/ centres) or on- Job.
- (2) Manager (Training) will be responsible for planning, development and implementation of training programs under the supervision of Director (Finance). He will facilitate the functional heads in fulfilling their training needs.
- (3) Need assessment will be carried out once in every 5 years covering all functional areas of PGCB. Manager (Training) jointly with concerned functional head will carry out the need assessment. In cases of necessity help from professional experts will be taken. This plan will be reviewed every year to update annual plan. Annual plan will be from July to June in order to match the annual budget.
- (4) While budgeting training courses all relevant cost elements like, honorarium to resource persons, travel cost, material and reproduction cost, refreshment and food for trainees and resource persons, field visit, certificate etc. will be considered and borne by PGCB authority (Participants DA will not be utilised to support (food and refreshment during the period of training).
- (5) PGCB shall allocate sufficient fund in the budget to implement annual training plan.

- (6) As a part of socialisation, all categories of personnel shall undergo 'Induction Training/Orientation' immediately after new recruitment. Placement or posting will be done only on completion of Induction/ Orientation Training.
- (7) After placement an employee will undertake on-job training in the relevant field for a prescribed period. The concerned functional head will appoint a mentor for this purpose from his team. Besides, technical training relevant to the job will be planned.
- (8) All positions at the level of DGM or equivalent will be filled in from amongst the officers having completed Senior Staff Course (Appendix-10) in any institution. A Senior Staff Course will be designed and implemented in required number of batches to cover the target group (i.e. DGM & Managers). All existing DGM's and Managers will participate in such course on priority basis before they are promoted to higher positions.
- (9) If an employee fails to comply with the requirements of item 4, 5 under policies, the person responsible for such variation will be identified and be subjected to disciplinary action.
- (10) If an employee trained at home or abroad for a specific goal or purpose will have to continue in the same function till that goal or purpose is achieved.
- (11) In case of a new project where a different and new technology has been planned to be established, provision of training will be made to disseminate knowledge. The concerned person obtaining training shall plan on-job training to other personnel with intimation to the functional head. Such person will continue to be posted in the same functions till such knowhow or skill is disseminated to others.
- (12) PGCB will seek assistance from donor agencies to implement its training plan where relevant.
- (13) PGCB will ensure effective implementation of this training policy. Resources will be mobilized to carry out Planning and Monitoring, Curriculum Development, Evaluation and Record keeping.

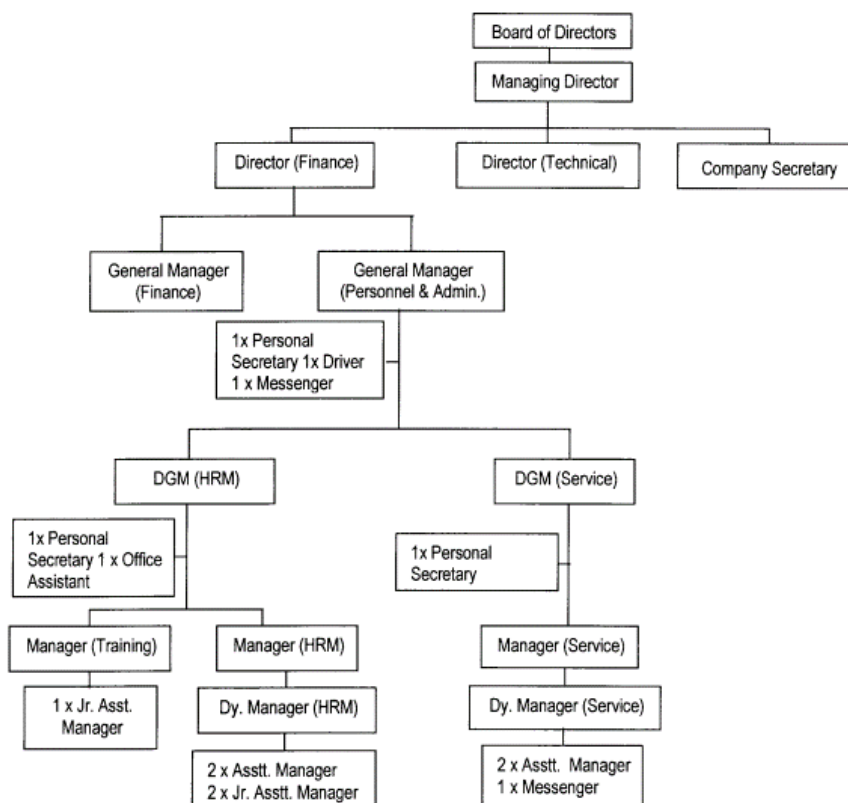
Figure 3-8 shows the training process in PGCB as clearly stated.



Source: "TRAINING POLICY" received from PGCB

Figure 3-8 Training process in PGCB

Figure 3-9 shows the training organization in PGCB.



Source: "TRAINING POLICY" received from PGCB

Figure 3-9 Training organization in PGCB

Table 3-16 shows the training content of PGCB's annual training plan for transmission grid workers, project workers, power system operation workers, electricians, overhead line workers, and supervisors.

Table 3-16 Excerpt from annual training plan of PGCB (fiscal year 2022-2023)

<For transmission grid workers>

S.N.	Subject of Training	Target Group	Batch No	Time	Duration (Days)	Participants per Batch	Man Days	Venue/ Organizer
1	Conflict and Negotiation Management	XEN to CE	1	July'22	2	37	74	PGCB/BPMI/ Other Organization
2	Various act, laws & rules (Ex. PGCB Service rules, & Bangladesh Labor Law and Rules)	XEN to CE	1	July'22	2	37	74	PGCB/BPMI/ Other Organization
3	Strategic Planning and Strategic Management	XEN to CE	1	August'22	2	37	74	PGCB/BPMI/ Other Organization
4	Strategic Leadership and Change Management	XEN to CE	1	September'22	2	37	74	PGCB/BPMI/BIM/ Other Organization
5	Total Quality Management	AE to CE	6	September'22	3	35	630	PGCB/BIM/ Other Organization
6	Group Dynamics and Team Building	AE to CE	6	May'23	3	35	630	PGCB/Other Organization
7	Training of Trainers (TOT)	XEN to CE	1	October'22	2	37	74	PGCB/Power Cell/BPMI/BIM/
8	Training on Emotional Intelligence	XEN to CE	1	September'22	1	37	37	PGCB/Other Organization
9	Training on Effective Communication Skills and Developing Business Communication Skills	SAE to CE	20	September'22	2	40	1,600	PGCB/BPMI/BIM/ Other Organization
10	Training on Good Governance & National Integrity Strategy (NIS) Awareness	SAE to CE	20	September'22	1	40	800	PGCB/RPATC/ BPMI
11	Supervisory Skills and Management Competency	AE to CE	6	December'22	1	35	210	PGCB/Other Organization
12	Knowledge & technique of asset management and its controlling system	XEN to CE	3	August'22	3	20	180	PGCB/Other Organization
13	Project Planning, Development and Management (PPDM)	XEN to CE	1	March'23	2	37	74	PGCB/BPMI/Other Organization
14	Operation and maintenance work of transmission line and substations	XEN to CE	1	October'22	1	37	37	PGCB/BPMI
15	Increasing Driving Skills Awareness about Organization Development	XEN to CE	1	February'23	2	37	74	PGCB/Other Organization
16	Fault finding analysis ability during inspection	AE to SDE	5	November'22	1	40	200	PGCB/Other Organization

17	Advance Fire Safety & Disaster management	SAE to SDE	20	August'22	1	40	800	PGCB/Other Organization
18	Inventory Management	AE to SDE	5	April'23	2	40	400	PGCB/Other Organization
19	Filing, Documentation and Record Keeping	AE to SDE	5	May'23	1	40	400	PGCB/Other Organization
20	Knowledge & technique of asset management and its controlling system	AE to SDE	5	August'22	2	40	400	PGCB/Other Organization
21	Store Management	AE to SDE	5	August'22	2	40	400	PGCB/Other Organization
22	Concept of system operation	SAE	25	July'22	1	40	1,000	PGCB/Other Organization
23	Concept of power transmission system	SAE	25	January'23	1	40	1,000	PGCB/Other Organization
24	Concept of Substation & transmission line equipment	SAE	25	February'23	1	40	1,000	PGCB/BPMI
25	OHSAS	SAE	25	February'23	1	40	1,000	PGCB/BPMI/ Other Organization
Total =							11,042	

<For project workers>

S.N.	Subject of Training	Target Group	Batch No	Time	Duration (Days)	Participants per Batch	Man Days	Venue/ Organizer
1	Various act, laws & rules (Ex. PGCB Service rules, & Bangladesh Labor Law and rules)	SAE to CE	1	December'22	2	30	60	PGCB/Other Organization
2	Conflict and Negotiation Management	XEN to CE	1	July'22	2	20	40	PGCB/BIM/ Other Organization
3	Training on Good Governance & National Integrity Strategies/ (NIS) Awareness	SAE to CE	1	August'22	1	30	30	PGCB/RPATC/ BPMI
4	Contract management	AE to CE	1	April'23	3	20	60	PGCB/CPTU/BPMI/ Other Organization
5	Supervisory Skills and Management Competency	XEN to CE	1	May'23	2	20	40	PGCB/Other Organization
6	Strategic Planning and Strategic Management	AE to CE	1	August'22	2	25	50	PGCB/Other Organization
7	Total Quality Management	XEN to CE	1	September'22	2	25	50	PGCB/BIM/Other Organization
8	Strategic Planning and Strategic Management	XEN to CE	1	October'22	1	25	25	PGCB/Other Organization
9	Training on Effective Communication Skills and Developing Business Communication Skills	AE to CE	1	August'22	1	30	30	PGCB/BPMI/BIM/ Other Organization
10	Increasing Driving Skills Awareness about Organization Development	XEN to CE	1	July'22	1	20	20	PGCB/Other Organization

11	Project Planning, Development and Management (PPDM)	AE to SDE	1	November'22	3	25	75	PGCB/BPMI/Other Organization
12	Design of AIS & GIS Grid Substation & Transmission Line	AE to SDE	1	November'22	1	36	36	PGCB/BPMI/Other Organization
13	Concept of Substation & transmission line equipment	AE to SDE	1	December'22	1	36	36	PGCB/BPMI/Other Organization
14	Concept of power transmission system	AE to SDE	1	January'23	1	36	36	PGCB/BPMI/Other Organization
15	Public Procurement Act-2006 and Rules-2008	AE to SDE	1	September'22	1	37	37	PGCB/CPTU/ RPATC/BPMI/BIM
16	Total Quality Management	AE to SDE	1	September'22	1	37	37	PGCB/BIM/Other Organization
17	Training on Emotional Intelligence	AE	1	March'23	1	20	20	PGCB/Other Organization
18	Knowledge of Microsoft office (MS) Application	AE	1	November'22	1	22	22	PGCB/RPATC/BIM/ Other Organization
19	AutoCAD (3D modeling)	AE	1	March'23	3	22	66	PGCB/Other Organization
20	e-GP	AE	1	July'22	2	25	50	PGCB/RPATC/ Other Organization
21	Knowledge of Morphological Study	SAE to XEN	1	June'23	2	25	50	PGCB/Other Organization
22	ISO14001 Environmental Management System	SAE to XEN	1	March'23	2	25	50	PGCB/Other Organization
23	ISO 9001 Quality Management System	SAE to XEN	1	May'23	2	25	50	PGCB/Other Organization
24	Environmental auditing & Environmental Performance Standard Assessment	SAE to XEN	1	October'22	2	25	50	PGCB/Other Organization
25	Knowledge of Sustainable Environmental Management	SAE to XEN	1	November'22	2	20	40	PGCB/BPMI/Other Organization
26	Training on Civil works/Design	AE	1	March'23	3	20	60	PGCB/Other Organization
Total =							1,120	

<For power system operation workers>

S.N.	Subject of Training	Target Group	Batch No	Time	Duration (Days)	Participants per Batch	Man Days	Venue/ Organizer
1	Knowledge of SMART Grid Operation	SAE to CE	2	March'23	2	20	80	PGCB/Other Organization
2	Various Laws & Rules (Ex. Electricity act, rules, regulations and safety, PGCB Service rules, & Bangladesh Labor Law and Rules)	SAE to CE	2	July'22	2	2	80	PGCB/Other Organization
3	Disaster management	SAE to CE	2	September'22	1	15	30	PGCB/Other Organization
4	Total Quality Management	AE to CE	2	November'22	2	15	60	PGCB/BPMI/Other Organization
5	Conflict and Negotiation Management	XEN to CE	2	December'22	1	20	40	PGCB/BPMI/Other Organization

6	Strategic Planning and Strategic Management	XEN to CE	2	August'22	2	25	100	PGCB/Other Organization
7	Training on Leadership	XEN to CE	2	September'22	2	20	80	PGCB/BPMI/BIM/Other Organization
8	Training on Emotional Intelligence	XEN to CE	1	January'23	1	20	20	PGCB/Other Organization
9	Supervisory Skills and Management Competency	XEN to CE	1	February'23	1	25	25	PGCB/Other Organization
10	Organization Behavior	SAE to CE	2	March'23	2	20	80	PGCB/Other Organization
11	Training on Good Governance & National Integrity Strategy (NIS) Awareness	SAE to CE	2	August'22	1	35	70	PGCB/RPATC/ BPMI/
12	Training on Effective Communication Skills and Developing Business Communication Skills	SAE to CE	2	March'23	2	20	80	PGCB/BPMI/BIM/Other Organization
13	Increasing Driving Skills Awareness about Organization Development	SAE to CE	2	April'23	1	25	50	PGCB/Other Organization
14	e-GP	SAE to XEN	2	June'23	2	20	80	PGCB/RPATC/Other Organization
15	Power System Reliability, Stability, Operation & Control	SAE to XEN	1	June'23	2	20	40	PGCB/BPMI/Other Organization
Total =							915	

<Remark> CE: Chief Engineer, XEN: Executive Engineer, SDE: Sub Divisional Engineer, AE: Assistant Engineer, SAE: Sub Assistant Engineer

<For electricians, overhead line workers, and supervisors>

S.N.	Subject of Training	Target Group	Batch No	Time	Duration (Days)	Participants per Batch	Man Days	Venue/ Organizer
1	Cable Joint, Conductor Joint & Repairing of Machines/Tools	Electrician A to Electrician C	5	May'23	2	40	400	PGCB/Other Organization
2	Electrical Safety Guidelines	Electrician A to Electrician C	5	August'22	2	40	400	PGCB/Other Organization
3	Fire Fighting & Safety Measure	Electrician A to Electrician C	5	June'23	2	40	400	PGCB/Other Organization
4	Repair & Maintenance of Transformer and Circuit Breaker	Electrician A to Electrician C	5	February'23	2	35	350	PGCB/Other Organization
5	Operation and Maintenance of Substation Equipment	Electrician A to Electrician C	5	December'22	2	35	350	PGCB/Other Organization
6	Electrical Safety and Hazards	Electrician A to Electrician C	5	March'23	2	35	350	PGCB/Other Organization
7	Annual Maintenance of Substation Equipment and Transmission Lines	Electrician A to Electrician C	5	November'22	2	30	300	PGCB/Other Organization

8	ROW and Dead Line Checking, Tools Keeping & Safe Working Practice	Electrician A to Electrician C	5	May'23	2	30	300	PGCB/Other Organization
9	Manner & Etiquettes	Electrician A to Electrician C	5	January'23	2	30	300	PGCB/Other Organization
10	Ethics & Integrity	Electrician A to Electrician C	5	March'23	2	30	300	PGCB/Other Organization
11	Maintenance Work of OPGW and Optical Fiber	Electrician A to Electrician C	5	August'22	2	30	300	PGCB/Other Organization
12	Maintenance work of Charger & Battery	Electrician A to Electrician C	5	September'22	2	30	300	PGCB/Other Organization
Total =							4,050	

Source: "Annual Training Program July 2022- June 2023" received from PGCB

PGCB has set up simulation equipment for training (132kV switchgear equipment, transformers, 33kV switchgear equipment, protection control equipment, etc.) within the premises of the 230/132kV Maniknagar Substation in the southern part of Dhaka city. These are used as a 3-5 day introductory training for new employees in the power transmission and substation field.

These training simulation facilities were originally used on actual site but were removed in 2017 and reused for training purposes. A series of equipment, from disconnectors to circuit breakers and transformers, are connected as in a normal substation, and the switches and circuit breakers can be opened and closed in the same way as normal equipment. In addition to maintenance methods, the training on protection and control equipment is also provided, in which relay trips can be simulated and training equipment to simulate and detect failures can be used. As these are outdoor facilities, these training courses are not held during the rainy season. This training simulation facilities are also used in training sessions sponsored by BPMI.

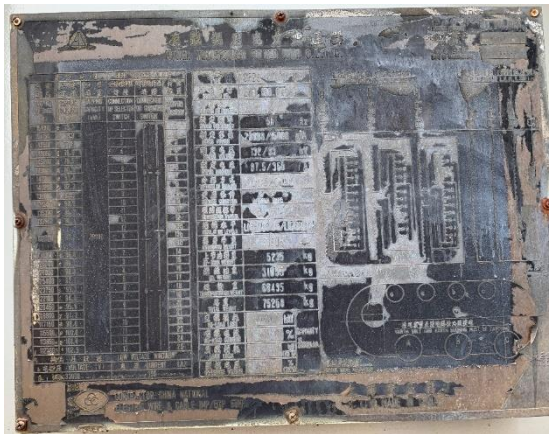
This is PGCB's only outdoor training simulation facility, and PGCB is planning to build a new training facility in Ishwardi city (Pabna District) located in northern area.



Training equipment (switchgears) within the substation premises



Training equipment (protection control device) within the substation premises



Transformer name plate
(It shows that it is made in China and very old.)



132kV relay panel

Source: JICA Survey Team, photographed on May 10, 2023

Figure 3-10 PGCB training simulation facilities (230/132kV Maniknagar Substation premises)

3.4.3 Power distribution company

Interviews were conducted with four power utilities: BPDB, BREB, DESCO and DPDC. Information was also collected from WZPDCL using a questionnaire. BPDB is also a power generation company, as mentioned above in 3.4.1.

(1) BREB

BREB is a power utility established for the purpose of providing high-quality electricity

services to all people in Bangladesh, and manages and supervises 80 PBSs (Palli Bidyut Samities, rural electric cooperatives) across the country. BREB is responsible for power distribution business to customers in rural areas through PBS, which accounts for 75% of the total customers and 55% of the electricity sold in Bangladesh, supplying electricity to 61 of the 64 districts in Bangladesh.

BREB provides training collectively, rather than individually at PBS. (However, there are cases where each PBS conducts its own training.) BREB owns a 6-acre facility located in the Shabar district, 30 km from Dhaka, with training facilities capable of on-the-job training and an accommodation that can accommodate 220 people. BPMI also borrows the facility from BREB when conducting practical training in power distribution. There is a training facility (Training Academy) adjacent to the Headquarters, where lecture-based training is conducted. (See Figure 3-11)

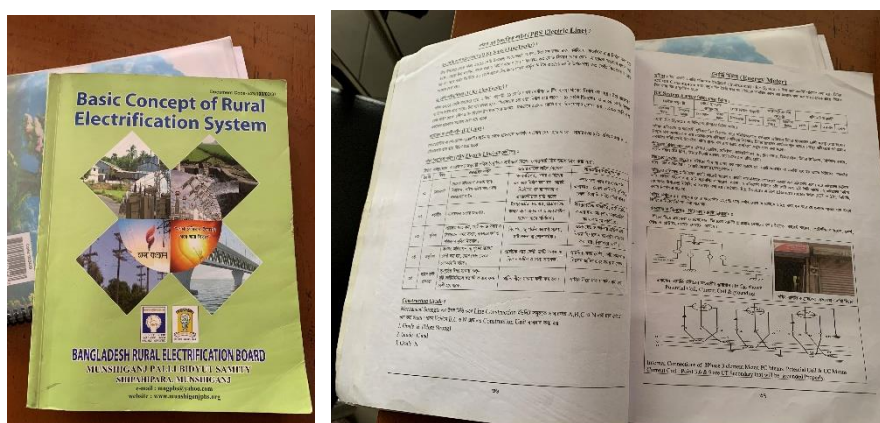


(Left: Entrance; Center: Computer room equipped with Desk Top Computers; Right: Lecture room)

Source: JICA Survey Team, photographed on February 19, 2023

Figure 3-11 Lecture rooms, computer rooms, etc. in BREB's Training Academy

A lecture was being held when the JICA survey team visited in February 2023, and the lecture textbook was of a high level and seemed to have sufficient contents as shown in Figure 3-12.



Source: JICA Survey Team, photographed on February 19, 2023

Figure 3-12 Lecture textbook of training held at BREB's Training Academy

বাণিজ্যিক প্রশিক্ষণ ক্যালেন্ডার (২০২২-২০২৩)

বাণিজ্যিক প্রশিক্ষণ ক্যালেন্ডার (২০২২-২০২৩)

৯. Evaluation System : (a) Pre Test (b) Post Test (c) Mid Term Evaluation (d) Final Evaluation

Field Training for PBS Assistant Junior Engineer (O&M/E&C)

- Course Code : TC760
- Course Name : Field Training for PBS Assistant Junior Engineer (O&M/E&C)
- Course Type : Technical Construction (TC)
- Total Period : 19 Days
- Course Objective : To develop theoretical and practical knowledge and skill on PBS distribution system construction
- Participant : BREB SAE, PBS AIE (O&M/E&C).
- Course Content :

Topic No	Topics	Class Hour
T-01	Inauguration & Importance of the Course and Introduction to Project Division & PBS	1
T-02	Pole Framing, Digging, Introduction & Anchor Installation	2
T-03	Conductor Installation	2
T-04	Equipment Installation	2
T-05	Energization Procedures	1
T-06	Service Drop & Meter Installation	2
T-07	1 Mile As Built Staking	1
T-08	Final Line Inspection	2
T-09	Warehouse Inspection	1
T-10	Substation Construction, Inspection & Test Energization	1
T-11	PDB Line Renovation	1
T-12	House Wiring Standards & Wiring Program for Domestic Consumer	1
T-13	Lineman Work Force Supervision	1
T-14	Operation and Maintenance Work	1
Total =		19 Days

Note : One Period = One Class hour = 40 Minutes

8. Training Methodology :

(a) Class room lecture (b) Group Discussion (c) Exercise & Presentation (d) Demonstration

9. Evaluation System : (a) Pre Test (b) Post Test (c) Mid Term Evaluation (d) Final Evaluation

PBS System Design

- Course Code : TE010
- Course Name : PBS System Design (Revision: 01)
- Course Type : Technical Engineering (TE)
- Total Period : 60
- Course Objective : To achieve adequate Knowledge on Design & Construction of PBS Distribution System.
- Participant : REB DD(Tech)/XEN, REB AE, AGM (COM), AGM(ENGG.), Consultant Graduate Engineer.
- Course Content :

Topic No	Topics	Class Hour
-	Registration and Pre-Evaluation	-
T-01	Inauguration & Importance of the Course	01
T-02	Technical Introduction to Electrical Line Construction Project	01
T-03	System Design Criteria and Line Routing	03
T-04	Mapping : Manual & Digital System	02
T-05	Grounding and the MGN (Multi Grounded Neutral) System	02

Topic No	Topics	Class Hour
T-06	Construction Standards, PBS Instruction 100-28 (1φ Part)	03
T-07	Construction Standards, PBS Instruction 100-28 & 100-45 (3φ & Miscellaneous Part)	04
T-08	Voltage Levels and Calculations	03
T-09	Over voltage Protection & Insulation Levels	02
T-10	Over current Protection	03
T-11	Introduction to Electrical Transformers	02
T-12	Energy Meters	02
T-13	Voltage Regulators and on load tap changer	03
T-14	Capacitors and Power Factor Improvement	02
T-15	System Losses & Calculation	04
T-16	Construction Grades and Grades for disaster trend area	02
T-17	Line Clearances	02
T-18	Poles and Cross-arms and their load bearing capacity	02
T-19	Conductor Characteristics & Thermal Conductivity	02
T-20	Anchor and Guys and their mechanical load	02
T-21	Renovation & up-gradation of taken over & existing overloaded line from others organization.	03
T-22	Awareness and Requirement of ISO 9001 : 2015	01
T-23	Disaster management	02
T-24	Safety of electrical system and dress code of line crew	01
T-25	Ethics & National Integrity	02
T-26	Course Review & Post Evaluation	01
T-27	Examination	01
T-28	Closing Session (Question & Answer Review and Closing Speech)	01
Total =		60

Note : One Period = One Class hour = 40 Minutes

8. Training Methodology :

(a) Class room lecture (b) Group Discussion (c) Exercise & Presentation (d) Demonstration

9. Evaluation System : (a) Pre Test (b) Post Test (c) Mid Term Evaluation (d) Final Evaluation

Distribution Line Staking

- Course Code : TE200
- Course Name : Distribution Line Staking. (Revision : 01)
- Course Type : Technical Engineering(TE)
- Total Period : 35
- Course Objective : Improve Skill for staking of PBS Distribution System.
- Participant : REB DD(Tech)/XEN, REB AE, REB SAE, AGM (COM), AGM(ENGG.), AIE(COM), AIE(Engineering), Consultant Inspector.
- Course Content :

Topic No	Topics	Class Hour
-	Registration and Pre-Evaluation	-
T-01	Inauguration & Importance of the Course	01
T-02	The Purpose of Staking, Uses of Staking Sheets and Introduction to revised Staking Sheet REB Form No. 348R	01
T-03	The Staking Process for New Distribution Line :	02

Source: Training Calendar 2022-2023 Received from BREB

Figure 3-13 Excerpt from BREB's training menu for PBS (on-site work training, power distribution system design, etc.)

(2) DESCO

DESCO is responsible for power distribution business in the northern area of Dhaka metropolitan area.

DESCO has lecture-based facilities such as two lecture rooms (capacity: 40 people) and a computer laboratory (capacity: 20 people), but it does not have simulation equipment for on-the-job training. All trainings are conducted through on-the-job training (OJT). In addition, trainings provided by external organizations such as BPMT, BPDB, Central Procurement Technical Unit (CPTU), and The Institute of Engineers, Bangladesh (IEB) are also utilized. Regarding overseas training, in addition to training at the time of material procurement and acceptance, DESCO has signed MoUs with two organizations, AIT and Putra Business School-University of Putra Malaysia (PBS-UPM) and are participating in training programs.

Table 3-17 and Table 3-18 show the training results by type of training and theme of training in the fiscal year 2021-2022, respectively.

Table 3-17 DESCO's training results (Fiscal year 2021-2022, by type of training)

Type of Training	Number of Training	Number of Trainees	Man-Hour	Percentage of Man-Hour
In-house	190	9,240	66,827	59.34%
Outsource	162	1,238	33,351	29.62%
Foreign Training	11	54	6,640	5.90%
On the Job Training	57	772	5,790	5.14%
Total	420	11,304	112,608	100%

Source: "Training Calendar 2022-2023" received from DESCO

Table 3-18 DESCO's training results (Fiscal year 2021-2022, by theme of training)

Theme of Training	Number of Training	Number of Trainees	Man-Hour	Percentage of Man-Hour
Management	81	3,536	25,703.4	22.83%
Technical	240	5,426	63,339.95	56.25%
Accounts, Finance & Audit	31	1,135	10,900	9.68%
ICT	68	1,207	12,664.45	11.25%
Total	420	11,304	112,607.8	100%

Source: "Training Calendar 2022-2023" received from DESCO

As an example of the training plan for fiscal year 2022-2023, Table 3-19 and Table 3-20 show in-house training and on-the-Job-Training (OJT) scheduled to be implemented in July 2022, respectively.

Table 3-19 Excerpt from DESCO's monthly training plan (in-house training, July 2022)

S.N.	Subject of Training	No. of Participants	Course Schedule		Day
			From	To	
1	Financial Management & Related Policies of DESCO	30	3-Jul-22	5-Jul-22	3
2	Customer Relationship Management (CRM)	35	3-Jul-22	3-Jul-22	1
	Various types of Transformers, their Functions. Maintenance & Repair				
3	Legal Issues Relating to Electricity	35	4-Jul-22	4-Jul-22	1
	Electricity Act - 2018				
4	Procurement Guidelines of DESCO	30	5-Jul-22	5-Jul-22	1
5	Manners & Etiquette	25	6-Jul-22	6-Jul-22	1
	Vehicle & Fuel related policies of DESCO				
6	Cable Joint Process	35	6-Jul-22	6-Jul-22	1
	Cable Fault Detection				
7	Best Practice in Electrical Distribution System	30	7-Jul-22	13-Jul-22	3
8	Electrical Distribution System Operation	35	7-Jul-22	7-Jul-22	1
	Electrical Distribution System Maintenance				
9	Service Rules & Administrative Policies of DESCO		12-Jul-22	14-Jul-22	3
10	Basics of Substation Automation System	35	14-Jul-22	18-Jul-22	3
11	Essential Computer Applications	18	17-Jul-22	17-Jul-22	1

12	Good Governance	35	18-Jul-22	18-Jul-22	1
	Right to Information				
13	Smart Prepayment Meter & GIS Mapping	30	19-Jul-22	19-Jul-22	1
14	Annual Performance Agreement (APA)	30	19-Jul-22	19-Jul-22	1
15	Rooftop Solar & Net Metering Implementation	35	20-Jul-22	20-Jul-22	1
16	Sustainable Procurement	30	20-Jul-22	24-Jul-22	3
17	KPI Security	35	21-Jul-22	21-Jul-22	1
18	Inventory Management	30	24-Jul-22	24-Jul-22	1
	Preparation of DPP				
19	Grievance Redress System (苦情補償システム)	30	25-Jul-22	25-Jul-22	1
	Recruitment, Promotion, ACR Policy				
20	E-Filing	30	25-Jul-22	25-Jul-22	1
21	Citizen Character of DESCO	30	26-Jul-22	26-Jul-22	1
	National Integrity Strategy				
22	E-Governance Software of DESCO	25	26-Jul-22	26-Jul-22	1
23	System & Commercial Activities of DESCO	30	27-Jul-22	31-Jul-22	3
24	Special Training (on demand)	(Any)	3 days		

Source: “Annual Training Program July 2022- June 2023” received from DESCO

Table 3-20 Excerpt from DESCO's monthly training plan (OJT, July 2022)

S.N.	Tentative Date	Topic	Division / Department
1	3 rd July	Inspection of Rooftop Solar System	Aragon and Dakhin Khan
	13 th July	Operation, Maintenance, Troubleshooting of Prepaid Meter	
2	5 th July	Power Transformer Maintenance and Troubleshooting	Tongi (Central) and Turag
	17 th July	CCNA & Linux Server Administration	
3	12 th July	Customer Service Excellence	Monipur and Uttarkhan
	19 th July	Corruption Perception and It's Social Impacts	
4	14 th July	Underground Cable Installation (Cable Specification, cable laying, Jointing & AIS-GIS Termination) and type of cable fault	Office of CE (D&P)
	21 st July	Introduction to various project monitoring and evaluation software (PMIS, FAMS, IBUS++, AMS, Power projected)	
5	13 th July	Conflict Management	Shahali and Tongi west
	24 th July	Commercial Activities of S&D	
6	17 th July	Effective Feedback	Shan Kanir and Bashundhara
	25 th July	Personal/ Professional Development	
7	18 th July	System Activities of S&D	Rupnagar and Badda
	27 th July	Compliance and Reporting Issues	
8	21 st July	Employee Relations	Gulshan and Baridhara
	28 th July	Employee Engagement as a Team Work	
9	19 th July	Strengthening Stakeholder Engagement	Khilkhet and Ibrahimpur
	31 st July	Mobile/ Web Apps/ Mobile Financial System (MFS)	
10	On the Job Training Program will be held at the time of annual maintenance of substation and equipment		
11	On the Job Training at Head Quarter's Division / Department will be held based on demand from the concerned Division/ Department.		

Source: “Annual Training Program July 2022- June 2023” received from DESCO

(3) DPDC

DPDC is responsible for power distribution business in the southern area of Dhaka metropolitan area.

DPDC has a training center with a dedicated building, and the structure is as shown below. In addition, DPDC has a training facility with simulated equipment that allows practical training.

<Training Building>

6th Floor: T&D Office
 5th Floor: 50 seated & 30 seated Training Rooms
 20 seated Computer Training Lab.
 4th Floor: 120 seated Conference Room, Guest Room
 3rd Floor: Library, Achieve Room, Office Room
 2nd Floor: Prayer Room, Canteen
 1st Floor: Meter Testing Lab & Lab Office Room
 Gnd Floor: Garage & Substation

<GIS Building>

Computer Training Lab.
 Office Room
 Guest Room
 Visitor Waiting Room



(Left: Training room; Center: Computer Training Lab; Right: Canteen)

(Source: JICA Survey Team, photographed on February 14, 2023)

Figure 3-14 Facilities in DPDC training center

The training center has a total of twenty staff, including Superintending Engineers and others.
 (See Table 3-21)

Table 3-21 Breakdown of DPDC training center staff

S.N.	Post Name	Total Existing Employee	Employees as Per Setup	Shortage/ Surplus of Employee
1	Superintending Engineer	1	1	0
2	Executive Engineer	1	1	0
3	Manager (HR)	1	1	0
4	Sub-Divisional Engineer	1	0	-1
5	Deputy Manager (HR)	0	1	+1
6	Assistant Engineer	1	1	0
7	Assistant Manager (HR)	1	0	-1
8	Assistant Manager (Finance)	1	1	0
9	Assistant Manager (ICT)	0	1	+1
10	Sub-Assistant Engineer	0	3	+3
11	Junior Assistant Manager (HR)	1	0	-1

12	Junior Assistant Manager (ICT)	0	0	0
13	Accountant/JAM (Finance)	1	1	0
14	Assistant Accountant	0	0	0
15	Office Supervisor	1	0	-1
16	Office Assistant Cum Computer Operator	2	1	-1
17	Senior Accounts Assistant (SAA)	1	0	-1
18	Lineman	0	1	-1
19	Driver	4	1+2*	-1
20	Office Support Staff	2	1+1*	0
21	Sweeper/Cleaner	1	0+2*	+1
Total		20	15+5*	0

*No. of outsourced employee

Source: "Training Calendar 2022-23" received from DPDC

The activity content of DPDC training center is as follows.

- (1) Conducting in-house training for DPDC Employees
- (2) Facilitating On-the-Job-Training in various officers
- (3) Sending Trainees (DPDC Employees) to other Training Organizations
- (4) Facilitating Foreign Trainings
- (5) Facilitating attendance to various seminars, conventions, etc.
- (6) Arranging Training for intern students from various Institutes/ Universities
- (7) Arranging Training for unemployed persons as per the direction of Government of Bangladesh
- (8) Arranging Training Facilities for other organizations on rent basis

Regarding the training results for the fiscal year 2021-2022, the number of hours achieved was 195,526 hours, and the achievement rate was 111.82% whereas the total target number of hours was 174,850 hours, which is calculated from: the target number of hours per person was 50 hours/person/year and the number of employees was 3,497.

The breakdown of the 195,526 hours is as follows. The ratio of in-house training (In-house Training and On-the-Job-Training) is over 90%, indicating that the dependence on BPMI is low.

✓ In-house Training:	37,374 hours	(19.10%)
✓ On-the-Job-Training:	140,603 hours	(71.90%)
✓ Training at other organizations, e.g. BPMI:	14,636 hours	(7.48%)
✓ Foreign Training:	1,020 hours	(0.52%)
✓ Workshop, Seminar, etc.:	1,893 hours	(0.96%)

Table 3-22 DPDC's training plan for the fiscal year 2022-2023

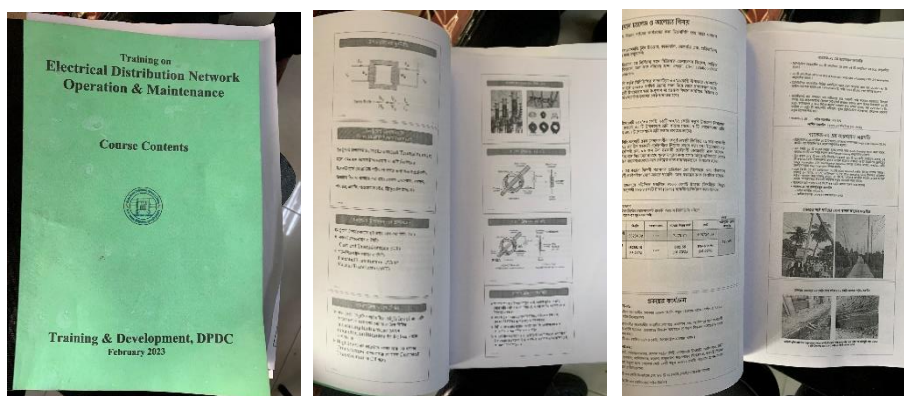
S.N.	Topics	No. of Batches	No. of Participants per Batches	Total Participants	No. of Working days	Hours per day	Total Man-Hours	Probable Time
1	AMI and Prepaid Metering System	1	40	40	5	8	1,600	Jul-22
2	Electrical Distribution Operation & Maintenance	2	40	80	5	8	3,200	
3	Training on Annual Performance Agreement (APA) and National Integrity Strategy	1	80	80	1	8	640	
4	Training on implementation of National Integrity Strategy (NIS) Action Plan	1	60	60	1	4	240	
5	Training on implementation of e-governance and innovation action plans	1	60	60	1	4	240	
6	13 th Foundation Training Course	1	40	40	20	8	6,400	Aug-22
7	AMI and Prepaid Metering System	1	40	40	5	8	1,600	
8	Geographical Information System (GIS)	1	40	40	5	8	1,600	
9	Electrical Distribution Network Operation & Maintenance	2	40	80	5	8	3,200	
10	Operation & Maintenance of Sub-station Equipment	2	40	80	5	8	3,200	
11	Training on Annual Performance Agreement (APA) and National Integrity Strategy	1	80	80	1	8	640	
12	Grievance Redressal Mechanism and Training on GIS Software	1	60	60	1	4	240	
13	Training on Right to Information	1	60	60	1	4	240	Sep-22
14	14 th Foundation Training Course	1	40	40	20	8	6,400	
15	Renewable Energy and Energy Efficiency	5	40	200	3	8	4,800	
16	Office Management	1	40	40	5	8	1,600	
17	Electrical Distribution Network Operation & Maintenance	2	40	80	5	8	3,200	
18	Operation & Maintenance of Sub-station Equipment	1	40	80	5	8	1,600	
19	Training on Annual Performance Agreement (APA) and National Integrity Strategy	2	40	80	1	8	640	
20	Training on implementation of National Integrity Strategy (NIS) Action Plan	1	60	60	1	4	240	
21	Training on implementation of e-governance and innovation action plans	1	60	60	1	4	240	Oct-22
22	14 th Foundation Training Course (Contd.)	1	40	40	10	8	3,200	
23	Renewable Energy and Energy Efficiency	5	40	200	3	8	4,800	

S.N.	Topics	No. of Batches	No. of Participants per Batches	Total Participants	No. of Working days	Hours per day	Total Man-Hours	Probable Time
24	Electrical Distribution Network Operation & Maintenance	2	40	80	5	8	3,200	
25	Operation & Maintenance of Sub-station Equipment	1	40	40	5	8	1,600	
26	Training on Annual Performance Agreement (APA) and National Integrity Strategy	2	40	80	1	8	640	
27	Training on implementation of National Integrity Strategy (NIS) Action Plan	1	60	60	1	4	240	
28	Training on implementation of e-governance and innovation action plans	1	60	60	1	4	240	
29	15 th Foundation Training Course	1	40	40	20	8	6,400	Nov-22
30	An Improvement of Soft Skill & Hard Skill for Customer Service Operation	2	40	80	5	8	3,200	
31	Electrical Distribution Network Operation & Maintenance	2	40	80	5	8	3,200	
32	Operation & Maintenance of Sub-station Equipment	1	40	40	5	8	1,600	
33	Training on Annual Performance Agreement (APA) and National Integrity Strategy	2	40	80	1	8	640	
34	Grievance Redressal Mechanism and Training on GIS Software	1	60	60	1	4	240	
35	Training on Right to Information	1	60	60	1	4	240	
36	15 th Foundation Training Course (Contd.)	1	40	40	20	8	6,400	Dec-22
37	An Improvement of Soft Skill & Hard Skill for Customer Service Operation	2	40	80	5	8	3,200	
38	Electrical Distribution Network Operation & Maintenance	3	40	120	5	8	4,800	
39	Training on Annual Performance Agreement (APA) and National Integrity Strategy	2	40	80	1	8	640	
40	Service Commitment Training	1	60	60	1	4	240	
41	Workshop on Actions to meet the Challenges of the 4 th Industrial Revolution	1	60	60	1	4	240	
42	16 th Foundation Training Course	1	40	40	20	8	6,400	Jan-23
43	Electrical Distribution Network Operation & Maintenance	2	40	80	5	8	3,200	
44	eGP & Public Procurement Act & Rules	3	40	120	5	8	4,800	
45	Planning to Reduce Power Interruption	5	40	200	3	8	4,800	

S.N.	Topics	No. of Batches	No. of Participants per Batches	Total Participants	No. of Working days	Hours per day	Total Man-Hours	Probabl e Time
46	Training on Annual Performance Agreement (APA) and National Integrity Strategy	2	40	80	1	8	640	
47	Training on implementation of National Integrity Strategy (NIS) Action Plan	1	60	60	1	4	240	
48	Training on implementation of e-governance and innovation action plans	1	60	60	1	4	240	
49	16 th Foundation Training Course (Contd.)	1	40	40	20	8	6,400	Feb-23
50	Electrical Distribution Network Operation & Maintenance	2	40	80	5	8	3,200	
51	eGP & Public Procurement Act & Rules	3	40	120	5	8	4,800	
52	Crisis & Disaster Management Plan for DPDC	5	40	200	3	8	4,800	
53	Planning to Reduce Power Interruption	5	40	200	3	8	4,800	
54	Grievance Redressal Mechanism and Training on GIS Software	1	60	60	1	4	240	
55	Training on Right to Information	1	60	60	1	4	240	
56	NOCS Operation and Management	3	40	120	5	8	4,800	Mar-23
57	Financial Management and Accounting Information System and Financial Discipline	5	40	200	3	8	4,800	
58	eGP & Public Procurement Act & Rules	3	40	120	5	8	4,800	
59	Crisis & Disaster Management Plan for DPDC	5	40	200	3	8	4,800	
60	Crisis & Disaster Management Plan for DPDC	5	40	200	3	8	4,800	
61	Service Commitment Training	1	40	40	1	8	320	
62	Workshop on Actions to meet the Challenges of the 4 th Industrial Revolution1	1	60	60	1	4	240	Apr-23
63	NOCS Operation and Management	3	40	120	5	8	4,800	
64	Financial Management and Accounting Information System and Financial Discipline	5	40	200	3	8	4,800	
65	Motor Vehicle Driving	3	40	120	5	8	4,800	
66	Planning to Reduce Power Interruption	5	40	200	3	8	4,800	
67	Training on implementation of National Integrity Strategy (NIS) Action Plan	1	60	60	1	4	240	
68	Training on implementation of e-governance and innovation action plans	1	60	60	1	4	240	
69	Motor Vehicle Driving	3	40	120	5	8	4,800	

S.N.	Topics	No. of Batches	No. of Participants per Batches	Total Participants	No. of Working days	Hours per day	Total Man-Hours	Probable Time
70	Grievance Redressal Mechanism and Training on GIS Software	1	60	60	1	4	240	May-23
71	Training on Right to Information	1	60	60	1	4	240	
72	Motor Vehicle Driving	3	40	120	5	8	4,800	Jun-23
73	Service Commitment Training	1	60	60	1	4	240	
74	Workshop on Actions to meet the Challenges of the 4 th Industrial Revolution	1	60	60	1	4	240	
Total In-house Man-Hour = 181,520								
Total Employees = 3,454								

Source: "Training Calendar 2022-23" received from DPDC



Source: JICA Survey Team, photographed on February 14, 2023

Figure 3-15 Example of lecture textbook used in DPDC in-house training

DPDC is conducting training related to protection and control in its protection relay work room (testing equipment, Ry unit, etc.) inside Ullon 132/33/11kV Substation (132kV is under the jurisdiction of PGCB and DPDC is under the jurisdiction of 33/11kV and below) located in the center of Dhaka city.

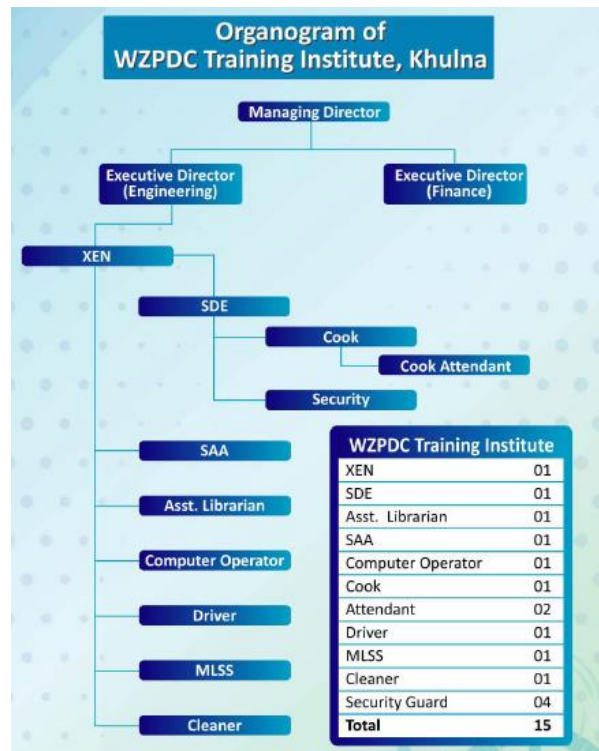


Source: JICA Survey Team, photographed on May 11, 2023

Figure 3-16 DPDC's relay work room (testing equipment, Ry unit, etc.) inside Ullon 132/33/11kV Substation

(4) WZPDCL

WZPDCL is responsible for power distribution business in Khulna Division, Barishal Division, and parts of Dhaka Division (Faridpur District, etc.), and is headquartered in Khulna, the third largest city in Bangladesh. WZPDCL has its own Training Institute in Khulna and conducts training through the organization shown in Figure 3-17.



Source: WZPDCL Training Calendar 2022-2023

Figure 3-17 Organization of WZPDCL Training Institute

WZPDCL Training Institute has the following facilities of training.

- 2(Two) class rooms, 01(One) Laboratory room, 01(One) Computer Training Room
- 1(One) Conference Room
- 1(One) Model Sub-station with classroom & Recreation Facilities
- Audio Visual projection system: Overhead Projector, Multimedia Projector
- Course Material (Soft Copy or Hard Copy)
- Library with different reference books and Booklet
- Dormitory having 8(Eight) single rooms, 4(Four) double rooms and 4(Four) general hostel rooms having accommodation facility of 32 trainees at a time
- 1(One) Dining room
- Common room having indoor games facility (Chess, Playing Card, Lubo, Table Tennis, Carom)
- Outdoor Game: Having Playground with Gallery (Lawn Tennis, Badminton, Volley ball)
- 1(One) GYM Room with 02 Treadmill, 2 exercise cycle, Dumb bell, Power Twister, Hand Gripper, Weight Machine
- Newspaper, Magazine (Energy & Power)
- Wonderful Garden with seating arrangement
- Television with Akash DTH
- 1(One) Male Praying Hall & 1(One) Female Praying Hall
- Unlimited Internet Facility through Wi-Fi Router

Shows the training course of WZPDCL.

Table 3-23 Training course of WZPDCL

Category	Name of Training Course
Computer Course	✓ Basic Idea on Computer Hardware, Trouble Shooting & Maintenance. MS Word, Excel, Power Point, Internet & E-mail ✓ Auto CAD ✓ Online MOD, E-Filing, New-Connection & Customer Service Excellence ✓ Electronic Government Procurement (e-GP)
Corporate & Finance Management	✓ Account & Financial Management, Delegation of Finance Power, Auditing Settlement of Audit Objection, Basic Idea on TAX, CD-Vat, VAT and Financial Matter ✓ Human Resource Development, Human Relation, Company Service Rules, Etiquette & Manner ✓ Human Relation, Motivation, Manner, Ethics & Etiquette ✓ Office Administration, Record Keeping & Personnel Management
Enhancement of Technical Expertise	✓ Operation & Maintenance of Substation, Substation Equipment, Power & Distribution Transformer ✓ Testing, Commissioning, Maintenance & Troubleshooting of Substation ✓ Energy Meter Installation, Connection, Testing & Loss Reduction Techniques & Electricity Act-2018 ✓ Energy Meter Installation, Connection, Testing (HT, LTI, LT, 33kV Import Meter & 11kV Feeder Meter), Data Downloading Procedure, Data Analysis and Net Metering ✓ Distribution Line, Power & Distribution Transformer, Energy Meter & Customer Service Excellence ✓ Power Distribution System Protection & Switchgear ✓ Smart Grid, Smart Prepayment Meter & GIS Mapping

Category	Name of Training Course
General (Miscellaneous)	✓ Occupational Health, Safety Environment, First Aid & Disaster management ✓ Security Training Course ✓ Orientation / Introduction Course

Source: WZPDCL's answers to the Questionnaire

In 2022-2023, 76 lecturers and instructors for these courses were / will be invited from within WZPDCL and 15 were / will be invited from outside. The total training budget of WZPDCL is 5,000,000 BDT.

3.5 Status of technical cooperation and human resource development support in the power sector by other donors

During the 1st survey in Bangladesh in February 2023, the JICA survey team confirmed the status of support for human resource development in the power sector through questionnaires and interviews with the World Bank (WB) and Asian Development Bank (ADB).

3.5.1 World Bank (WB)

WB does not implement projects with the theme of human resource development itself, but each WB project has components and sub-components for the purpose of TA (Technical Assistance), and in addition to financial support, it also provides support as training for BPDB, BREB, etc., PGCB, SREDA, Power Division, and other implementing agencies. In addition, to promote renewable energy, IDCOL¹¹ and SREDA widely provide training to stakeholders, private businesses, policy makers, etc. Trainings were also conducted for BPDB on gas turbine and steam turbine O&M, project management, environmental compliance requirements, human resources management, accounting and financial management, etc. As shown in Table 3-24, Component or Sub-component related to TA are separately set and the budget is managed separately to ensure that TA training is conducted reliably.

Table 3-24 Components related to TA of the upcoming WB projects

Project Name	Implementing Agency	Period	Total project budget (*) (WB contribution amount of the total)	Component related to TA	
				Component (Name, contents)	Budget (*)
Bangladesh Scaling-up Renewable Energy Project	IDCOL, SREDA, EGCB	Mar 2019 to Jul 2025	413.72 (156.00)	Component 3: Technical Assistance a) Resource Assessment b) Site identification and development c) Rooftop enabling environment d) Capacity building and training e) Waste-to-energy technology pilot	3.64

¹¹ Infrastructure Development Company Limited, government-affiliated financing institution that provides financing for renewable energy projects

Project Name	Implementing Agency	Period	Total project budget (*) (WB contribution amount of the total)	Component related to TA	
				Component (Name, contents)	Budget (*)
				f) Project management	
Electricity Distribution Modernization Program	BREB, MPEMR	Dec 2021 to Dec 2026	3,213.00 (500.00)	Result Area: Strengthened institutional and regulatory capacity a) Sector institutional and regulatory capacity and gender consideration b) Annual institutional strengthening and gender activities of BREB c) Annual institutional strengthening and technical assistance activities of Power Cell	70
Enhancement and Strengthening of Power Transmission Network in Eastern Region	PGCB	Mar 2018 to Dec 2013	718.06 (450.64)	Component 2: Institutional Development and Implementation Support	28

(*) million USD

Source: World Bank's disclosed materials

WB does not provide any support to BPMI and has no support plans. Considering the importance of human resource development, BPMI has asked WB to invite highly reputed lecturers to Bangladesh, but since WB provides loans and financial support principally, this has not been realized as it would be difficult for WB.

3.5.2 Asian Development Bank (ADB)

Like WB, ADB does not provide financial support to training institutions such as BPMI, but each ADB project includes training as an activity item. ADB has been implementing the Bangladesh Power System Enhancement and Efficiency Improvement Project since 2016 and is continuing it. In this project, the following initiatives are being implemented for the implementing agencies PGCB, DESCO, BREB, and Power Division.

Table 3-25 Excerpt from the implementation items on ADB "Bangladesh Power System Enhancement and Efficiency Improvement Project"

S.N.	Implementation Items	Implementing Agency	Excerpt from TOR related to TA (Technical Assistance)
1	DESCO SCADA Project	DESCO	f. Technology transfer and Training. (i) Ensure effective technology transfer in all areas through appropriate training and working in close coordination with the assigned DESCO staff.

S.N.	Implementation Items	Implementing Agency	Excerpt from TOR related to TA (Technical Assistance)
2	BREB Project Implementation Monitoring Consultants	BREB	b. Capacity building (i) Capacity building of BREB and PBS staff Identify to undertake in-house network planning, design and project formulation; (ii) The consultant will focus on developing this capacity at two selected PBSs, prepare a staff development plan including additional staff required, if any; (iii) Identify equipment and software requirement, and arrange for procurement in consultation with BREB; (iv) Provide training to undertake the tasks identified; (v) Assist and guide staff of the two selected PBSs to prepare a five-year plan for system development, and to establish systems to conduct updates of the plan every year. Prepare two such 5-year plans along with PBS staff for 2017–2021 and update the pan for 2018–2022
3	Translating Improvement in Electricity Supply to Better Livelihood in Rural Bangladesh	BREB	150. (iii) Capacity building program developed and implemented based on identified business development activities training of trainers developing and implementing user awareness programs; (iv) Provide skills and technical training as well as provide entrepreneurial support to above mentioned businesses through creating linkages with stakeholders such as the Bangladesh Small and Cottage Industries Corporation and Bangladesh Women Chambers of Commerce and Industry. Areas for training will include but not be limited to financial services, such as micro-credit; business development services, including skills training, and market linkages and access; (v) Provide technical and skills training to 200 people identified through a survey (conducted by the NGO with support from the PBS) on employment opportunities and energy based livelihoods and safe, efficient and environmentally friendly usage of energy;
4	Capacity Building Component	Generating Companies	165. The technical assistance will provide consultancy support to (i) conduct feasibility studies for at least two wind parks and two solar parks; and (ii) develop a template for Power Purchase Agreements (PPAs) between the generating companies and BPDB (the single buyer) for wind and solar power plants, and the concession agreement between a project company and the government.
5	Transmission Planning, Project Preparatory Support for PGCB, and Renewable Integration Studies/Protocol Development	PGCB	196. The technical assistance will provide specific support to PGCB for three activities: (a) review transmission network plans for the period 2016-2025, enhance the plans, and establish a regular 10-year transmission planning activity at PGCB that would satisfy both engineering as well as investment planning requirements for tariff and other regulatory determinations, (b) prepare plans, conceptual designs and feasibility studies for grid substations required to be built in rural and industrial areas to serve the growing demand over the period 2016–2025, and (c) conduct a grid integration study to examine impacts on reliability, stability and economics of developing wind and solar PV power plants, for the period 2016–2030.
5-2	GIS-based management system installed in ten PBSs	PBS	226. The technical assistance project under ADB would have two phases: (I) completion and consolidation of work done so far by BREB with the support of the World Bank and JICA, (II) expansion of the GIS-based information system to at least eight other PBSs.
5-3	Pre-feasibility study on small scale LNG for industries/ electricity production	Power Division and others	247. xi) Organize an inception workshop, mid-term workshop, and a concluding workshop to discuss and disseminate the findings among the Power Division/Power Cell staff, and other stakeholders

S.N.	Implementation Items	Implementing Agency	Excerpt from TOR related to TA (Technical Assistance)
5-4	Implementation of tariff methodology, energy auditing and efficiency improvement procedures for power plants	Power Division, BERC ¹² and others	277. (i) Review the institutional structure of BERC to facilitate the revised and upgraded regular filing of tariffs envisaged under the TA period and beyond, and prepare an institutional structure for BERC to face the challenges of additional and deeper involvement of the regulating sector utilities; (ii) Prepare qualifications and job descriptions and lists of duties of identified staff for BERC tariff regulation division, and assist BERC to recruit and train such staff; (iii) In consultation with the team leader, all members of the TA team, BERC and regulated utilities, prepare a comprehensive plan for capacity building both at BERC and in regulated utilities, prepare time schedules, identify TA team member resource persons and external resources persons, to provide a full range of training, capacity building and exposure visits, by way of consultation sessions, seminars, and hands-on workshops; (iv) Implement the capacity building plan, manage all capacity building work under the TA, and make revisions to the plan as the TA work progresses into the second tariff filing; 他
5-4	Analysis of transmission and distribution losses and establishing regulatory loss targets	BREB / PBS	289. (xv) Propose the institutional structure to achieve the above loss calculation and targeting activity, and provide training and exposure to distribution utilities, BERC, and other relevant staff on the procedure
5-5	Energy efficiency of buildings, establishment of a building energy efficiency rating system	SREDA	301. (xi) Propose the institutional structure to continue to facilitate building energy efficiency improvement and the BEER (Building Energy and Environment Rating), and provide training and exposure to SREDA and other agency staff, on the procedure;

Source: ADB's disclosed material "Project Administration Manual (Bangladesh Power System Enhancement and Efficiency Improvement Project)"

4. Recommendations for the future

4.1 Review and recommendations regarding human resource development and training implementation in general

Chubu Electric Power Group, total energy service corporate group in Japan, formulated "Chubu Electric Power Group Management Vision 2.0"¹³ (hereinafter referred to as "Management Vision 2.0") in November 2021 and also formulated "Chubu Electric Power Group Medium-Term Management Plan"¹⁴ (hereinafter referred to as the "Medium-term Management Plan") in April

¹² Bangladesh Energy Regulatory Commission

¹³

https://www.chuden.co.jp/english/resource/corporate/philosophy/managementvision/m_vision2_01.pdf

¹⁴

2022 in which new medium-term management goals targeting fiscal 2025 has been set and new initiatives for each business area has been summarized and Chubu Electric Power Group is now addressing management issues. “Medium-term Management Plan” also includes plans to strengthen the corporate management foundation in the areas of "technology development/intellectual property," "DX strategy," "human resources plan," and "compliance, safety and health, and coexistence with local communities" and human resource development is a part of this "human resource plan."

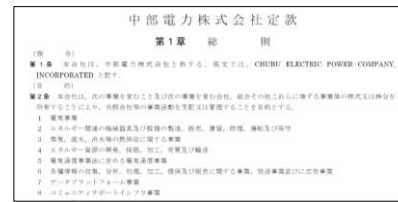
Chubu Electric Power Co., Inc. was split into separate companies in April 2020 due to the separation of power generation and transmission associated with electric power liberalization under Japanese governmental policy, and is facing major changes in the business environment, such as accelerated decarbonization efforts and DX progress. The corporate management plans, etc. have been completely revised and human resources strategies and plans have also been created from scratch, unlike in the past. Additionally, in April 2022, the company established a new Human Resources Strategy Office and is actively investing in human resources, which are the very essence of corporate value. Figure 4-1 shows the flow of the Chubu Electric Power Group's human resource strategy and human resource development policy.

Against this background, in order to develop human resources who understand the Chubu Electric Power Group's mission, management issues, attitude and values and can take action, Chubu Electric Power Group is systematically implementing training curricula that include position/ rank-specific training. Based on the Chubu Electric Power Group's human resource development policy (Figure 4-1), training plans have been formulated with the outline shown in Table 4-1, and training implementation system has been established by position grade or work proficiency level as shown in Figure 4-2 and trainings are being conducted. Chubu Electric Power Group also provides training that matches diverse work styles, including the introduction of online training.

In this way, the Chubu Electric Power Group reviews or renews its “management vision” and “medium-term management plan” whenever the business environment changes, and human resources strategies and human resources development policies are also updated in a timely manner by the Human Resources Strategy Office so that these will correspond to the corporate management policy.

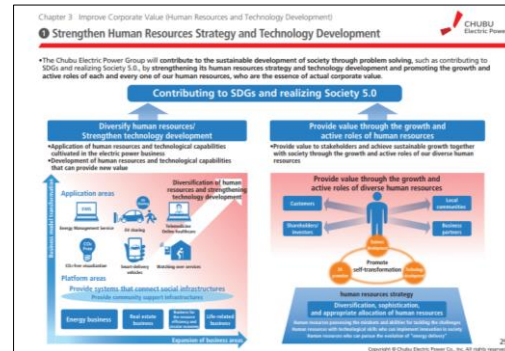
[Company Articles of Incorporation]

General rules (trade name, business purpose, etc.), rules for stocks, general meetings of shareholders, directors, auditors, etc.)



[Clarification of management issues, formulation of management plans]

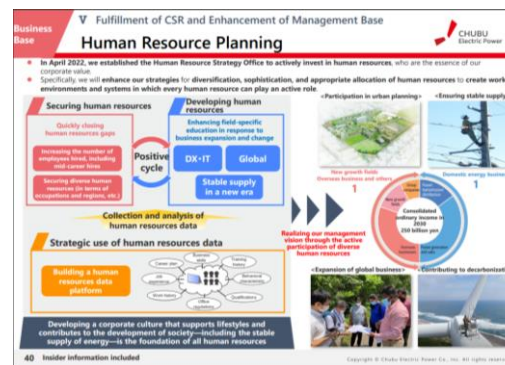
(Need to strengthen corporate business foundation in terms of human resources)



“Management Vision 2.0 ”

(November 2022)

(Strengthen Human Resource Development and Technology Development)



“Medium-Term Management Plan ”

(April 2021)

(Human Resource Planning)

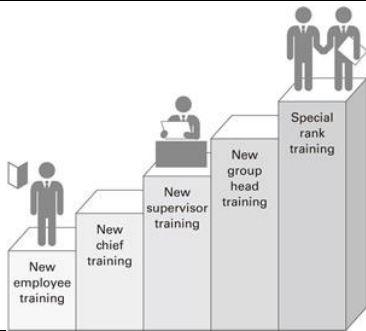
[Human resources development policy]



Source: JICA survey team based on disclosed information of Chubu Electric Power Group

Figure 4-1 Flow of human resource strategy, human resource planning, and human resource development policy (Chubu Electric Power Group)

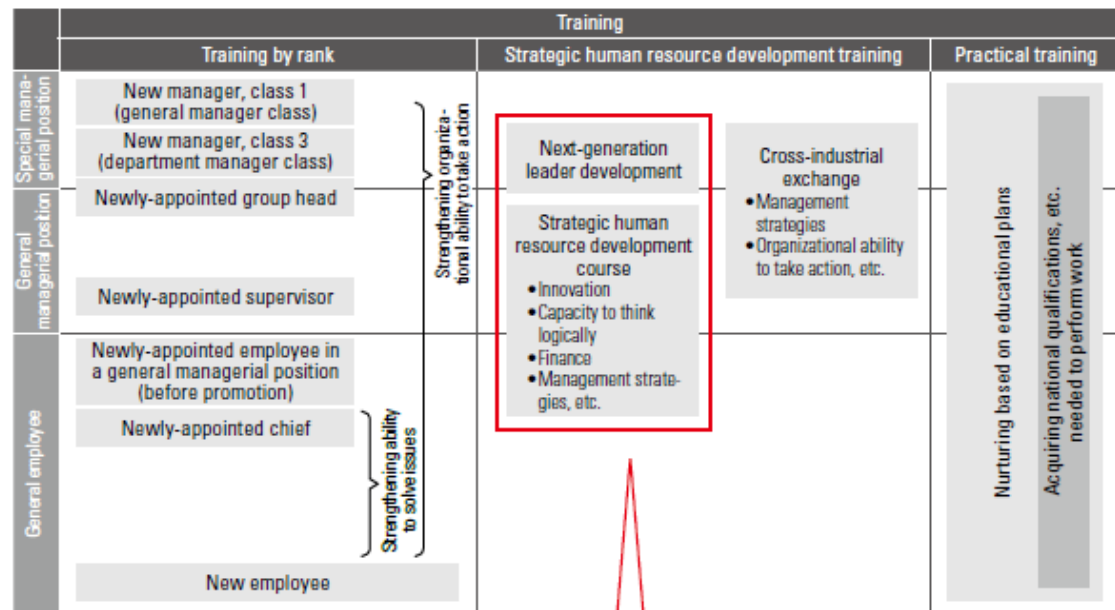
Table 4-1 Outline of Chubu Electric Power Group's training plan

Category	Overview
Training by rank	Training participants are expected to develop an understanding of the roles of ranks and gain knowledge and abilities necessary for these roles.  The diagram shows a staircase with five steps, each representing a different level of training. From left to right, the steps are: 'New employee training' (with a person icon), 'New chief training' (with a person icon), 'New supervisor training' (with a person icon), 'New group head training' (with a person icon), and 'Special rank training' (with two people icons). The steps are ascending from left to right.
Diversity training	As part of our promotion of diversity, we mainly focus on training to promote the development of female employees' careers and male employees' involvement in housework/child-raising. - Seminars for balancing work with childcare and nursing care - Female chief career development training - Self-setup training, and other training  The icon shows five stylized human figures in different colors: green, orange, red, blue, and light blue. They are arranged in a group, with some figures slightly overlapping, representing a diverse group of people.
Strategic human resource development training	To create new value in new business fields, we provide training to develop skills related to strategic planning and finance.
Practical training	We provide technical knowledge and skill training relating to the department's business. We also provide the training enabling participants to learn common skills that increase efficiency and improve the sophistication of operations.
Personal development support	We leverage a range of systems to support personal growth to enable employees to obtain qualifications and skills highly related to their work. - Correspondence courses - Qualification acquisition support system - Domestic study-exchange program - Groups for improving business skills

Source: Chubu Electric Power Co., Inc.'s website in English

<https://www.chuden.co.jp/english/esg/social/diversity/development/>

Training system chart



We provide the following training to nurture future leaders and managers.

- **Next-generation leader development**

We are nurturing next-generation leaders who can foresee the future from a medium- to long-term perspective and create new value even in an era of drastic changes. Among department manager class employees, we select those who will lead the Company's management in the future and provide training to gain needed skills and knowledge, such as organizational theories, tactical thinking and leadership. In FY2021, 10 persons participated in the training.

- **Strategic human resource development course**

We are nurturing human resources capable of creating new value in new business areas. We provide training on needed capabilities and skills, such as those related to management strategies, innovation and analysis of financial data. In FY2021, 203 persons participated in the training.

Source: Chubu Electric Power Group Report 2022 (Integrated Report)

https://www.chuden.co.jp/english/resource/corporate/ecsr_report_2022_all.pdf

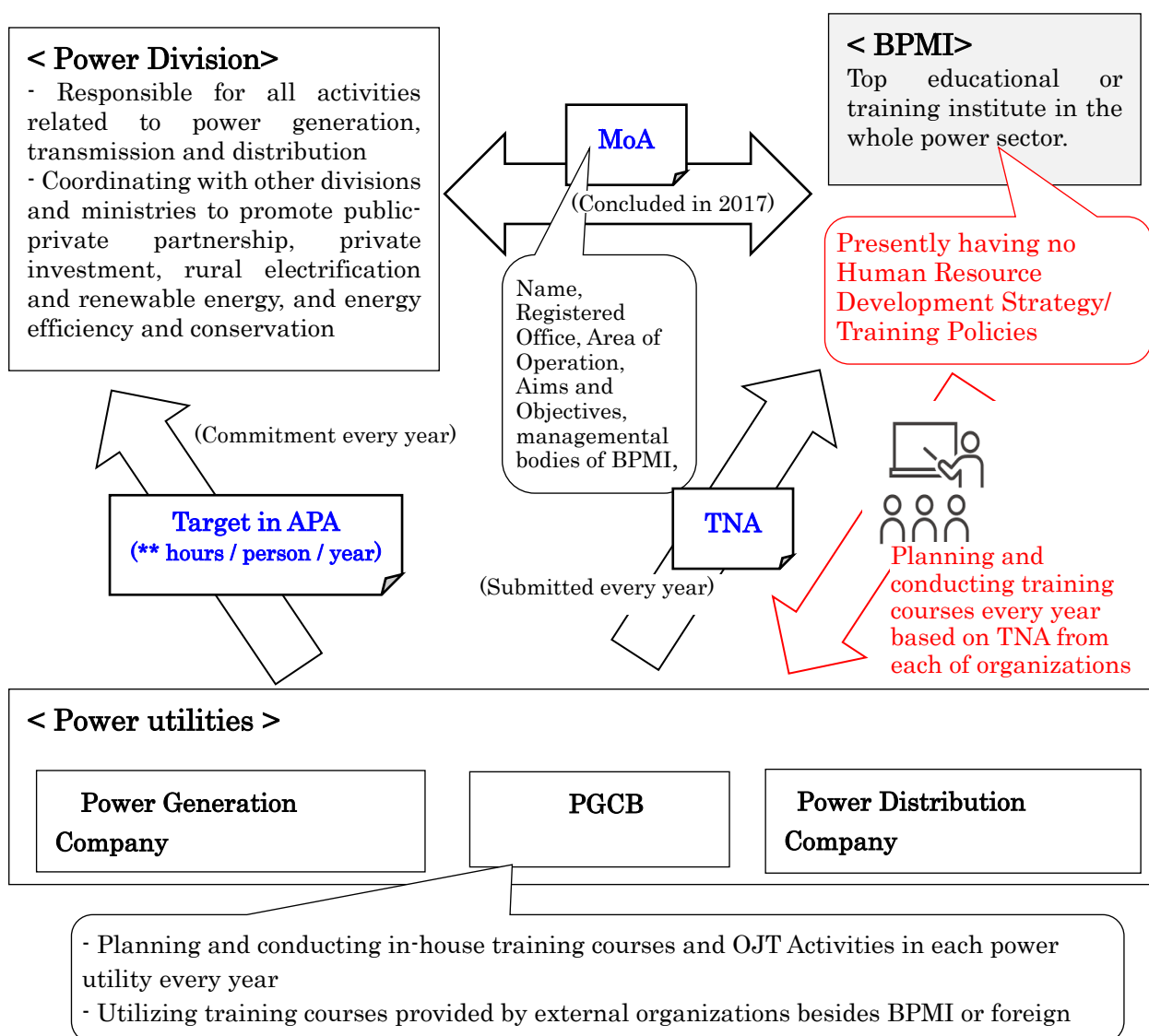
Figure 4-2 Example of Training System Chart (Chubu Electric Power Group)

Considering the current situation in Bangladesh, as described in 0, BPMT and each power utility are sharing the role of training in implementing it. Each of power generation companies, power transmission company and power distribution companies draws up its training plans every year and implements trainings that includes in-house trainings and external trainings. The training menu and content cover all aspects of related technologies. In addition, the technical content of OJT is also substantial, and it can be said that there is a high level of awareness of human resource development initiatives that combine training and OJT.

However, not all power utilities have a general framework for training policies, training strategies, etc., nor do they implement training based on a systematic training framework. In fact, the objective with top priority is to achieve the goal “annual training hours per employee” set by the APA (60 hours/person/year, for example), and the training menu itself and the volume of each

training session, number of hours, number of participants, etc. may not necessarily be optimal.

Although circumstances such as the presence or absence of human resource development policy and/or training implementation policy and the formulation process vary depending on each power utility, the situation described in Chapter 2 and Chapter 3 regarding the entire Bangladesh power sector, including BPMI, can be summarized as shown in Figure 4-3.



Source: Prepared by the JICA survey team based on the result of this survey

Figure 4-3 Current situation of training implementation in the power sector of Bangladesh

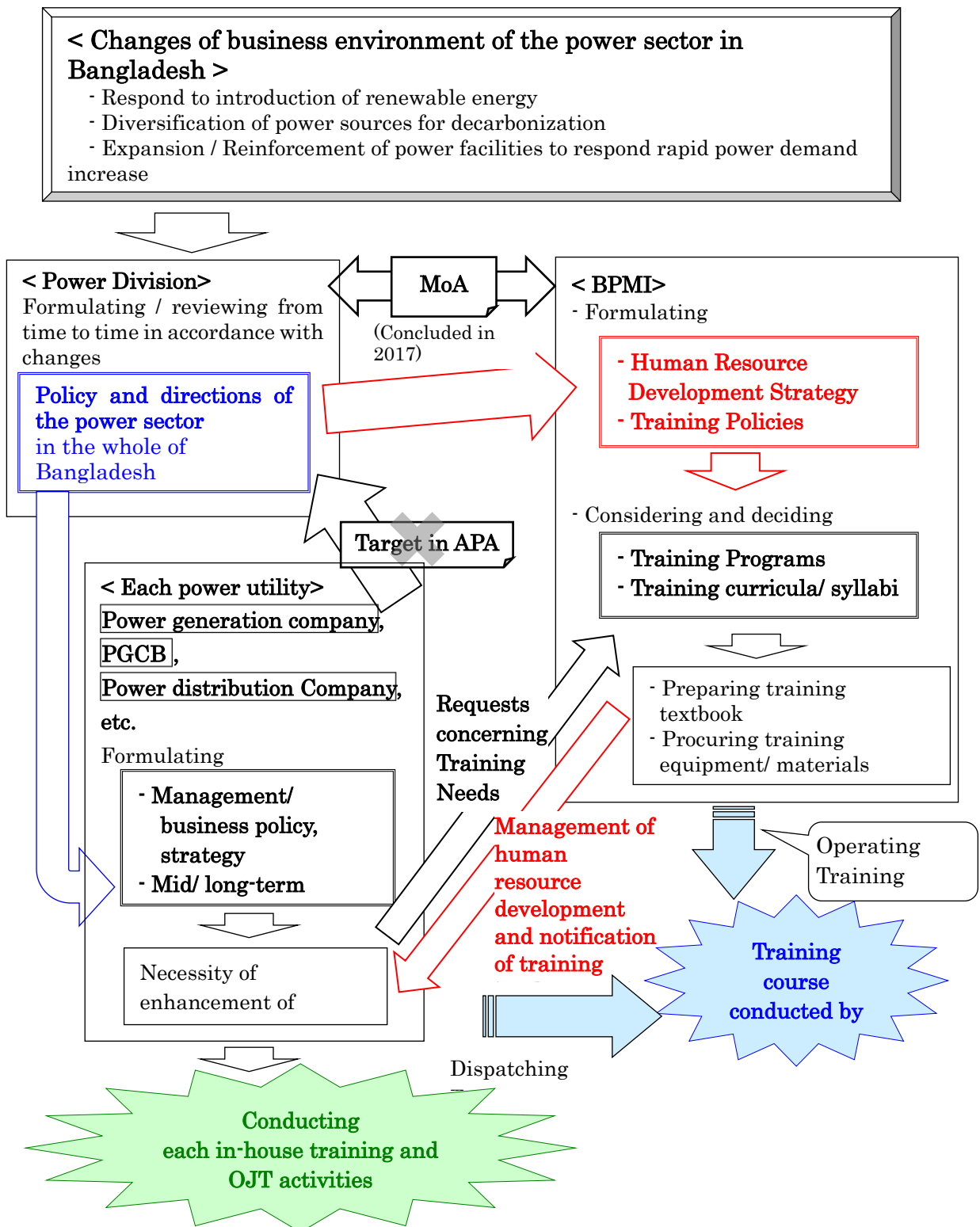
The purpose, organization, activities, members, etc. of BPMI are stipulated in the MoA, that includes provisions equivalent to the company's articles of incorporation. Therefore, BPMI's position as a Top educational and training institute within the power sector has been well established. However, the reality is that BPMI plans and implements training every year based on

TNA from each power utility. In the case of BPMI, as in the example of Chubu Electric Power Group (Figure 4-1), human resources strategies and human resources development policies linked to management vision and management plans have not been formulated, and as a result, training programs based on human resources strategies and development policies are not established.

Chubu Electric Power Group is an electric power company group that engages in power generation, transmission, and distribution, and its human resource development and training department is part of the company, but BPMI is an independent organization responsible for human resource development for the entire power sector in Bangladesh. Therefore, in the case of BPMI, instead of the company's management policy and management plan, human resource development strategies and training policies should be formulated based on the policies and direction of the entire country's power sector drawn up by the Power Division, etc. In addition, the business environment and new technologies surrounding the power sector are constantly changing also in Bangladesh, and the policy and direction of the power sector should be adjusted accordingly. Therefore, it is also necessary to review and optimize human resource development strategies and training policies as appropriate.

In the future, the mechanism for training implementation like the one shown in Figure 4-4 is proposed. APA between each power utility and the Power Division will be abolished, and the volume of training will not be based on the number of training hours, but the necessary training programs will be formulated based on BPMI's human resource development strategy and training policy as well as the training needs of each power utility. Additionally, the authority regarding human resource development and training implementation will be basically held by BPMI, not the Power Division, and BPMI will be in charge of and control human resource development matters over the entire power sector.

One of the main achievements of this MP Project is to develop a system for collecting and managing energy statistical data, and to strengthen the energy data management system to formulate, plan, implement, and monitor policies based on the collected information. Based on this latest information, this MP Project aims to contribute to the construction of a low-carbon energy supply and demand system while ensuring that the entire electricity sector is optimally operated, ensuring a stable supply of energy and economic rationality. The success or failure of human resource development in the power sector will be the key to realizing its effects.



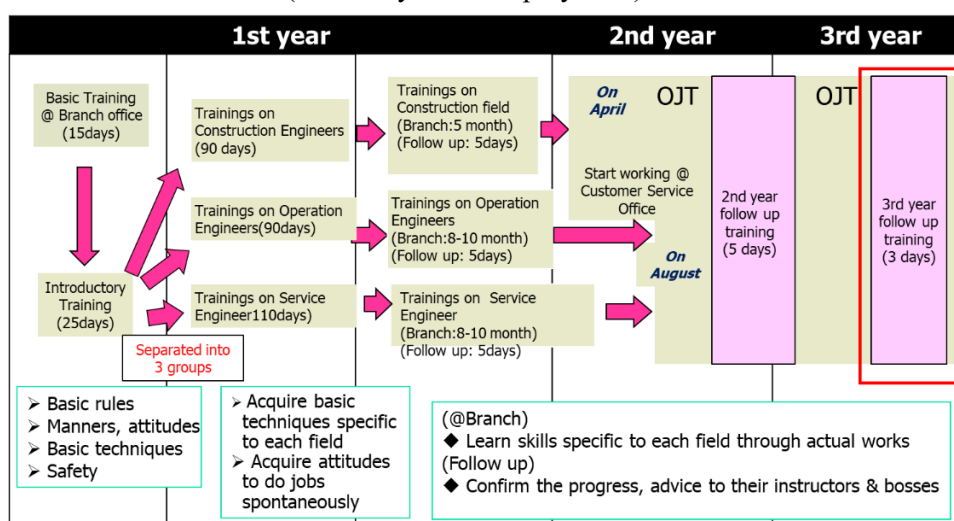
Source: Prepared by the JICA survey team

Figure 4-4 Future vision for training implementation in the power sector of Bangladesh
(Proposal)

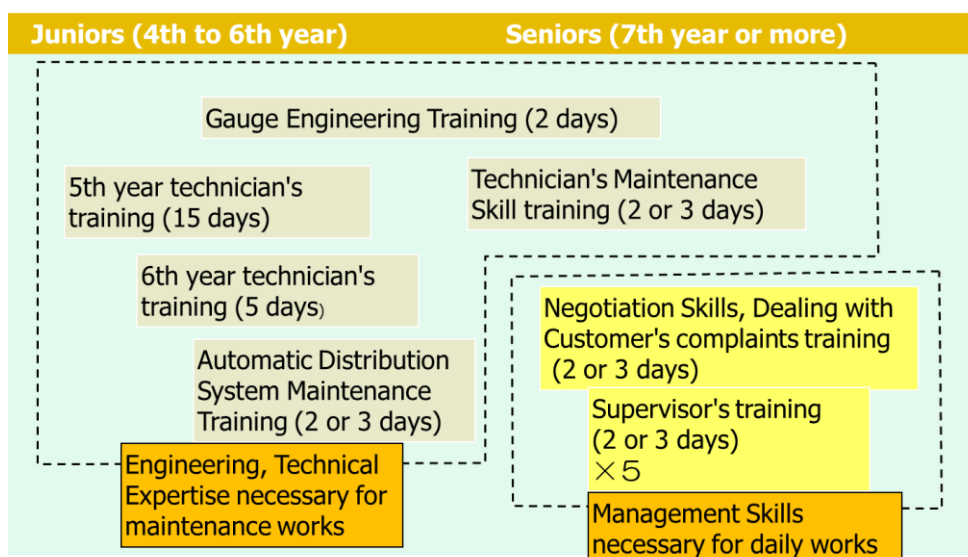
<Training by rank>

Some power utilities' training calendars clearly state how many position-level trainees are expected for each training program (PGCB's example: Table 3-16). However, it is desirable to have a training system organized by rank (by position or level of proficiency in work). This will allow each employee to receive the necessary training in the required year and will ensure that the capabilities of human resources at each organization are improved. As an example, Figure 4-5 shows the training required by the number of years since joining the company at the Chubu Electric Power Group's power distribution division.

<Intensive Educational Period (1st to 3rd year of employment)>



<After Intensive Educational Period >

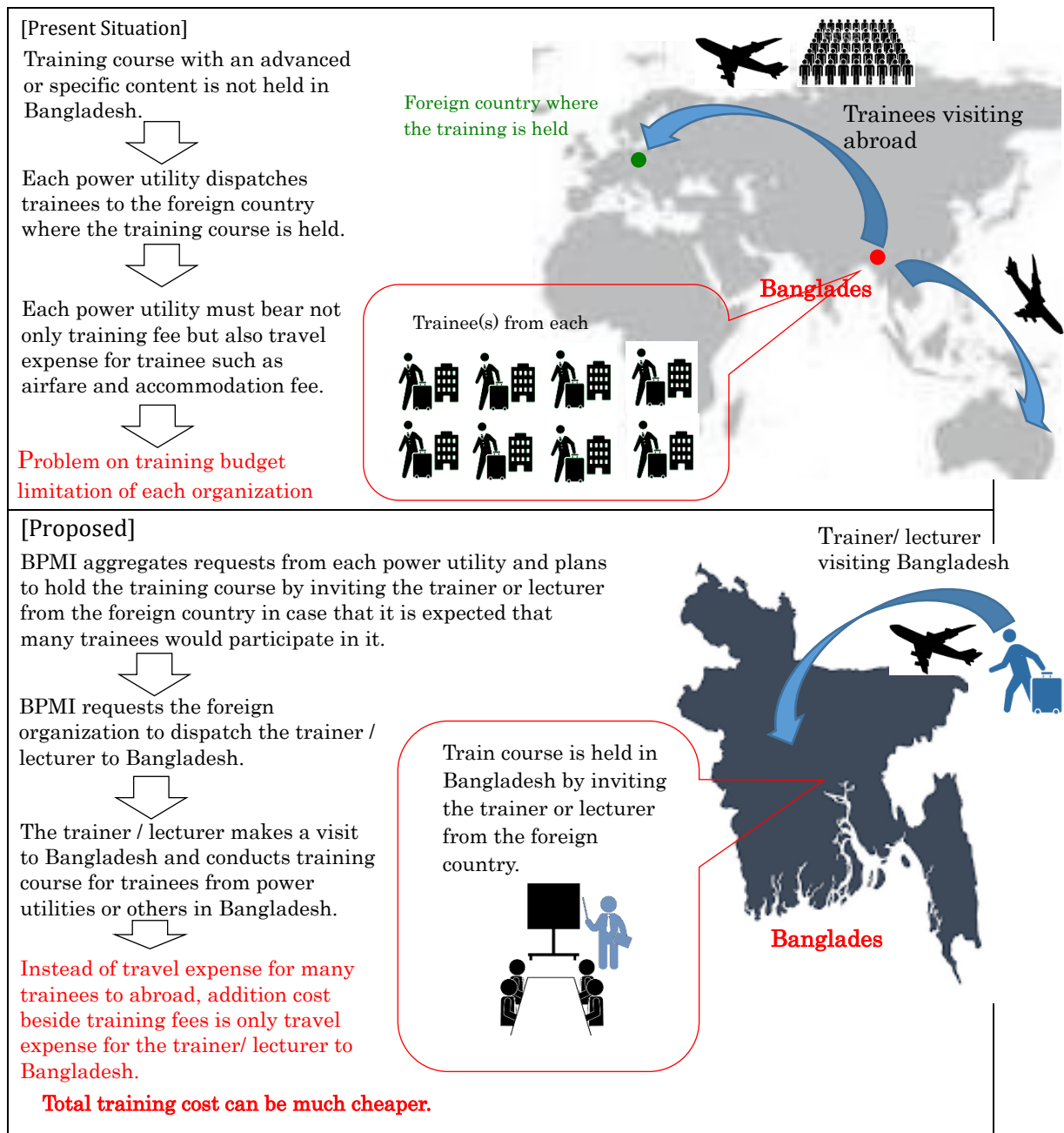


Source: Chubu Electric Power Group

Figure 4-5 Example of Training system by number of years since joining the company (reference, Power Distribution Division)

<Training using foreign resources>

For advanced and specific content, training must be conducted overseas, and in addition to the participation fee, travel expenses are borne by each power utility as training expenses, making up a significant portion of the training budget. (See footprint 2). Although it is meaningful to travel abroad to receive training, the current situation is that it is extremely costly. Since BPMI assumes the role of a national organization that coordinates training for the entire power sector in Bangladesh, efforts such as holding training sessions inside Bangladesh will also be necessary. The procedure for this method is that BPMI aggregates the needs of each power utility, invites trainers or instructors from abroad, and gathers trainees from all related power utilities to train in Bangladesh.



Source: Prepared by the JICA survey team

Figure 4-6 Present situation of Foreign Training and proposal on how to proceed in the future

As stipulated in the MoA, BPMI has a role in collecting information and evaluating new technologies in order to introduce new technologies in the power sector from abroad to Bangladesh, and BPMI is also expected to play a role in introducing effective technologies and training engineers.

4.2 Review and recommendations regarding content of the training courses

In the questionnaire sent to each power utility during the 1st survey in Bangladesh, the JICA survey team asked about new training courses that they are requesting. The information provided by the responding organizations is as follows.

Table 4-2 New training needs desired by each power utility (only listed in questionnaire responses)

Category	Power utility	Requests of New Training Course (Original Texts) or Other Requests
Power Generation	NWPGCL	- Thermal Design of Combined Cycle Power Plant - Fluid Modelling / Analysis and Heat Transfer Modelling - Renewable Energy Simulation and other training on new advanced technology related to power generation.
	EGCB	- Borescope Inspection of Compressor, Turbine & Generator - List of Need based Training
	RPCL	- We need to open a new training course on “4 th IR Challenges against implementing the changing technology. 4 or 5 personnel need to be trained up for sharing the knowledge among RPCL employees. - We need numerous engines/ turbines based and newly introduced technology, renewable energy related trainings. It may be 10 to 15 day long training programme with practical implacable course content and syllabus.
Power Transmission	-	-
Power Distribution	DPDC	- Training on Rooftop solar and Net Metering as a source of clean energy. - Advanced training on GIS integration in DPDC area. - Various training on introducing clean energy production and consumption pattern ¹⁵
	DESCO	- Stability of Network for the penetration of Variable Renewable Energy (VRE) - Maintaining the Stability of Distribution Network for the Penetration of scattered small size VRE - Load flow study, convenient point of evacuation, Capacity, Curtailment issues, harmonics, impedances etc. (Technologies such as AMI, SCADA, GIS are initiated in DESCO as well as we started OCSMS for customer service, Inventory management software for better service. Those require skilled personnel, but we have limited skilled manpower.)
	WZPDCL	- Prepayment Meter and Solar Energy

Source: Answers to the Questionnaire collected during the 1st survey

The proposals on new training courses to be established or strengthened in the future regarding electric power technology in the fields of power generation, transmission, and distribution are as

¹⁵ “clean energy production and consumption pattern” means managing how to operate Roof top solar and use electricity at home such as HEMS.

follows.

(1) Power generation

In Bangladesh, gas-fired power generation makes up the majority of the power source mix, but all power generation companies have installed or plan to install solar power generation in addition to thermal power generation. Therefore, it is necessary to strengthen training on equipment operation management (panels, power controllers, etc.) and site management related to solar power generation. In addition, the "Integrated Energy and Power Master Plan (hereinafter referred to as IEPMP)" created by this MP Project envisages the introduction of other renewable energies such as wind and biomass, and if the introduction is realized, training related to these technologies will also be required.

In Bangladesh, construction of the Rooppur nuclear power plant (1,200MW x 2 units) is currently underway, and operation is scheduled to begin in 2025. Nuclear power generation requires high-level technologies in areas such as reactor containment vessels, nuclear reactor operation management, radiation detection equipment operation management, radioactive waste management, and training assuming emergency such as nuclear disaster¹⁶, so it is important to strengthen capabilities in these areas. However, BPMI will not be involved in nuclear power plant technology and human resource development matters, and the Power Division will administrate them.

Additionally, IEPMP proposes the introduction of hydrogen (H₂) and ammonia (NH₃) co-firing in gas-fired and coal-fired power plants from the late 2030s onwards. These technologies are currently being developed and made a trial in developed countries, but if they are to be introduced in Bangladesh in the distant future, there will be a need for training.

(2) Power transmission (System operation¹⁷)

Currently, in order to improve the reliability of the Dhaka supply system, the main trunk power transmission lines are being converted into two circuits at various locations. As a result, power transmission capacity will increase dramatically, but as a result, system operation will also become more complex, creating technical issues such as voltage regulation, N-1 operation, and power flow analysis in the event of occurrence of an accident. In addition, it is necessary to establish operation know-how regarding grid interconnection and pass on the technology regarding issues such as the increase in power flow from the south to the north and international interconnection lines with neighboring countries, which are envisioned in the IEPMP. As power systems become more complex, the need to analyze voltage distribution and power flow using

¹⁶ (1) Establishment of a rapid initial response system, (2) Decision-making regarding the implementation of protective measures through cooperation between the central government and local organizations, (3) Resident evacuation, evacuation indoors, etc.

¹⁷ National Load Dispatch Center (NLDC) is responsible for power system operation, and the NLDC is established within the Load Dispatch team of the System Operation Group, which belongs to the Operation & Maintenance Division of PGCB.

system analysis software (PSS/E, NEPLAN, etc.) increases dramatically, so holding training sessions focus on specializing in how to use such software is strongly proposed.

In addition, with the increase in the amount of renewable energy introduced in the future, it will become necessary to strengthen capacity in aspects such power generation forecasting that takes into account weather data, the issue of frequency and voltage maintenance due to sudden fluctuations in output, and issues related to interconnection technology requirements on large-scale distributed power sources such as renewable energy. Additionally, if nuclear power generation is introduced, there will be technical issues such as what to do in the event a large-scale generator drops out, and measures to mitigate the impact.

(3) Power distribution

With economic development in Bangladesh, electricity demand is expected to increase dramatically. Especially in Dhaka, where there is a large influx of population from rural areas to urban areas, the IEPMP predicts that by 2050, the maximum demand in the DESCO area will be about 6 times the current level, and in the DPDC area it will be about 3.5 times the current level. On the other hand, improving supply reliability is a major issue in rural areas. Additionally, DPDC requires new customers with a contracted capacity of 3kW or more to install solar PV on their rooftop, and the amount of interconnected distributed power sources at the power distribution level will increase dramatically in the future. It is assumed that this will lead to a significant increase in the amount of energy used, and it is necessary to develop grid interconnection requirements.

When a distributed power source is interconnected to the grid, the distribution company must check and ensure whether it meets the requirements for grid connection (relays related to frequency and voltage, isolated operation detection function, etc.), or that there will be no voltage management problems even if the distributed power source is interconnected to the grid.

Based on the above, in the field of power distribution, there are the following issues based on the content proposed as a distribution system plan in the IEPMP, and the training needs for each are the following themes.

- (a) Voltage control problems caused by increased loads, harmonic problems caused by increased inverter loads, etc.
- (b) Improving supply reliability (patrol of/ inspection on power distribution equipment, fault point detection/fault recovery response technology, maintenance (grounding resistance management, trimming or cutting down of obstructive trees, planned repair or replacement of equipment, etc.)
- (c) Grid interconnection technology (confirmation of grid interconnection requirements, etc.)
- (d) Support for system advancement (SCADA, GIS, etc.)

Regarding (b), training courses still exist. Taking DPDC as an example, which publishes the

details of each training course, the details of the "Electrical Distribution Network Operation & Maintenance" training course listed in Table 3-22 are as shown in Table 4-3. During the 5 days x 8 hours of training, trainees can learn many topics. Themes related to improving reliability have been implemented as h, k, and o. In the future, they have to add new training course on further reliability improvement measures that will be considered by each power distribution company and will be added as new initiatives. In addition, efforts will also be needed to further enrich the content training content on the existing training course.

Table 4-3 Detail of DPTC training course “Electrical Distribution Network Operation & Maintenance”

Participants	Foreman/ Lineman/ Electrician/ Lineman Mate
Number of Batches	8
Participants in each group	50
Course Objective:	To familiarize with the distribution line and line materials/equipment and to develop participants self-conception on distribution network.
Module 01: Course General	a. Definition of Current, Voltage, Ampere, Resistance, Active power, Reactive power etc. b. Demonstration on electrical equipment and tools. c. Demonstration on electrical materials. d. Demonstration on different type of meters used in power system: energy meter, ampere meter, volt-meter. e. CT & PT: Basic Principles, type, Installation. f. Bus-bar: Single line diagram, Type, maintenance, advantages and disadvantages. g. Battery and battery charger. h. Protection, fuse check and rating of fuse for transformer. Selection of MCCB, Transformer earthing, testing of distribution transformer (AVO, Megger). i. Using VHF or UHF in Communication. j. Electrical Safety k. Distribution line maintenance & routine maintenance of distribution transformer. l. Discussion on system loss. m. Discussion on activities required for the reduction of system loss. n. Role of Lineman & Foreman for achieving revenue. o. Continuity & Insulation Test of underground cable, transformer & line. p. DPDC service rule: Remuneration and Benefit Package, Entitlement of leave. q. Fire-fighting and safety application. r. Personal Protective Equipment (PPE)

	s. Electrical Hazards.
Expected Output	Expert & skilled employee on electrical distribution network will be produced.
Expected Outcome	- Troubles of the electrical distribution network can be easily identified and removed. - Electrical distribution network will be operated smoothly. - Load balance will be done properly. - Distribution network maintenance cost will be reduced.
Expected Impact	- Life time of Electrical distribution network will be increased. - Network interruption will be reduced. - Customer satisfaction will be increased.

Source: "Training Calendar 2022-23" received from DPDC

4.3 Review and recommendations regarding training implementation system

As mentioned above, although it has been more than six and a half years since BPMI was established on June 8, 2017, the training center of BPMI is still operated in a temporary building with only three lecture rooms, etc. and there is no dedicated staff. Therefore, there has not been structure in place yet that allows BPMI to exercise its ownership to coordinate and lead the human resources development of the entire power sector in Bangladesh, which is the purpose stipulated in the MoA at the time of its establishment.

In this way, building a training implementation system that includes the development of hardware (training center buildings, simulation equipment, facilities, materials for training, etc.) is an urgent issue for BPMI. However, although requests have been made to donors such as WB for funding for hardware development, no organization has yet announced financial support. A major reason for this is that BPMI's future vision and roadmap as a training institution have not become clear and not been disclosed yet. First of all, top priority should be given to building framework for human resource development so that BPMI can explain and gain understanding of the business viability of BPMI.

It is desirable to proceed with building the framework within the following three major themes;

- (1) Establishment of policies, rules, and strategies regarding BPMI human resource development
- (2) Clarification of the division of roles in human resource development and training activities in the entire power sector of Bangladesh, and determination of the general outline of the training program
- (3) Building an operational and management system for BPMI as a training institution, strengthening operational and management skills and know-how, and clarifying BPMI's future vision and formulating a roadmap.

Currently, each power utility is conducting its own in-house training courses on an annual basis.

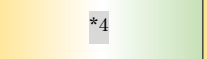
As shown in Table 3-1, there are multiple power generation companies and power distribution companies under the Power Division, but currently each of them conducts training with similar content individually. Regarding power generation, training cannot be standardized because the manufacturers and specifications of each power plant unit are different, and human resource development based on OJT using the actual equipment of each unit is essential. There are some areas that can be shared in training regarding the basic specifications of thermal power plant equipment. Regarding power distribution, there are no major differences in basic technologies among companies, so to some extent, training can be shared.

In Japan, there is a case where some extremely specialized technical training is sponsored by the Central Research Institute of Electric Power Industry (CRIEPI), and trainees from each electric power company gather together CRIEPI to participate in the training. On the other hand, trainings on basic technologies are carried out independently by each electric power company. However, in order to fully implement human resource development and training initiatives, a large amount of budget is required in terms of both hardware and software. Considering the current situation in Bangladesh, it is financially difficult for each power utility to secure a budget to set up its own training facilities and implement training courses based on sufficient funding every year.

Therefore, in accordance with the stipulation of the MoA, depending on the content of training courses, it is better to consolidate training resources into BPMI and have BPMI conduct the training all at once to achieve overall optimization. It is necessary to conduct such consideration in (2) above.

Regarding power transmission, there is currently only one PGCB, so there is little need to consolidate training related to power transmission at BPMI. Considering the above, role sharing as shown in Figure 4-7 is envisaged as the future BPMI training jurisdiction (idea).

*  Scope of training jurisdiction of BPMI

Field	Learning Level			Remark
	Elementary Fundamental ^{*1}	Middle ^{*2}	Advanced, Specific Matters ^{*3}	
Power Generation			Each organization	Training regarding common equipment (boiler, cooler, etc.) is consolidated by BPMI ^{*5}
Power Transmission		PGCB		Implemented independently by PGCB
Power Distribution				There is no significant difference between each distribution company, and aggregation by BPMI is possible.
Renewable Energy				Necessary power utilities participate
Energy Conservation				Necessary power utilities participate
General (Finance, Management Control)				Matters common to power utilities
General new technology (VR etc.)				Matters common to power utilities

*1: Basic training for about three years after newly joining the company

*2: Required specialized training to know the performance of each device

*3: Troubleshooting and other advanced content that is specific to each company.

*4: New employees need to learn about the power sector as a whole, not just transmission and substation. So, this part is implemented with BPMI. However, if the PGCB already has sufficient training materials and training facilities, it can be implemented at the PGCB as it is currently.

*5: There are many requests from power generation companies for simulated equipment and cut models to learn the basic specifications of thermal power plant equipment. It is thought that it is more efficient to consolidate these devices into BPMI, as introduction costs are high.

Source: Prepared by the JICA survey team based on the discussion with BPMI

Figure 4-7 Future BPMI training jurisdiction (idea)

It is proposed that BPMI intensively and comprehensively manage human resource development and training matter so that a certain level of quality training can be implemented based on human resources strategies linked to power sector policies. Furthermore, Vision 2041 sets an indicator that the total power generation capacity will reach 60 GW in 2041, and as Bangladesh's economic development and living standards improve, the scale of business in the power sector will rapidly expand in a both quantitative and qualitative manner. As a result, the number of people working in the electricity business is expected to increase.

Therefore, in the future, the number of people targeted for human resource development will increase significantly compared to the current number, so it will be virtually impossible in terms of volume for BPMI to carry out all human resource development initiatives listed in the MoA philosophy. As a result, the scope of BPMI's training jurisdiction listed in Figure 4-7 will need to be reviewed at an appropriate point in the future. Measures such as transferring training

jurisdiction to each company will be taken on the premise that training know-how is accumulated in each power generation, power transmission, and power distribution company and that the volume of trainees and the quality of training will be maintained to a certain level.

4.4 JICA assistance plan (proposed)

As described in 4.3, as an urgent issue for BPMP, building framework and system for human resource development should be given top priority rather than developing the hardware. As mentioned above, human resource strategies and training programs need to be reviewed as appropriate in line with future changes in the power sector situation and accompanying policies and measures to optimize human resource development in the power sector. To this end, it is necessary not only to take temporary initiatives such as formulating human resource development policies, rules, and strategies, and building training programs, but also to foster problem-solving ability and ownership of BPMP as a power sector human resource development institution. Only when problem-solving ability and ownership are firmly established in BPMP will a certain level of human resources be secured in the electric power sector sustainably in the future, and the effects of stable and efficient electric power business operation will be realized.

JICA has been working to realize these technology transfer and ownership-building initiatives through the implementation of technical cooperation projects in various fields, which is a unique feature of JICA that is not found among other donors. It is significant that JICA takes the lead in supporting BPMP in this direction, and the technical cooperation projects carried out by JICA have high expectations from the Minister of Power, Energy and Mineral Resources of Bangladesh.

In addition, JICA has implemented a number of projects related to human resource development in the power sector of Bangladesh and has a large track record of transferring know-how and other technologies related to human resource development at electric power companies, which are basis of realizing one of the most stable and efficient electric power companies in the world. JICA has recently been implementing projects related to the power sector in Bangladesh as shown in Table 4-4. To realize the effects of these projects more deeply and continuously, it is of extremely high priority to carry out comprehensive efforts related to human resource development in the power sector of Bangladesh.

Table 4-4 JICA's recent projects related to the power sector in Bangladesh

Category	Project Name
Technical Cooperation Project (Information collection and confirmation survey)	Integrated Energy and Power Master Plan Project (this MP Project, 2021 -)
	Data collection survey on development of infrastructure in power and energy (2018 -)
	Power System Master Plan (2016)

	The project for development of energy efficiency and conservation master plan (2013-2014)
Dispatch of Expert	Advisor for Power and Energy Policy (2019 -)
Japanese ODA Loan	Matarbari Ultra Super Critical Coal-Fired Power Project Phase 1
	Dhaka Underground Substation Construction Project
	Dhaka-Chittagong Main Power Grid Strengthening Project
Overseas Investment	Sirajganj Combined Cycle Power Plant Project

Source: JICA's information

Based on this background, “Establishment of Human Resource Development Framework for Power Sector in Bangladesh” is proposed as the next technical cooperation project (draft).

[Overall Goal] The capabilities of power sector employees are improved so that the power supply with high quality and high reliability can be ensured in Bangladesh. [Project Purpose] Human resource development framework and training system in BPMP is established and enhanced. [Outputs] 1) Establishment of policies, rules, strategies on human resource development in BPMP. 2) Determination of role sharing of human resource development and training activities between BPMP and each utility / Arrangement of overall training program of BPMP 3) Enhancement of skills and knowhow of institutional operation and management in BPMP / Formulation of BPMP's future clear vision and roadmap

Source: Draft Application Form as of 9 May 2023

Figure 4-8 Draft overall goal, project purpose and outputs of the next technical cooperation project

Regarding the overall training program in “Output 2)”, three electric power fields will be focused on: power transmission and substation, power distribution, and renewable energy. In the case of Bangladesh, the power transmission and distribution sector are handled by public entities, some IPPs are involved in power generation business.

As shown in Table 3-1, there are entities such as BIFPCL (50:50 JV between BPDB and the Indian government-owned power company National Thermal Power Corporation (NTPC)) and BCPCL (mentioned above) that have foreign capital from India and China etc., even if they are under the Power Division, so they are excluded from the scope of the next technical cooperation project. JICA is considering targeting the power transmission and distribution business as the beneficiary of Japan's ODA project. Particularly in the power distribution field, it is recommended that BPMP establish a general framework for a training program for PBSs, which are under BREB and that a certain level of training be provided with PBSs to improve supply reliability and ensure

work safety and public safety. Such effort will be extremely important to develop widely human resources who will take on the role of power distribution business throughout the country.

Furthermore, the MP Project aims to build a low-carbon energy supply and demand system, and to achieve this goal, it is important to advance approaches such as human resource development related to renewable energy. In addition, as described in 0, by strengthening the interconnection technology of distributed power sources in each of the power transmission and distribution fields, it will be possible to smoothly accept power generated by renewable energy into the power transmission and distribution network, the effect on contributing to low carbonization and decarbonization can be expected.

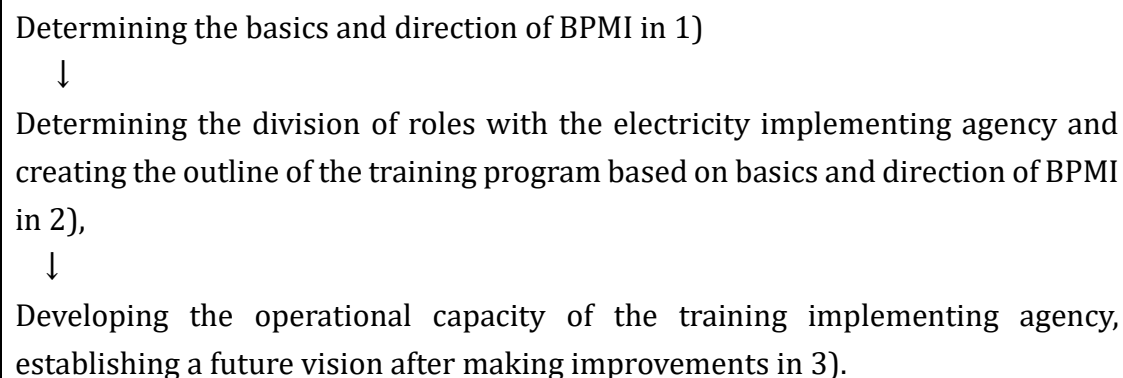
The following items are assumed to be required for the operation and management know-how of training facilities in “Output 3”).

- Creation of training curriculum and syllabus based on the outline of the training program
- Arranging trainers (lecturers/instructors) etc. (Acquiring know-how of training trainers (ToT), building the trainer (lecturer/ instructor) certification system, in case of assigning in-house trainers; acquiring know-how of inviting trainer in case of assigning from outside), or rules, if dedicated trainers are seconded from the outside institute to cover the in-house trainers
- Procurement of simulated training equipment, IT equipment, etc., and operation and maintenance after installation
- Know-how on recruiting trainees (within the Bangladeshi power sector and for foreign power companies)
- Operation, maintenance and other managerial task of trainee dormitories, cafeterias, places of worship, etc.

Furthermore, interviews were conducted with BPMI itself and the Power Division to confirm their future vision of BPMI during the 1st survey in Bangladesh. According to their comments, there are two choices about BPMI’s operation in the future; one is that BPMI will be operated with contributions from power utilities (no fees will be collected from training participants from these power utilities.), another is that BPMI will be an independent institution on the premise of building a market mechanism as a training business and collecting participation fees from all training participants. BPMI also has a plan in the future to open the door to foreign countries for training, gather trainees in Bangladesh, conduct training, and earn participation fees. To this end, they think that BPMI should grow to take a leading position in power sector training across a wide area, including neighboring countries. Such initiatives can only be considered on the premise that BPMI secures highly specialized human resources and builds up the know-how to operate and manage the training facilities mentioned above. As the activity related to “Output 3)”, a future vision/roadmap for BPMI will be also developed based on the future prospects of the electric

power sector and relationships with neighboring countries.

The flow of Outputs 1) to 3) in the next technical cooperation project (draft) is as follows.



As for the project implementation period, it is necessary to reform the BPMI organization and review the training system. Since the schedule is tight for a three-year project, it is necessary to set a period of about five years.

Table 4-5 shows the approaches to global issues expected in the next technical cooperation project (draft)

Table 4-5 Approaches toward solving global issues (SDGs) by the next technical cooperation project

Approach by the next technical cooperation project	Global Issue to be addressed
(1) Dissemination of reliable and affordable electric power	Poverty eradication (Goal 1 on SDGs) 
(2) Capability development of BPMI as the educational institute	Improvement of educational system (Goal 4 on SDGs) 
(3) Improvement of entire power sector	Ensure access to affordable, reliable, sustainable and modern energy for all (Goal 7 on SDGs) 
(4) Power generation efficiency improvement, Power system loss reduction, Utilization promotion of renewable energy source	Reduction of greenhouse gas emission (Goal 13 on SDGs) 

Source: Prepared by the JICA expert team based on the discussion result with BPMI

III. Capacity Building

1. Energy Balance Table

Energy balance table is published by International Energy Agency (IEA) not only for Organisation for Economic Co-operation and Development (OECD) countries but also for non-OECD countries. In addition, Latin American Energy Organization (OLADE) and Asia Pacific Economic Cooperation (APEC) have published energy balance table for each country. In this section, we will follow the IEA's criteria for preparing energy balance table and explain the points to be considered.

1.1 Purpose of preparing energy balance table

Energy balance table provides an overview of domestic energy supply and demand. It is necessary for the formulation of energy policy and future targets. In addition, the energy balance table calculates various energy indicators such as energy efficiency, energy consumption in each sector, energy self-sufficiency rate, energy intensity, CO₂ emissions, etc., and provides the necessary data for energy demand forecasting models. In addition, it is useful for preparing GHG (Greenhouse Gas) inventories and NDCs (Nationally Determined Contributions) reports and comparing energy supply and demand between countries. For this purpose, it is important to maintain time-series data.

1.2 Structure of energy balance table

Energy balance table consists of three parts: primary energy supply, transformation processes, and final energy consumption.

Primary Energy Supply	Transformation Processes	Final Energy Consumption
Domestic production import export Stock changes	Electricity plants Oil refineries others	Industry sector Transportation sector Residential sector Commercial sector Agriculture/forestry/fisheries Non-energy use

1.3 Positive and negative indication in energy balance table

In the energy balance table, the followings are shown as negative.

Primary energy supply	Transformation Processes
Export	Amount of energy input into transformation facilities such as power plants, refineries, etc. (including nuclear, hydro power, geothermal, solar, and wind power)
Increase stock changes (because more inventory means less supply)	Own use
	Losses

In the energy balance table, supply and demand were balanced.

Primary energy supply + Transformation processes - Final energy consumption = 0

1.4 Energy Unit

The calorific value of energy such as oil, coal, and gas is different, so energy units must be standardized. The IEA uses oil equivalent (10,000 kcal/kg-oil equivalent) as its energy unit. Physical units of coal, crude oil, and natural gas are converted to oil equivalent using the calorific value provided by each country, while physical units of petroleum products are converted to oil equivalent using the IEA standard calorific value. The IEA energy conversion factors are shown below.

Energy	Conversion factor
Coal	Depending on each country
Natural gas	Depending on each country
Crude oil	Depending on each country
Refinery gas	1.150 toe/t
LPG	1.130 toe/t
Gasoline	1,070 toe/t
Jet fuel	1.065 toe/t
Kerosene	1.045 toe/t
Deisel oil	1.035 toe/t
Fuel oil	0.960 toe/t
Naphtha	1.075 toe/t
Lubricant	0.960 toe/t
Bitumen	0.960 toe/t
Other oil products	0.960 toe/t

Source: An explanation of IEA energy balance table and conversion to I/O compatible energy and CO2 emission data, Kazunari

Kainou, August 2006

1.5 Transformation Processes

(1) Transfer

Transfer means an energy conversion that does not involve combustion or chemical reactions, and includes the conversion of NGLs and light crude oil to chemical plants as raw materials.

(2) Statistical differences

For various reasons, supply and consumption may not be equal. The difference is adjusted for by statistical differences. The statistical differences is said to be 2-3% in developed countries and 5-10% in developing countries.

(3) Power generation efficiency (heat rate)

The heat rate of thermal power generation is calculated from the input energy and the amount of power generation, but other heat rates are defined by the IEA as follows.

Nuclear energy:	33%
Geothermal:	10%
Hydro, solar and wind:	100%

Therefore, the energy input (ktoe) when each power generation facility below generates 100 GWh of electricity per year is as follows.

Nuclear energy:	$100\text{GWh} \times 860\text{kcal/kWh} \div 10,000\text{kcal/kg} \div 33\%$
Geothermal:	$100\text{GWh} \times 860\text{kcal/kWh} \div 10,000\text{kcal/kg} \div 10\%$
Hydro, solar and wind:	$100\text{GWh} \times 860\text{kcal/kWh} \div 10,000\text{kcal/kg}$

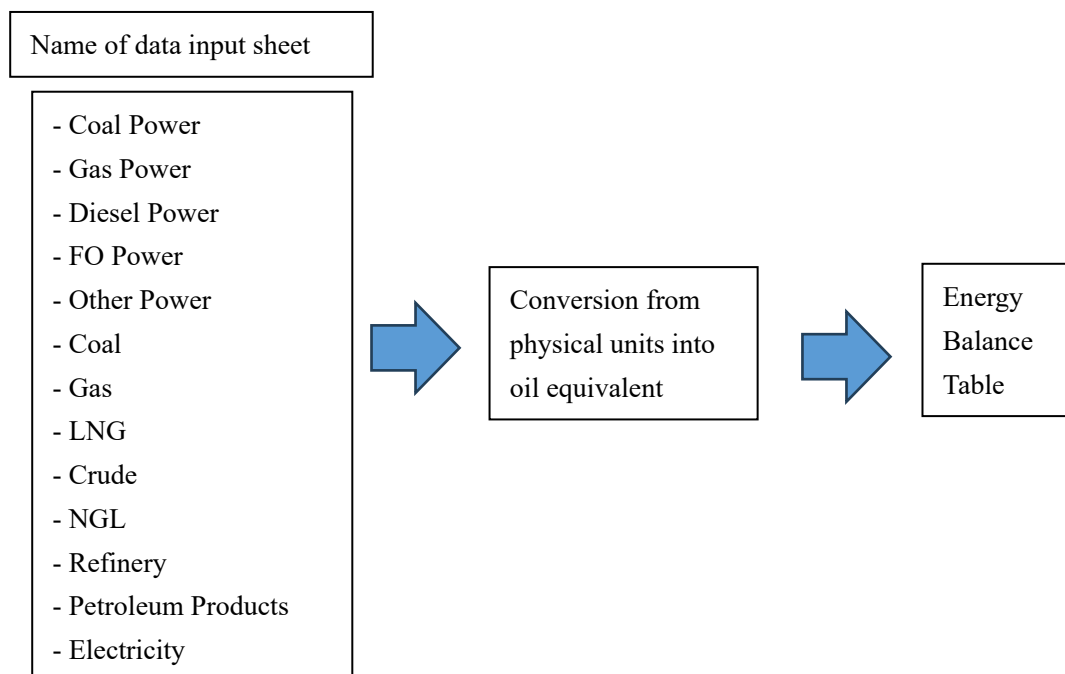
(4) Transmission and distribution losses

Since transmission and distribution losses include stolen electricity, transmission and distribution losses may increase in developing countries. In developed countries, it is about 10%. For a detailed explanation of the IEA's Energy Balance Table, please refer to the following URL. https://wds.iea.org/wds/pdf/worldbal_documentation.pdf

1.6 Prototype Energy Balance Table

In this study, a prototype energy balance table (hereinafter referred to as a prototype model) was developed in Excel and submitted it to counterparts (Power Cell, Hydrocarbon Unit, and BPDB). The prototype model consists of 15 sheets. 15 sheets are divided into 13 data input sheets, calorific value sheets, and energy balance sheets. When the required data is entered in the yellow cells of 13 data input sheets, the physical unit of each energy is converted into oil equivalent and

placed on the energy balance sheet.



2. Energy Demand Forecasting Model

The training procedure for energy demand forecasting model was reviewed and an orientation was conducted to Energy and Mineral Resources Division (EMRD) and Power Division (PD). The meeting with EMRD was held on 6 July 2022 in the conference room of Hydrocarbon Unit. Participants included EMED's Joint Secretary and other senior officials, as well as over 20 people from EMRD affiliated organizations such as Hydrocarbon Unit, Petrobangla, gas and LPG supply companies, and distribution companies.

The meeting with PD was held on 7 July 2022 in the conference room of PD. Participants included PD's Additional Secretary and other senior officials, as well as over 30 people from PD affiliated organizations such as BPDB, SREDA, Power Cell, and so on. The orientation including practical exercises was conducted as follows.

Approach and the Concept	Fundamentals of energy/econometric modeling and theories: Introduction to energy balance table, economic and statistical theories to understand the quantitative models for energy demand analysis and forecasting.
Set up of SimpleE	1. SetUp of SimpleE in a PC and to start the program 2. Introduction to the SimpleE worksheets

Simple Exercise	1. Exercise regression to explain Final Energy Demand using GDP 2. Exercise of introduction of international energy price as external variable
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Main training was divided into two teams (EMRD and PD) since the number of participants was large (62 people). Training for EMRD took place from August 20 to September 1, 2022. On the other hand, training for PD took place from September 25 to October 4, 2022. In the model training, the structure of energy balance table was explained in order to understand energy data to be input into the model. Also, the theory of econometric models was explained as the basis for model preparation. After that, the participants installed a software called “SimpleE” on their personal computers. In the model training, a simple demand forecasting model was developed following the instructor's instructions. The meaning of the output given by the model was also explained. The lecture content was difficult for those who are not familiar with econometrics. The training content is as follows.

Step 1 Basics of econometrics and Introduction to SimpleE

Contents

1 Fundamentals of energy/econometric modeling and theories:

- Energy balance table and the interfaces to the energy markets and energy policies
- Concept of energy/econometric modeling
- Role of tools and models
- Options of methodologies and the role of econometrics

2 Utilization of Excel Spreadsheet as platform

- Exercises of regression models with Excel—graphical solution and options of internal functions
- Concept of minimum/maximum solution and the application to least square
- Statistical indicators of regression by excel

3 Introduction of SimpleE and preparation of data

- Installation of SimpleE
- Basic structure of SimpleE and the role of three sheets—Data, Model, and Simulation
- Preparation of Bangladesh Energy/Economic data and introductory operations

4 Introductory exercises

- Introductory Exercises on the use of data sheet-preparation of time-series variables and definition/code-naming of variables
- Introductory Exercises on the use of model sheet-Simple Regression models and creation/definition of equations
- Introductory Exercises on the use of simulation sheet

5 Analysis for the determinants of Bangladesh energy demands

- Model sheet in depth
- Regression exercises of Bangladesh energy demands and economic indicators

- Interpretation of statistical indicators—Coefficients, R-Square, t-statistics, etc.
- Concepts of dummy, lagged variable and utilization of graphics

Step 2 Analysis of Bangladesh Energy Sector and the applications

Contents

1. Finding of the energy demand determinants (Non-Power)
 - 1) by sectors (Industry, Transport, Residential, Commercial/Public)
 - 2) by type of energies (coal, gas, oil, renewables)
2. Finding of the energy demand determinants (Power)
 - 1) by sectors (Industry, Transport, Residential, Commercial/Public)
3. Impacts of policy variables on demand by sectors and by fuels
 - 1) GDP and/or Value added
 - 2) Prices
 - 3) Energy efficiency
4. Calculation of CO₂ emissions
5. Policy/Scenario simulation
 - 1) Changes of GDP/Value Added on demand by sector and by source
 - 2) Changes of prices on demand by sector and by source
 - 3) Impacts of technologies—EV and Hydrogen/Ammonia on demand by sector and by source
 - 4) Changes of energy efficiency on demand by sector and by source
 - 5) Options of net 50% reduction and net zero

