FEASIBILITY STUDY OF IMPLEMENTATION OF ADVANCED METERING INFRASTRUCTURE FOR SMART GRID DEVELOPMENT

A Thesis submitted in partial fulfillment of the requirements for the Award of Degree of
Bachelor of Science in Electrical and Electronic Engineering

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Certification

This is to certify that this project and thesis entitled "**Feasibility study of implementation of advanced metering infrastructure for smart grid development**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 31 January 2021.

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The thesis entitled **" Feasibility study of implementation of advanced metering infrastructure for smart grid development,"** submitted by **Mohammad Monowar Hossain Munna**, ID No: 163-33-3756, Session: Fall 2016 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on 31 January 2021.

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Declaration

I hereby declare that this thesis is based on the result found by myself. The materials of work found by other researchers are mentioned reference. This thesis is summited to Daffodil international University for partial fulfillment for the requirement of the degree of B. Sc. In Electrical and Electronics Engineering. This thesis neither whole nor in part has been previously submitted for any degree.

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Dedicated to

My Parents

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List of Abbreviations

AMI	Advanced Metering Infrastructure
DMS	Distribution Management System
SAS	Substation Automation System
SCADA	Supervisory Control and Data Acquisition
AMI	Advanced Metering Infrastructure
ARR	Annual Revenue Require
GIS	Geographical Information System
TMU	Transformer monitoring units
DT	Distribution Transformer
LOB	Line of Business
HT/LT	High Tension/ Tension Tension
DR	Demand Response
DAS	Distribution Automation System
OMS	Outage Management System
ESS	Energy Storage System
PV	Photo Voltaic
SMOC	Smart Meter Operation Centre
SOC	Security Operation Centre
SIIP	Small Independent Power Producer
QRPP	Quick Rental Power Producer
IPP	Independent Power Producer
RPP	Rental Power Plant
DER	Distribution Energy Resources
DESS	Distribution Energy Storage System
RE	Renewable Energy
NOD	National Operation Division
CNST	Communication Network System Technician
PLC	Power Line Carrier
DMS	Distribution Management System
DFDR	Digital Fault Disturbance Recorder
RTU	Remote Terminal Unit

ATO	Advanced Transmission Operations
AMI	Advanced Metering Infrastructure
ADO	Advanced Distribution Operations
AAM	Advanced Asset Management
AC	Alternating current
AMM	Automatic Meter Management
AMR	Advance Meter Reading
ADR	Automatic Demand Response
AGC	Automatic Generation Control
APSCL	Ashuganj Power Station Co. Ltd
BPDB	Bangladesh Power Development Board
BIS	Bureau of Indian Standards
CPP	Critical Peak Pricing
CB	Circuit Breaker
CR	Cluster Router
CIS	Customer Information System
CCTV	Closed Circuit Television
DESCO	Dhaka Electric Supply Co. Ltd.
DPDC	Dhaka Power Distribution Co. Ltd.
DLR	Dynamic Line Rating
DM	Demand Management
DSE	Distribution State Estimation
DCC	Data and Control Center
DVR	Digital Video Recorder
DMS	Distribution Management System
DG	Distributed Generation
DA	Distribution Automation
AMR	Automatic Meter Reading
TOU	Time of Uses

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ABSTRACT

Smart Grids are developing as the next generation power systems that transform the traditional ways of functioning of present electrical grids. Advanced Metering Infrastructure (AMI) is one of the key components in smart grids. An AMI covers of systems and networks, that are responsible for collecting and analyzing data received from smart meters. In addition, AMI also manages the different applications related with power and services based on the data collected from smart meters. Thus, AMI plays a significant role in the smooth functioning of smart grids. Providing security to AMI is necessary as adversaries can cause potential infrastructural damage and privacy threats in smart grid. One of the most effective and challenging topics identified, is cost-benefit analysis for AMI. This thesis explore the evolution of the metering Industry in Bangladesh. It covers the benefits of Advanced Metering Infrastructure (AMI), key challenges in implementing AMI, popular communication standards and innovative business models for rolling out AMI in Bangladesh.

Keywords: smart grids; advanced metering infrastructure; load management.

Chapter 1

Introduction

1.1 Background of the study

The utility electricity sector in Bangladesh has one national grid with a generation capacity of 20.383 MW as of December 2020. Bangladesh's energy sector is booming. According to the Bangladesh Power Development Board in July 2020, 93.3 percent of the population had access to electricity. However per capita energy consumption in Bangladesh is considered low.

The largest energy consumers in Bangladesh are industries and the residential sector, followed by the commercial and agricultural sectors.

Bangladesh’s highest demand 12,893 MW (29 May 2019) and Install capacity 20,383 MW (Nov 2020). This is far difference between electricity consumption and generation capacity. At present there is no shortage of power generation in Bangladesh but still load shedding happens in Bangladesh. Because of the transmission and distribution system in the smart grid has not been upgraded. Our grid system is conventional we have to adopt smart grid technology to improve our power system.

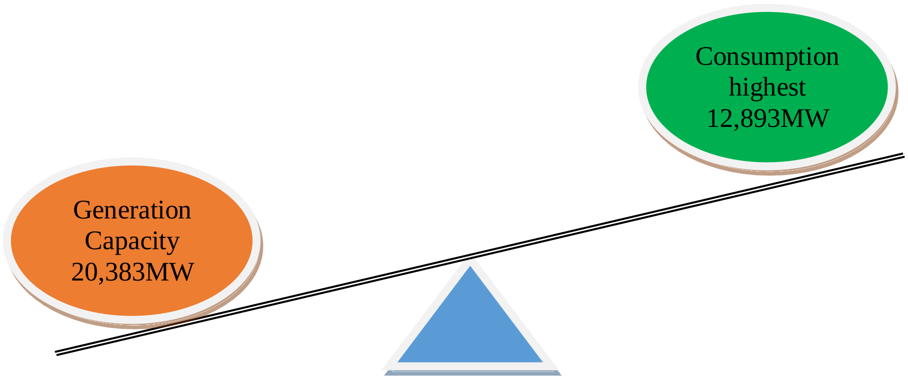

Figure 1.1: Compare between generation and consumption.

Advanced Metering Infrastructure (AMI) is one of the key components in smart grids. AMI (Advanced Metering Infrastructure) is the collective term to describe the whole infrastructure from Smart Meter to two way-communication network to control center equipment and all the applications that enable the gathering and transfer of energy usage information in near real-time.

Modernizing Bangladesh's grid system by investing in AMI promises to mitigate a number of strains placed on the grid due to growing demand for electric, gas and water resources. In particular, AMI will improve three key features of Banagladesh's grid system including:

- ***System Reliability:*** AMI technology improves the distribution and overall reliability of electricity by enabling electricity distributors to identify and automatically respond to electric demand, which in turn minimizes power outages.

- ***Energy Costs:*** Increased reliability and functionality and reduced power outages and streamlined billing operations will dramatically cut costs associated with providing and maintaining the grid, thereby significantly lowering electricity rates.

- ***Electricity Theft:*** Power theft is a common problem in Bangladesh. AMI systems that track energy usage will help monitor power almost in real time thus leading to increased system transparency.

The above literatures clearly indicate that Smart grid can play an important role to do more reliable and efficient in our national power system.

1.2 Significance of the Study

The conventional grid system is especially hazardous for Bangladesh. The present government is working to build a digital Bangladesh to ensure digital services at the doorsteps of the people using information technology. Electricity is a very important sector in building a digital Bangladesh. And there is no alternative to the smart grid to digitize the power sector. But our electricity service now relies on 'one-way interaction'.

Electricity is brought from the grid substation to the distribution company's substation. From there it is taken to the transformer again. The transformer stays in the customer's yard. All in all, there are some losses at every stage, which there is no way but to accept. But the problem is when it becomes too much. The system loss of the two distribution companies in Dhaka has less than 10 percent.it is clear that if we can monitoring with Smart Grid system then system loss will be reduced.

Smart meters provide new opportunities and challenges in networked embedded system design and electronics integration. They will be able not only to provide (near) real-time data but also process them and take decisions based on their capabilities and collaboration with external services. AMI benefits the entire grid by improving the accuracy of meter reads, energy theft detection and response to power outages, while eliminating the need for on-site meter reading. AMI brings financial gains to utility, water and gas companies by reducing equipment and maintenance costs, enabling faster restoration of electric service during outages and streamlining the billing process. AMI benefits electric customers by detecting meter failures early, accommodating faster service restoration, and improving the accuracy and flexibility of billing. Further, AMI allows for time-based rate options that can help customers save money and manage their energy consumption.

However, load shedding is a common picture in Bangladesh. But there is no shortage of power generation in Bangladesh. Experts attribute the cause of load shedding to faulty distribution lines and the inability to load management. But this load shedding can be brought down to almost zero through Smart Grid.

Considering all these facts, we have to think about Smart Grid adaptation in our country. This study smart grid implementation challenges and benefits in Bangladesh most appropriate and well justified in the Bangladesh context.

1.3 Objective

- To find out feasibility of Advanced Metering Infrastructure (AMI) implementation in Bangladesh
- Cost-Benefit analysis for Advanced Metering Infrastructure (AMI) pilot project.

1.4 Methodology

1.4.1 Study Design

The study was conducted mainly based on the data collected from the different secondary sources like Bangladesh power development board, power division, and power cell, U.S Department of Energy (DoE), Smart Grids European Technology Platform etc. Different statistical reports, relevant research papers, books and many national and international journals have also been reviewed for this study.

1.4.2 Information collection

Primary information was mainly collected by means of questionnaire survey and visited many others organization like PGCB, BREB, NESCO, BPDB, WZPDCL, DPDC etc. The primary data were collected through a questionnaire survey, interview, focus group discussions and field observation.

Photo 1.1: Interview with NESCO's officer

The secondary data were collected mainly by reviewing the relevant organization's annual reports, publications, literature, internet searching and discussion with local people.

1.5 Limitations

Followings are some of the limitations of this research study:

- The research was conducted by a survey. The specific focus on research paper only survey is a primary limitation of the case study
- Because of the short time available for field research, no long term monitoring for the technical performance of the system.
- It does not include broad details about the technology considered for this study but a brief detail.

1.6 Overview of the Chapters

This report is divided into 7 chapters. Chapter 1 gives the background of this study, mainly focusing on why what, and how the study has been carried out. Chapter 2 deals with an overview of the solar smart grid. This chapter mainly focuses on to know about smart grid and why we adopt smart grid technology and is it relevant for Bangladesh or not. Chapter 3 is the findings real scenario of Bangladesh power system. First of all, a brief country economy background is presenting. Chapter 4 is known about advanced metering infrastructure (AMI) technology. Chapter 5 is the findings cost-benefit analysis for pilot project of Advanced Metering Infrastructure.

Chapter 6 is showing strategy of implementation AMI. Chapter 7 concludes the findings of the study and proposes some recommendations based on the findings of this study.

Chapter 2

Smart Grid

2.1 introduction of Smart Grid

For the last few years, it is observed that the price of conventional fossil fuel e.g. crude oil has been kept on an upward trend. Furthermore, the reserves of non-renewable fuels such as coal, crude oil and natural gas are decreasing day by day in many of the fuel-rich countries. It is an alarming issue for the power sector of various countries that depend mainly on these conventional energy sources. The shortage of power supply in many countries is due to many reasons, e.g. shortage of energy resources, increasing pressure on keeping the environment pollution free, enormous power loss in energy delivery system, increasing demand etc. People are more conscious than before about their environment and sources of electric energy as they are aware of global warming, energy efficiency, and rational use of energy etc. issues. The sources of energy have a vital impact on climate change. Side by side, people are more aware of their energy usage policy, the efficiency of the energy systems, conservation of energy etc. A huge amount of greenhouse gas emission is due to the tremendous amount of fossil fuel burning to supply the enormous amount of daily electricity. The power industry is now facing unprecedented challenges to combats the growing electricity demand and requirement for safe, reliable, stable and quality power. To improve safety effectiveness and utilization of the energy precisely, new techniques have been proposed considering the demands of the people.

Smart Grid is one of the most impressive concepts nowadays to provide secure, reliable, clean, high-quality electricity supply and will be able to adopt various sources of electric power generation, highly market-oriented electric power exchanges, customer needs etc. The barrier for electric utilities is not only to manage the operation and control of the system but also to the market deregulation. The utilities need to provide better quality, more reliable electricity at a fair cost to the customers.

Smart Grid is a gradual development process that supports the innovation in technology, conservation and efficiency of energy use and the total management of electric energy. The Smart Grid is using the modern developed communication and information system which links a variety of customer equipment and assets together with sensors to create a smart platform. For efficient power system management, Smart Grid needs a robust communication infrastructure. Compared to the traditional grid, a Smart Grid is more intelligent, efficient, accommodating, motivating, opportunistic, quality-focused, resilient and green.

For these purposes, many countries are now looking into the option of Smart Grid as a future improvement way of the power grid. Based on present circumstances and practical situations, the development plans for the Smart Grid in Bangladesh should be taken care of immediately and seriously. The implementation of Smart Grid in Bangladesh is a challenging task with lots of problems in the power sector. This paper focuses on the Smart Grid implementation in Bangladesh as well as find out the challenges developing this system, progress and prospects of the development of the Smart grid in Bangladesh.

The term "Smart Grid" was first introduced by an article "Toward a Smart Grid" [l]. The actual definition of the smart grid has still not been yet established. According to the United States (U.S.) Department of Energy (DOE)'s Modern Grid Initiative [2], a smart grid that integrates advanced sensing technologies, control methods and integrated communications into the current electricity grid - both at transmission and distribution levels. The objectives of the smart grid, as identified by the U.S. DOE, are:

- Enabling informed participation by customers.
- Accommodating all generation and storage options.
- Enabling new products, services, and markets.
- Provide sang the power quality for the range of needs in the 21^{st} century economy.
- Optimizing asset utilization and operating efficiently.
- Addressing disturbances through automated prevention, containment, and restoration.
- Operating resiliently against all hazards.

2.2 Definition of Smart Grid technology

Smart Grid = Electric Power Grid +IT

That means the smart grid is nothing but the conventional grid with IT to achieve smart to give better reliability, flexibility, efficiency, resilience and better service end of the user.

The concept of smart grid was created in 2006 by European technology platforms and they define "smart grid as an electrical network that can intelligently integrate all user activity associated with - generators, consumer and their both to provide efficient, sustainable, economical and secure electricity supply with intelligent monitoring, control, communication, and self-healing technologies.

“Smart grid” normally refers to a class of technology people are using to carry utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from power plants and wind farms to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers -- mostly seen in big improvements in energy efficiency on the electricity grid and the energy users’ homes and offices.

- Better facilitate the connection and operation of generators of all sizes and technologies;
- Allow consumers to play a part in optimizing the operation of the system;
- Provide consumers with greater information and options for choice of supply;
- Significantly reduce the environmental impact of the whole electricity supply system;
- Maintain or even improve the existing high levels of system reliability, quality and security of supply;
- Maintain and improve the existing services efficiently;
- Foster market integration towards an integrated market.

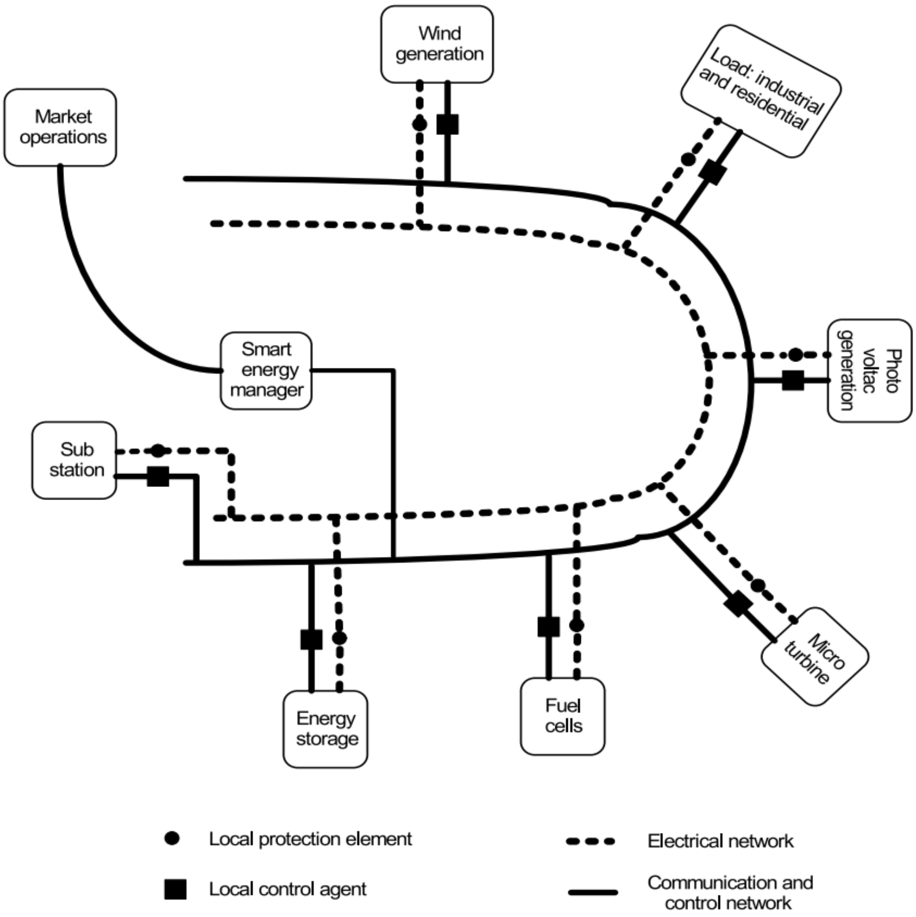

Figure 2.1: Smart grid basic integration layout.

2.3 Concept of Smart Grid

The U.S. Department of Energy expresses smart grid the digital technology that enable two-way communication between the utility and its consumer. The Smart Grid consists of controls, computers, automation, and new technologies and equipment working together with the electrical grid to respond digitally to our quickly changing electric demand [1]. Comparing with the traditional grid, a Smart Grid includes advanced metering and billing techniques, system automation, dynamic pricing techniques, demand-side management, congestion management, advanced sensing, electric vehicle charging, energy storage, integrated communication systems, modern technologies to support the distributed generation, complete decision support, forecast and human interfaces etc.

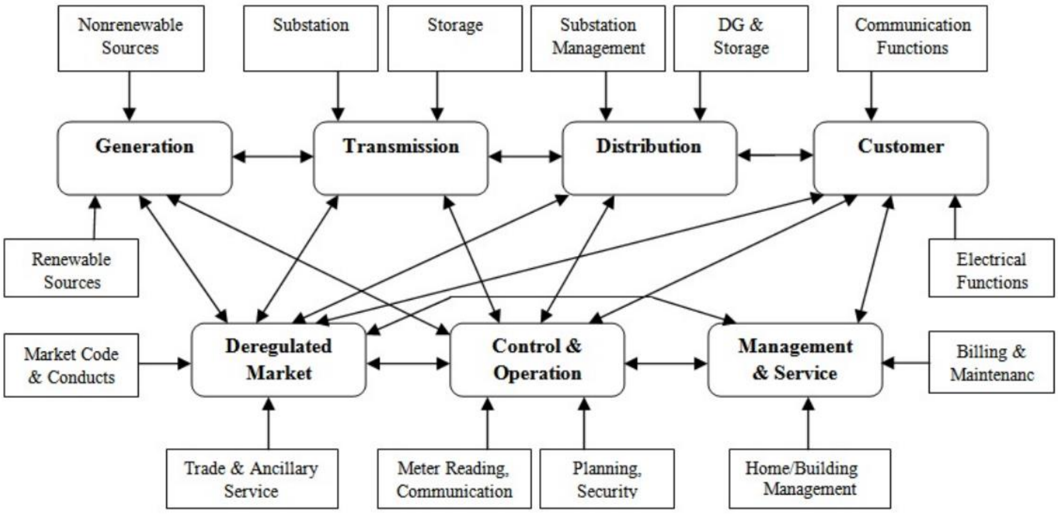

Figure 2.2: Basic diagram of smart grid.

Smart Grid makes the power system secure and reliable, economical in operation, incorporated with clean and green energy sources, optimized of assets and costs, interactive and real-time responsive, self-healing, flexible and compatible, integrated, accommodated with storage options, to provide power quality for the range of needs in a digital economy, to operate resiliently against physical and cyber-attacks and natural disasters, to capable of active participation by consumers, more efficient in transmission and distribution of electricity, quicker restoration of electricity after power disturbances, to help reduce operations and management costs for utilities and ultimately lower power costs for consumers, to help reduce peak demand which will also help lower electricity rates, better integration of customer-owner power generation systems, including renewable energy systems etc.

2.4 Smart Grid's Benefit

Smart Grid transforms the current power system into a new era of reliability, availability and efficiency. However the scope of this transformation is not very large and not defined. In order to share appropriate information between projects, one needs to have a defined functionality and features. Accordingly, the smart grid is characterized by the following goals and feature:

1) Reliability
2) Flexibility
3) Efficiency
4) Sustainability
5) Marker enable
6) Storage Option
7) Power Quality
8) Load Adjustment
9) Self-healing

2.4.1 Reliability

The smart grid makes use of technologies such as state estimation, which improves error detection and allows the network to self-heal without the intervention of engineer.

While multiple routes are characterized as smart grid features, older grids also feature multiple routes. The primary power lines on the grid were built using a radial model, later connected through multiple routes guaranteed, known as a network structure. However, this has created a new problem: if current flows or related effects across a network exceeds the limits of a certain network element, it may fail, and the current will be diverted to other network elements, which may eventually fail, resulting in a The problem is the domino effect. One of the strategies to prevent this is blackout or load shedding by turning the voltage drop (brownout).

2.4.2 Flexibility

The next-generation transmission and distribution infrastructure will be able to manage potential two-way power flows, distributing generations using photovoltaic panels such as electric cars, wind turbines, pumped hydroelectric power, fuel cells and other sources in roof construction.

Classic grids were designed for one-way flow of electricity, but if a local sub-network generates more electricity than it uses, the reverse flow can raise safety and reliability issues a smart grid handles these situations

2.4.3 Efficiency

Numerous contributions to the overall improvement of the efficiency of energy infrastructure are anticipated from the deployment of smart grid technology, in particular including demand-side management, for example turning off air conditioners during short-term spikes in electricity price, reducing the voltage when possible on distribution lines through Voltage/VAR Optimization, eliminating truck-rolls for meter reading, and reducing truck-rolls by improved outage management using data from Advanced Metering Infrastructure systems. The overall effect is less redundancy in transmission and distribution lines, and greater utilization of generators, leading to lower power prices.

Phase Load Balancing ensures the total load is distributed as evenly as possible across the three phases of the distribution grid.

2.4.4 Sustainability

The improved flexibility of the smart grid allows greater access to highly variable renewable energy sources such as solar power and wind energy, even without the addition of energy savings. The current network infrastructure is not built for many distributed feed-in points, and although some feed-ins are generally allowed at the local (distribution) level, the transmission-level infrastructure cannot adjust it. Due to the rapid fluctuations in the distributed generation due to cloudy or thin weather, there are significant challenges for electrical engineers who need to ensure stable power levels by changing the output of more controllable generators such as gas turbines and hydroelectric generators. For this reason, smart grid technology is a necessary condition for a large amount of renewable electricity in the grid. There is also support for in-vehicle grids.

2.4.5 Marker enable

The smart grid allows for systematic communication between suppliers (their energy price) and consumers (their willingness-to-pay) and permits both the suppliers and the consumers to be more flexible and sophisticated in their operational strategies. Only the critical loads will need to pay the peak energy prices, and consumers will be able to be more strategic in when they use energy. Generators with greater flexibility will be able to sell energy strategically for maximum profit, whereas inflexible generators such as base-load steam turbines and wind turbines will receive a varying tariff based on the level of demand and the status of the other generators currently operating. The overall effect is a signal that awards energy efficiency, and energy consumption that is sensitive to the time-varying limitations of the supply. At the domestic level, appliances with a degree of energy storage or thermal mass (such as refrigerators, heat banks, and heat pumps) will be well placed to 'play' the market and seek to minimize energy cost by adapting demand to the lower-cost energy support periods. This is an extension of the dual-tariff energy pricing mentioned above.

2.4.6 Storage option

Smart grids are electricity networks that utilize information technology to enhance the reliability, security, and efficiency of power systems [38]. A distinctive feature of smart grids is the ability to integrate the actions of all users including generators and consumers. Smart grids have a major role to play in a low-carbon future: they can be instrumental in energy-saving and accommodating a broad range of generation and storage options including renewable energy and thus are a key to both demand- and supply-side management of energy systems. All kinds of demand-side measures can serve as low-cost energy storage options when incorporating intermittent renewable generation on large scale.

2.4.7 Power Quality

Power quality is one of the important aspects of the smart grid and should not be neglected. Engineers have at their disposal many meters,[6] that can read and display electrical power waveforms and calculating the parameters of the waveforms. These parameters may include, for example, current and voltage RMS, the phase relationship between waveforms of a multi-phase signal, power factor, frequency, THD, active power (kW), reactive power (kVAr), apparent power (kVA) and active energy (kWh), reactive energy (kVArh) and apparent energy (kVAh) and many more. The smart grid is required to provide power with a high-quality level to consumers those features. Smart grid conceivers claim the use of intelligent relays and autoreclosures to realize self-healing.

2.4.8 Load Adjustment

The total load connected to the power grid can vary significantly over time. Although the total load is the sum of many individual choices of the clients, the overall load is not necessarily stable or slow varying. For example, if a popular television program starts, millions of televisions will start to draw current instantly. Traditionally, to respond to a rapid increase in power consumption, faster than the start-up time of a large generator, some spare generators are put on a dissipative standby mode. A smart grid may warn all individual television sets, or another larger customer, to reduce the load temporarily (to allow time to start up a larger generator) or continuously (in the case of limited resources). Using mathematical prediction algorithms it is possible to predict how many standby generators need to be used, to reach a certain failure rate. In the traditional grid, the failure rate can only be reduced at the cost of more standby generators. In a smart grid, the load reduction by even a small portion of the clients may eliminate the problem.

While traditionally load balancing strategies have been designed to change consumers' consumption patterns to make demand more uniform, developments in energy storage and individual renewable energy generation have provided opportunities to devise balanced power grids without affecting consumers' behavior. Typically, storing energy during off-peak times eases high demand-supply during peak hours. Dynamic game-theoretic frameworks have proved particularly efficient at storage scheduling by optimizing energy cost using their Nash equilibrium.

2.4.9 Self-healing

The Department of Energy has also identified both attack resistance and self-healing as major keys to ensuring that today's smart grid is future-proof. A key issue is a built-in ability to minimize the propagation of failures and resilience against such local failures. This capability should be incorporated with monitoring, communication, and reconfiguration features of power electronics systems. Additionally, power electronic interfaces must be configured to avoid nuisance trips.

2.5 Working principle of Smart Grid

At present distribution technology, when a tree limb or any other things like kite, Bird etc fall on the power line and creates fault. So that it causes a power outage at the consumer end side. For example the distribution company finds out only when a customer calls to complain. With a smart grid system, devices along the network can automatically tell the utility exactly when and where an outage occurred, close the circuit at that location, to “island” the fault, re-route power around failed equipment and create a detailed “trouble ticket” for a repair crew.

When customers are given access to data about their power use, they can change their habits to be more efficient and save money. Customers will eventually be able to see how the price of electricity changes depending on the time of day it is used, and they will be able to shift their use of the product to times when it is cheaper.

The biggest cost savings in using a smart grid may be found in improved efficiency of electricity-delivery operations. For example, once the voltage is known and updated frequently all-around a utility’s grid, the utility can work much more efficiently. Rather than supplying extra voltage into the grid to cover possible dips somewhere on that grid, voltage drops can be identified and addressed remotely. Such a direct response lets the utility supply the minimum amount of voltage needed for smooth operations. Utilities testing this benefit in the real world are reporting big cost savings almost immediately. [11]

2.6 Why implement the Smart grid?

- ✓ Enabling informed participation by customers.
- ✓ Accommodating all generation and storage options.
- ✓ Enabling new products, services, and markets.
- ✓ Provide sang the power quality for the range of needs in the 21st century economy.
- ✓ Optimizing asset utilization and operating efficiently.
- ✓ Addressing disturbances through automated prevention, containment, and restoration.
- ✓ Operating resiliently against all hazards.
- ✓ Increase GDP by creating more new, green-collar energy jobs related to renewable energy industry manufacturing.

2.7 Is smart grid relevant for Bangladesh?

Following some indicators, we can say whether the smart grid is relevant in Bangladesh.

- ✓ Blackout
- ✓ Power theft
- ✓ Advanced metering infrastructure
- ✓ Distributed energy resources and the microgrid

➢ Blackout

A blackout is a total crash of the power grid due to an imbalance between power generation and power consumption. The smart grid refers to an electricity system that collects real-time data on supply and demand to make the entire grid more efficient and less prone to failure.

Photo 2.1: Blackout of Bangladesh

A grid fails when the frequency plunges below the lower limit of the (48-52Hz) band or shoots up beyond the upper limit.

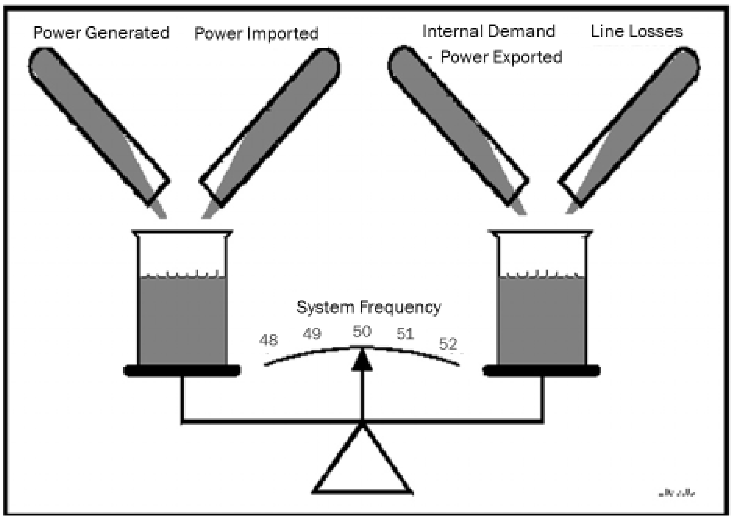

Figure 2.3: Frequency balanceing

There are many causes of power failures in an electricity network. Examples of these causes include faults at power stations, damage to electric transmission lines, substations or other parts of the distribution system, a short circuit. As a result, transmission lines stop accepting power supply and other grid constituents, including the generating stations go out of order.

Bangladesh was imported power around 500 MW from India through BIPTC. HVDC station in BIPTC does not add any inertia to Bangladesh power system. We observed the complete blackout of BPS on 1st November, 2014 for sudden outage HVDC station causing the country wide blackout and restoration took place 12 hours. The frequency transient after tripping of HVDC station is analyzes here.

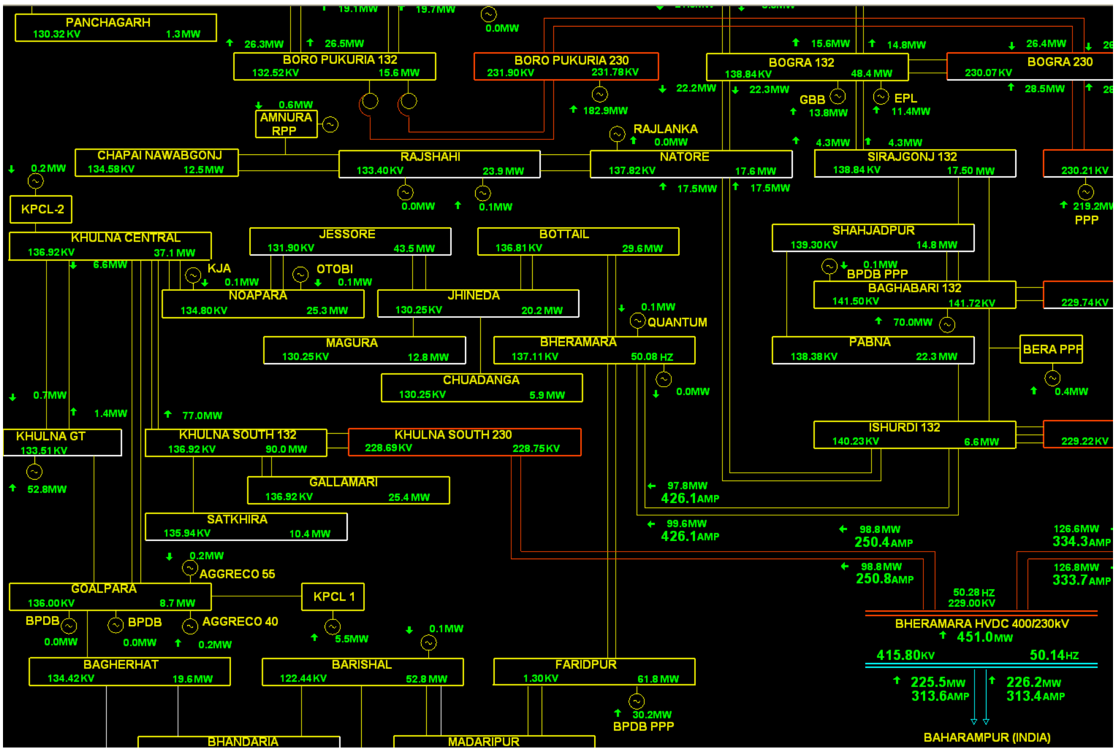

Figure 2.4: 444 MW HVDC substation tripped

The frequency disturbance events are recorded by digital fault disturbance recorder (DFDR) which takes 100 samples per second. From the recorded frequency transients on 1st November 2014 Shown Fig. 3.5 we observed that to HVDC station tripping, the network frequency was 50.333 Hz at 11:27:.4098 hrs. Due to tripping of HVDC at 11:27:28.344 hours, import of 444 MW (9.19% of total generation) stopped and that generation shortfall which caused an imbalance between demand and supply in the network. So, the system started to release kinetic energy consequently frequency declined rapidly and fallen to 48.636 Hz within 6.84 sec. Meanwhile under frequency scheme activated and frequency remained between 48.636 HZ to 49.636 Hz.

From the existing under frequency scheme it is observed that 69 MW load at 33 kV voltage level can disconnected through the first stage (48. Hz). Similarly 356MW and 576 MW load cab be disconnected through second stage (48.8 Hz) and third stage (48.7 Hz) respectively. But since the blackout took place at off-peak hour at around 11:28 hours hence all the 33 kV feeders were running well below their maximum load. Consequently, actual load shedding during frequency decline was far lower than expected load shed.

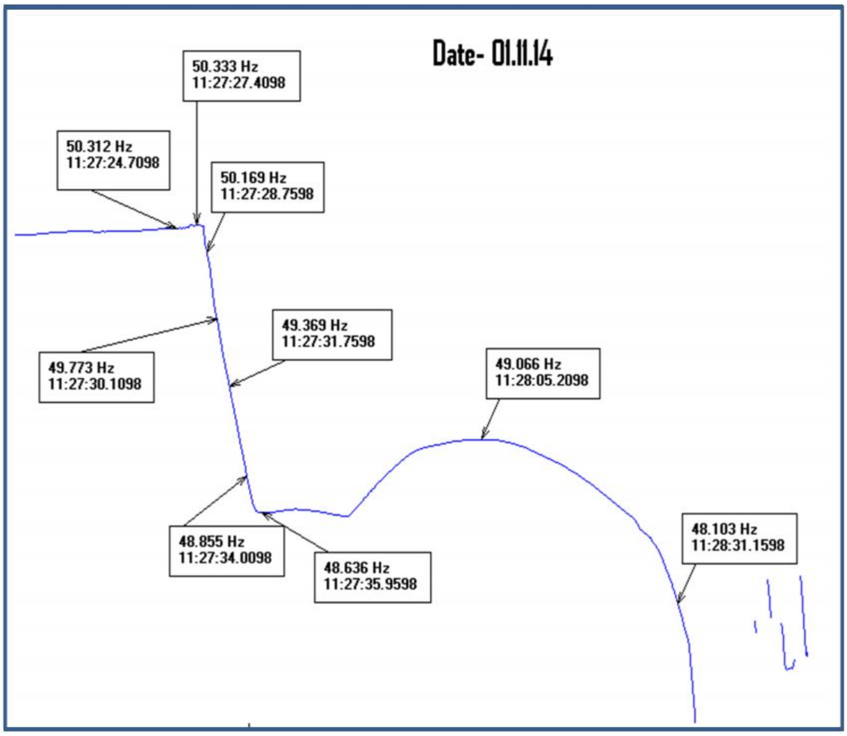

Figure 2.5: Frequency Transient prior to blackout on 1st NOV, 2014

From the frequency transient on 1st November, 2014 it is evident that a load cut off because of first sage operation of existing under frequency scheme could not affect the network frequency significantly. Action of second and third staged of under frequency. Prior to disturbance the system frequency was 50.312 Hz and down to 48.636 Hz within 6.8 sec. albeit under frequency scheme was activated but may be too late to remove the required amount of load to arrest frequency decline and finally the scheme cannot prevent the blackout of Bangladesh power system.

Load management with Smart grid is highly relevance to prevent of Blackout and blackouts are causing major economic losses [21].

➢ Electricity theft

“A task force of Dhaka Power Distribution Company (DPDC) has detected theft of some 8 lakh units of electricity in the city, disconnected illegal lines and fined Tk 2.5 crore. The task force has conducted the drive from 2 May to 27 May in DPDC areas.”

Picure2.2: Power theft test by manual [13]

It said by https://www.observerbd.com/details.php?id=71133. This is one scenario of power theft in Bangladesh. To prevent this theft should need take step as soon as possible.

The smart grid refers to the modernization of the power grid infrastructure with new technologies, enabling a more intelligently networked automated system with the goal of improving efficiency, reliability, and security, while providing more transparency and choices to electricity consumers. One of the key technologies being deployed currently around the globe is the Advanced Metering Infrastructure (AMI).

AMI refers to the modernization of the electricity metering system by replacing old mechanical meters by smart meters. Smart meters are new embedded devices that provide two-way communications between utilities and consumers, thus eliminating the need to send personnel to read the meters on site, and providing a range of new capabilities, such as, the ability to monitor electricity consumption throughout the network with finer granularity, faster diagnosis of outage with analog meters, utilities learned of outages primarily by consumer call complaints automated power restoration, remote disconnect, and the ability to send information such as dynamic pricing or the source of electricity (renewable or not) to consumers, giving consumers more and easier to access information about their energy use.

Advanced metering infrastructure

Practically, there are three ways to pay for a service. Before performing the service, after its execution and a combination of the two previous options, for example advance payment before the execution of service and additional payment or reimbursement after the execution. Payments and deposits may be divided into more parts, more advances or repayments. It is the same in the case of payments for other utilities (water, gas, heating, etc.). The most common model used for payments for energy is a combination of advance payments calculated on the basis of previous years and the subsequent settlement based on actual amount of the consumed energy at the end of the year, and additional payment or refund of the difference between the deposit and the actual amount. It is because no one knows in advance the amount of consumed energy by the customer in the next year and the supplier doesn't trust customers enough to allow them to pay the full amount after the energy consumption is billed to the customer. Practically the same situation is in the case of telecommunications services, but individual operators offer a much wider range of payment options and there are very popular prepaid cards, which allow the customer to pay for the service in advance.

Payments in advance are possible in energy billing, such advance payments bring the following advantages:

- The customer can’t consume more energy than he paid, and he can’t fall into unsustainable debt.
- Compliance of the individual requirements of customers. Some customers prefer this method of payment, even if it is not the cheapest solution for them.
- Payments are made in advance, which means earlier cash for suppliers.
- No additional billing system is needed.
- No charges for disconnecting, connecting or changing customer.

Smart metering is an essential part of the technology known as Smart Grids. This technology brings a breakthrough in the production, distribution and consumption of energies.

The basic components of the smart metering are the Smart Meters and two-way communication between the meter and the control center of the distribution company.

Smart Meter unlike conventional meters can measure more variables, in addition to monitoring the consumption of energy is also able to measure the quality of the delivered energy and energy consumption quality.

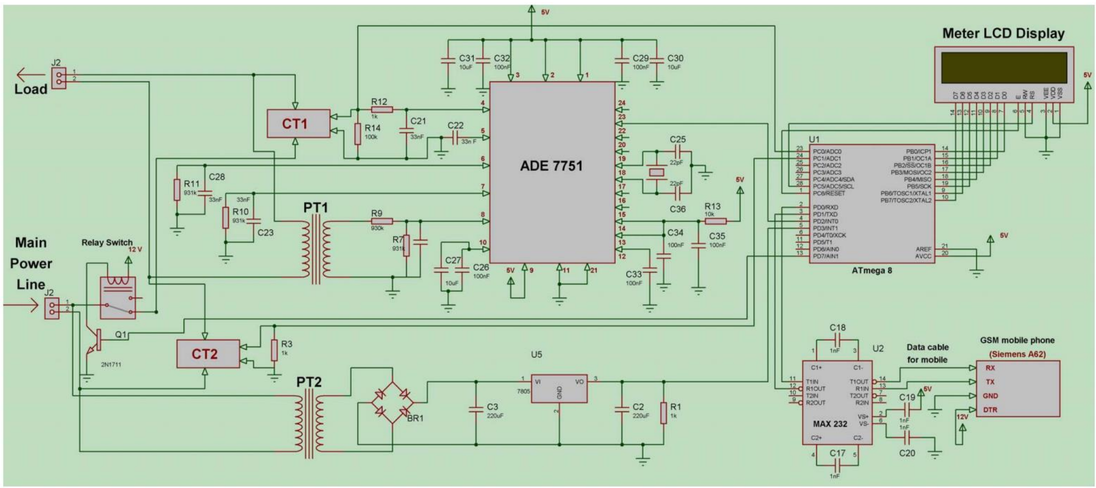

Figure 2.6: Complete circuit diagram of the smart metering.

Energy theft is one of the prime concern in AMI. It incurs a large financial losses in many countries. AMI method is based on principal component analysis to detect energy theft [19].

➢ Distributed energy resources and the microgrid

In Bangladesh, most of the power is generated from large-scale traditional centralized power stations. The generated power reach to the consumer through transmission and distribution (T&D) network associating higher loss and cost. The remote areas increase the cost and loss much more. However, large-scale power can be generated by multiple smaller scale power generation units, which are located at several locations within the entire service area. This is also known as decentralized generation or distributed generation, generating power in a decentralized manner.

For example, 500MW of power may be generated in a single power station or it may be generated by installing 500 numbers of generating units of 1MW, which are situated at different locations throughout the gird. Decentralization of generation removes the transmission network and only a low voltage distribution network is associated with it.

Distributed energy resources are small, modular, energy generation and storage technologies that provide electric capacity or energy where it is needed. There are options to be either connected to the local electric power grid or isolated from the grid in stand-alone applications for DER based system. DER technologies include wind turbines, photovoltaic (PV), fuel cells, micro-turbines, reciprocating engines, combustion turbines, cogeneration, and energy storage systems.

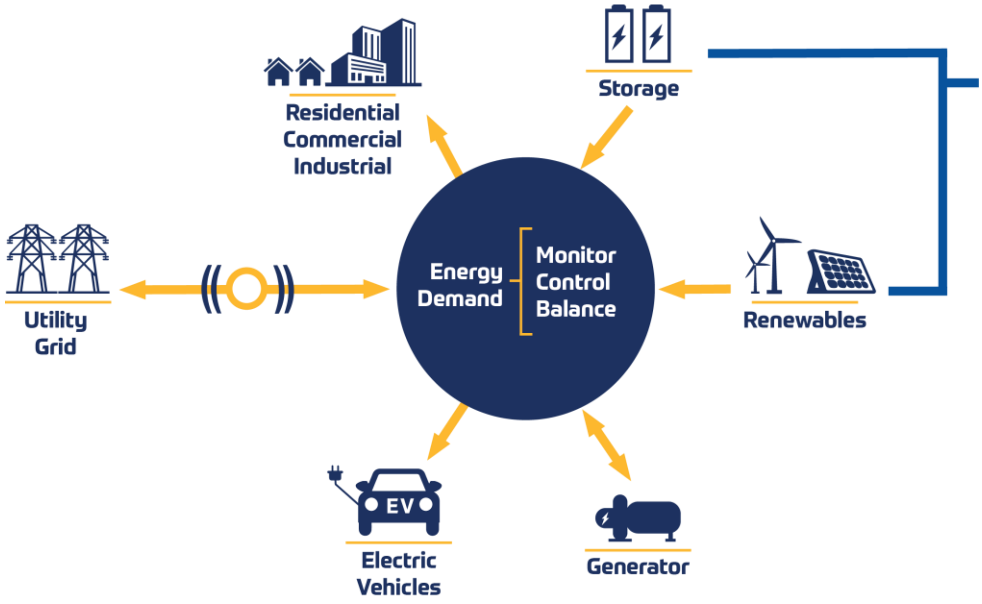

Figure 2.7: Distributed energy resources with minigrid system.

Distributed energy generation is a local and decentralized energy production system. A decentralized energy system is characterized by locating of energy production facilities closer to the site of energy consumption. As a relatively new field of research, several expressions are still currently used such as “decentralized generation”, “dispersed generation”, or “distributed energy resources” etc.

Distributed generation may be defines as a generator with small capacity close to its load that is not part of a centralized generation system. Also it is such kind electric power source that is connected directly to the distribution network or on the customer site of the meter. The key criteria in the definition of DER are the connection to the distribution network and the proximity to the end consumer [20].

Table 2.1: Smart grid relevant indicator

Problem	Value of Smart Grid	Relevance & Contribution
Blackout	Smart Grid could reduce blackouts dramatically.	Yes, it's highly relevance because of blackouts are causing major economic losses.
Distributed Energy Resources (DER) With Minigrid	Safer and higher integration of DER through active network management, DER management, advanced protection and controls	Yes, high relevance to effectively integrate between DER and Grid.
Electricity theft	Smart Grid can prevent electricity theft through Advanced Metering Infrastructure (AMI)	Yes, high relevance to effectively prevent and find out Electricity theft.

The above table clearly define that smart grid technology is highly relevant for Bangladesh. This very high time to adopt smart grid technology in Bangladesh.

Chapter 3

Scenario of Bangladesh Power System

3.1 Overview of Bangladesh Economy

The people's republic of Bangladesh is a country in South Asia. It is the eighth-most populous country in the world, with a population exceeding 164 million people. In terms of landmass, Bangladesh ranks 92nd, spanning 148,460 square kilometers (57,320 sq. mi), making it one of the most densely populated countries in the world. Bangladesh shares land borders with India to the west, north, and east, Myanmar to the southeast, and the Bay of Bengal to the south. It is narrowly separated from Nepal and Bhutan by the Siliguri Corridor, and from China by Sikkim, in the north, respectively. Dhaka, the capital and largest city, is the nation's economic, political and cultural hub. Chittagong, the largest seaport, is the second-largest city.

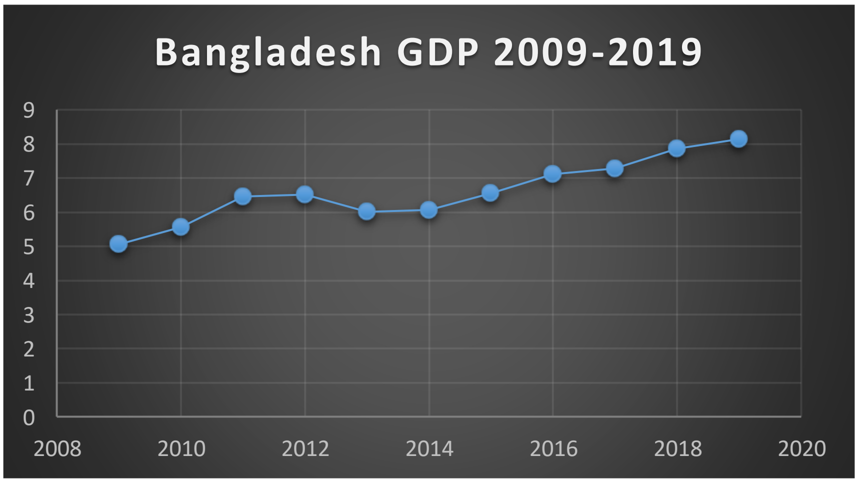

Chart 3.1: GDP Growth in Bangladesh [16]

The economy of Bangladesh is a developing market economy. It's the 35th largest in the world in nominal terms and 30th largest by purchasing power. it is classified among the Next Eleven emerging market middle income economies and a frontier market. Dhaka and Chittagong are the principal financial centers of the country, being home to the Dhaka Stock Exchange and the Chittagong Stock Exchange. The financial sector of Bangladesh is the second largest in the Indian subcontinent. Bangladesh is one of the world's fastest-growing economies.

Financial Year	GDP Growth	Annual Change
2019	8.15%	+0.29%
2018	7.86%	+0.58%
2017	7.28%	+0.17%
2016	7.11%	+0.56%
2015	6.55%	+0.49%
2014	6.06%	+0.05%
2013	6.01%	-0.51%
2012	6.52%	+0.06%
2011	6.46%	+0.89%
2010	5.57%	+0.53%
2009	5.05%	-0.97%

Table 3.1: Bangladesh GDP change 2009-2019

Bangladesh is considered a developing economy. Yet, almost one-third of Bangladesh's 165m people live in extreme poverty. In the last decade, the country has recorded GDP growth rates above 5 percent due to the development of the microcredit and garment industry. Although three-fifths of Bangladeshis are employed in the agriculture sector, three-quarters of export revenues come from producing ready-made garments. The biggest obstacles to sustainable development in Bangladesh are overpopulation, poor infrastructure, corruption, political instability, and slow implementation of economic reforms.

3.2 Electricity consumption scenario of Bangladesh

Key drivers of the power consumption growth are- steady population growth, urbanization, increasing per-capita income and higher purchase power, change in the lifestyle of country people, industrialization and increased digitalization. Bangladesh's population has been growing by around 1.5% each year. According to “World Population Prospects (WPP) 2015”, the population of Bangladesh will be 202 Million in 2050. The growing population implies an increasing demand for power consumption and a widening gap between supply and demand. Besides, the power demand is likely to increase substantially in line with rapid urbanization. Meanwhile, access to electricity in the country has seen steady improvement over the years as the country went through a long period of economic growth while favorable government policies to generate power in line with growing demand.

Currently Bangladesh is developing country and industry is growing up rapidly. Bangladeshi people change their life style. They use many type of Appliances that’s why domestic load is highest. Many types of consumption chart is below:

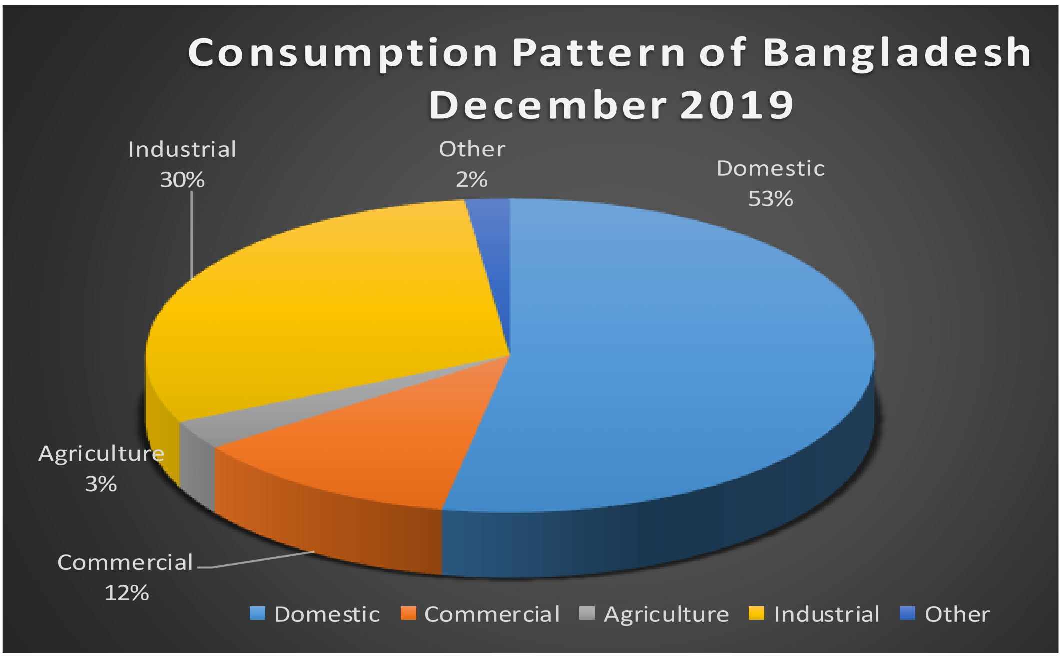

Chart 3.2: Electricity consumption pattern of Bangladesh [17]**.**

There are nine zones in the power distribution system in Bangladesh. Dhaka zone load demand is highest. Below the chart of area-wise load demand in Bangladesh.

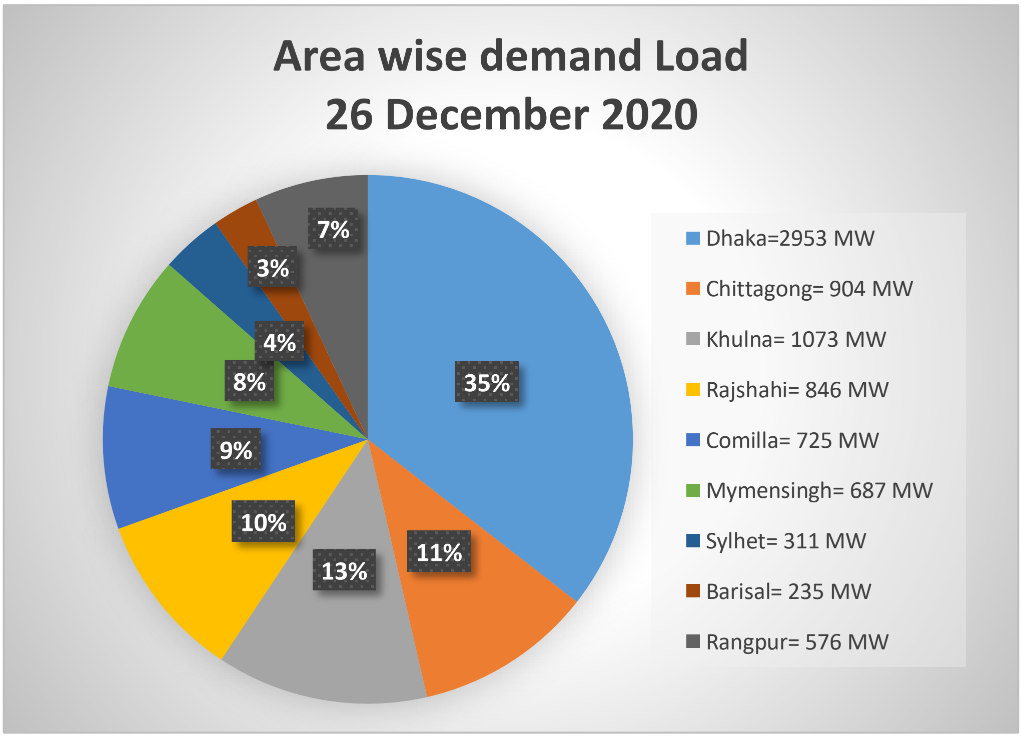

Chart 3.3: Area wise load consumption in Bangladesh [18]**.**

3.3 The structure of Bangladesh power system

Electricity is the main driving force of the country's economic development. Sustainable GDP growth and the country's growing economy need a sustainable, reliable and affordable electricity supply. Despite financial constraints and inadequate gas supply, the Bangladesh government has adopted various plans to meet the country's growing electricity demand.

In 1947, at the time of independence of India & Pakistan, the installed generating capacity in the then East Pakistan was only 21 MW. To formulate plans and improve the power supply situation of the country, the Electricity Directorate was established in 1948. Later, in 1959, “Water & Power Development Authority” (WAPDA) was created considering the growing demand for electricity and its importance in agriculture & industry. Later In 1971 the independence of Bangladesh the “WAPDA” was divided into two parts namely “Bangladesh Power Development Board” & “Bangladesh Water Development Board” by the Presidential Order 59 (PO-59) of 31st May 1972. As a result, Bangladesh Power Development Board (BPDB) was entrusted with the responsibilities of Operation, Maintenance, and Development of

Generation, Transmission & Distribution facilities of electricity throughout the country. By the ordinance (Ordinance No-LI of 1977), Rural Electrification Board (REB) was established for the development of electricity in the rural areas for the effective benefit of rural people in October 1977.

As part of the "Reforms-Funding" linkage agreed between the development partners and the Government, the implementation of Part (C) of the Project has been linked to redefining the franchise area of DESA and handing over of distribution networks outside Metropolitan Dhaka City to PBS's under REB, and formation of a corporatized Dhaka Electric Supply Company (DESCO) which will initially take over part of the distribution network of DESA and ultimately take over all its assets. Under the reform program, Dhaka Electric Supply Authority (DESA) was created for the proper management & electrification in Dhaka city and its adjoining areas in 1990. DESCO has started functioning in 1996 after taking over part of the distribution network of DESA. DESA has reformed again as Dhaka Power Distribution Company (DPDC) in July 2008.

Under the Companies Act, 1994, Power Grid Company (PGCB) was created in 1996 to look after the transmission system. The main operating function of PGCB is the wheeling of energy from BPDB power stations and Generation Companies to Distribution entities utilizing the transmission network. PGCB gets its energy wheeling charge from its clients (distribution entities) at the rate fixed by the Bangladesh Electricity Regulatory Commission (BERC).

Ashuganj Power Station has been converted into Ashuganj Power Station Company Ltd. (APSCL) in 1996, as a subsidiary company of BPDB. Northern Electricity Supply Company Ltd. (NESCO) was created in 2016 to look after the distribution system of the Rajshahi and Rangpur zone. NESCO is a distribution subsidiary of BPDB. West Zone Power Distribution Company Ltd. (WZPDCL) was created in 2002 to look after the distribution system of Barishal and Khulna Zone. WZPDCL is a distribution subsidiary of BPDB. Electricity Generation Company of Bangladesh (EGCB) has been formed as a Generation Company since 2004. EGCB has implemented 2x105 MW Peaking Power Plant at Shiddirgonj, 412 MW CCPP at

Haripur and 335 MW CCPP at Shiddirgonj. North West Power Generation Company (NWPGCL) was created in 2008. NWPGCL has implemented 225 MW Combined Cycle Power Plant at Sirajganj, 225 MW Combined cycle Power Plant at Khulna, 360 MW Combined cycle Power Plant at Bheramara, 225 MW Combined cycle Power Plant at Sirajganj (2nd unit), 225 MW Combined cycle Power Plant at Sirajganj (3rd unit) and 105 MW power plant at modhumoti, Bagerhat.

As a part of the new reform initiative, BPDB is currently in the process of identifying the Strategic Business Unit (SBU) for its generation and distribution sectors. According to the BPDB latest annual report, the functional and financial performance of the SBUs will be operated like components of a corporate body and will be evaluated separately under the legal framework of the existing BPDB structure.

Bangladesh power sector is mainly look after by Ministry of Power, Energy and Mineral Resources (MoPEMR). Power division is a wing of ministry of power, energy and mineral 16 resources. Power division has for sub sectors. These are-Power Cell, CE & EIA, SREDA, Bangladesh Energy and Power Research Council.

An electrical power system has three major segments. These three segments are generation, transmission and distribution. Electricity is produced from primary fuel in the generation subsector. The transmission network carries power produced at generation to the major load centers like grid known as transmission and finally connects to the end users i.e. retail customers though distribution system. As economically viable utility-scale electricity storage system is yet to be developed, demand created at the distribution system must be met instantaneously by producing power at the power generating stations and transmit through the transmission network, which bridges generation and distribution.

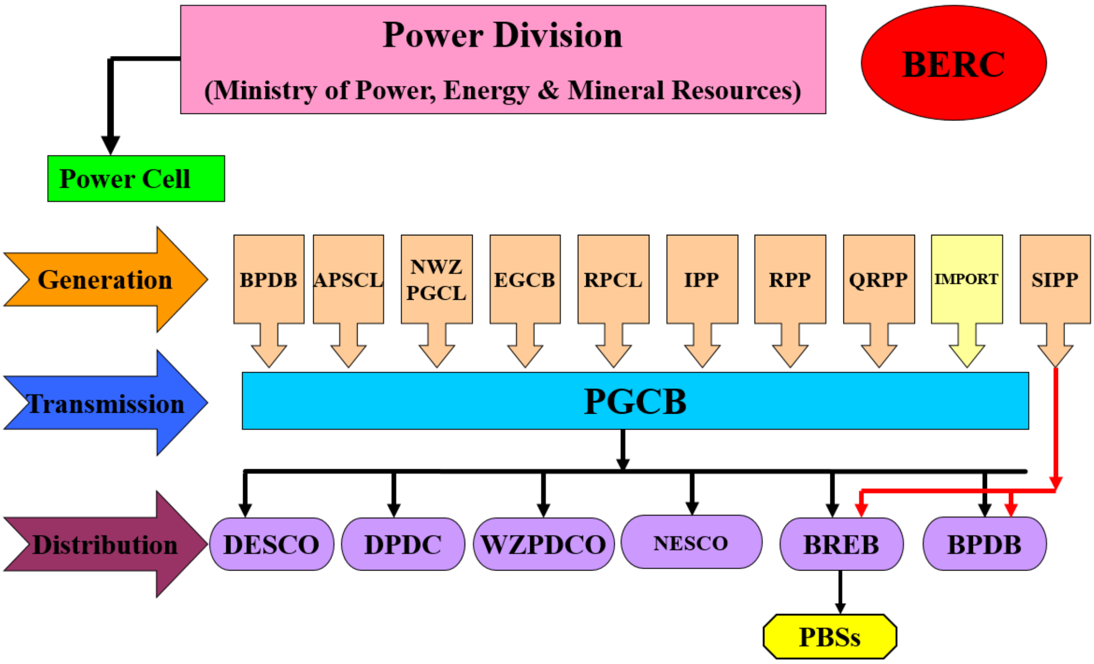

Figure 3.1: Bangladesh power system structure [19]

In Bangladesh, both public and private organizations responsible for generation. BPDB, APSCL, EGCB, NWPGCL, RPCL, CPGCBL, Joint venture, BPDB- RPCL Powergen Ltd. are Utility Generation BPDB APSCL EGCB NWPGCL RPCL CPGCBL Joint Venture B-R Powergen Ltd. IPP SIPP Transmission PGCB Distribution BPDB BREB PBS DESCO DPDC WZPDCO NESCO 18 public power generation entity. IPP, SIPP (Summit, Orion, Sinha etc.) are treated as private power generation entity.

Only PGCB is responsible for transmission of electricity from generation end to distribution end. PGCB maintain the only grid of Bangladesh. National Load Dispatch Center (NLDC) always keeps the load balance with generation. NLDC is one of the wing of PGCB.

Only government organizations are responsible for power distribution. BPDB, DESCO, DPDC, BREB, PBS, NESCO, WZPDCL are responsible for electricity distribution in Bangladesh.

3.4 Electricity generation in Bangladesh

Up until 2016, the major consideration of energy source for power generation was Natural gas, which is now being shifted to Coal and LNG, as the deposited amount of natural gas remains uncertain. Due to no significant gas discovery in recent years, the country is now facing a shortage of gas supply that has been discouraging gas-based power generation; therefore the government is now looking for big power projects to be run on Coal or other types of Energy the future. Meanwhile, Bangladesh has already started to import LNG and planning to shift its concentration to LNG-based power stations in the future.

As of now, Furnace Oil, HFO and Diesel based plants are the best available alternatives for producing electricity. However, Oil based power plants are highly expensive compared to Gas based plants. So, Oil based plants are the only short-term solution to mitigate the supply shortage of power within the shortest period.

Coal is the next available alternative. It can be a near-term option and can be indigenous or imported. However, Coal based power projects are highly debated as they might be harmful to the environment. Since the last few years, the government has been encouraging coal based projects for mitigating electricity shortage and to reduce dependency on gas based expensive fuel oil based plants.

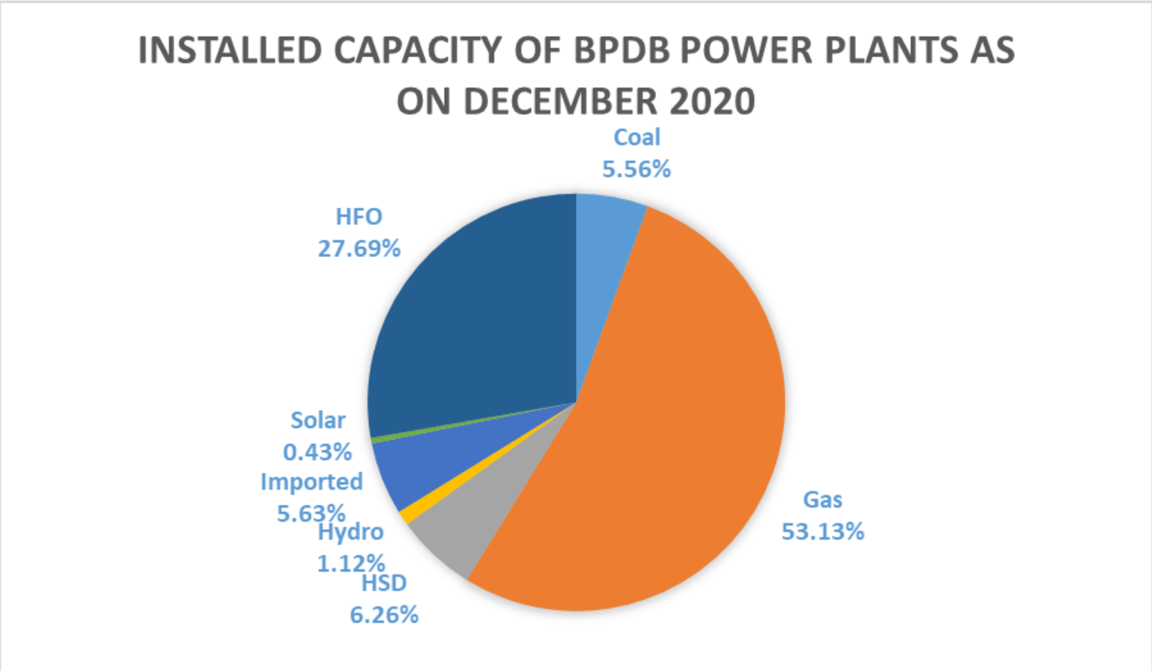

Chart 3.4: Electricity generation by various source [www.bpdb.gov.bd].

The government of Bangladesh is investing heavily to construct a nuclear based power generation plant at Rooppur, Pabna having a 2,400 MW capacity. Rooppur nuclear power plant will start electricity production by 2025.

3.4.1 Electricity Generation Company

There are many companies for power generation systems in Bangladesh.

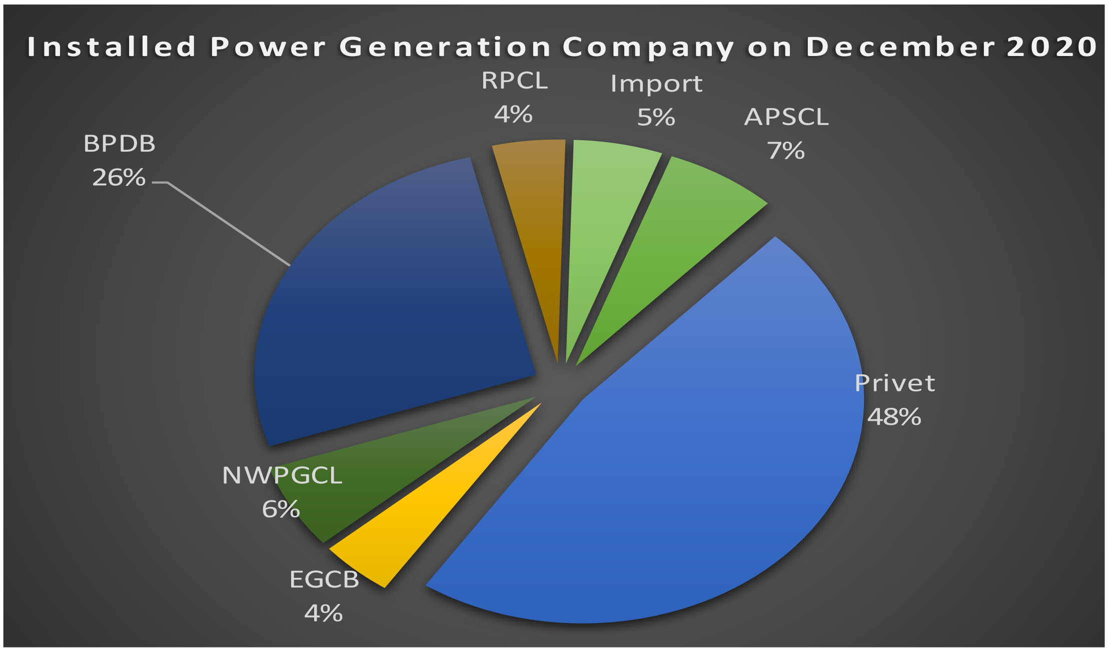

Chart 3.5: Installed power Generation Company wise [www.bpdb.gov.bd].

1) **APSCL:** Ashuganj Power Station Company Ltd. A government-owned public limited company and the largest power hub in Bangladesh. The current total power generation capacity of its 06 units is 1690 MW.
2) **NWPGCL:** North West Power Generation Company Ltd. a company currently operates six power plants. Power plants are playing a major role in socio-economic development including meeting the power demand of the country. The company has acquired the capability to implement power plants of any size by using all types of fuel at affordable prices.
3) **EGCB:** Under the Power Sector Reform of the Government of Bangladesh, Bangladesh Power Development Board was formed as a private limited company under the Companies Act, 1994. The current total power generation capacity of Electricity Generation Company (EGCB) Ltd.'s three power plants is 957 MW.

4) **RPCL:** Rural Power Company Limited (RPCL) was registered as a public limited company on December 31, 1994, by the Office of the Registrar of Joint Capital Companies and Firms to address the power crisis in the country. The company currently owns 953 MW through 04 (four) power plants and BPDB-RPCL Powergen Limited is a joint venture. Over the years, RPCL has gained extensive experience in implementing new projects, operating and maintaining power plants. Entrepreneurs of Bangladesh Rural Electrification Board and 05 Palli Bidyut Samiti RPCL. Subsequently, eight more PBS were acquired in phases, at present a total of thirteen pubs and shareholders of Bangladesh Rural Electrification Board RPCL.
5) **BPBD:** The BPDB is responsible for the major portion of the generation and distribution of electricity mainly in urban areas of the country. The Board is now under the Power Division of the Ministry of Power, Energy and Mineral Resources. BPDB is responsible for the generation and distribution of a large part of the country's total electricity demand. As of January 2020, BPDB had a total installed capacity of 5613 MW at its power plants located in different parts of the country. The main fuel used for power generation in BPDB plants is indigenous natural gas. BPDP operations also include projects that utilize renewable power sources including offshore wind power generation.
6) **Import:** Bangladesh imports 1,160 megawatts (MW) electricity from India. According to the Power System Master Plan 2016 with HVDC system.
7) **Privet:** Bangladesh has been maintaining a very significant GDP growth rate over the past few years which causes high electricity demand among the consumers. In 2009, when the current government came into power there was high pressure on them to provide an adequate amount of electricity to the different sectors. The name quick rental power plants itself suggests that the rental power plants are easy to set up and therefore, can supply electricity to the national grid within a very short period. The additional power supplied to the national grid through the QRPPs has made a significant positive impact in many areas of the economy. The supply of additional power has no doubt contributed to the expansion of economic activities in various sectors including manufacturing industries, RMGs, commercial and business activities, agriculture through providing irrigation and better marketing and processing services, and trade, communication, and other services.

3.5 Electricity Power Transmission

Electric power transmission is the bulk movement of electrical energy from a generating site, such as a power plant, to an electrical substation. The interconnected lines which facilitate this movement are known as a transmission network.

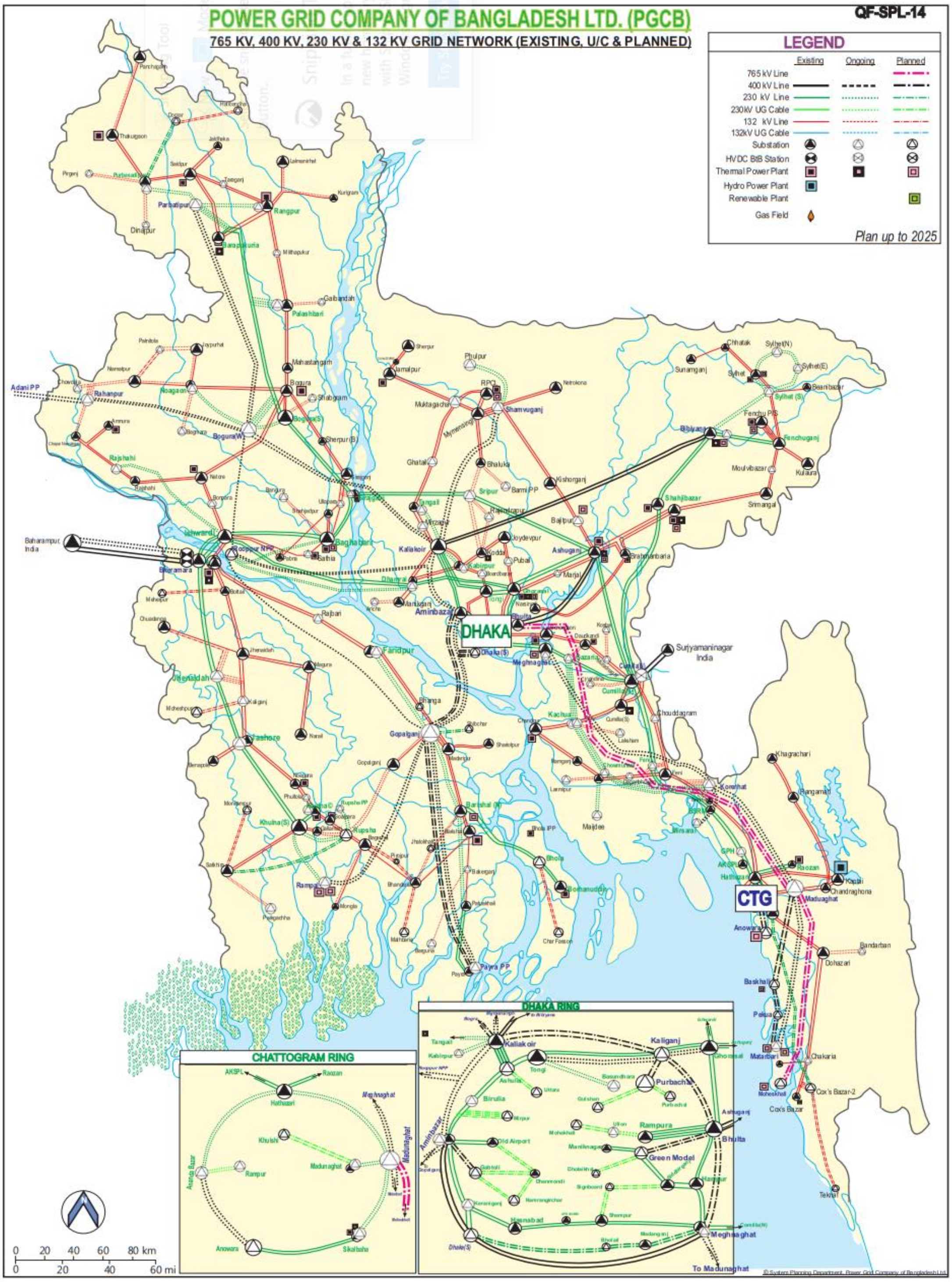

Figure 3.2: Map of Bangladeshi transmission line existing ongoing planning [https://www.pgcb.org.bd/PGCB/images/geo-map.pdf]

3.5.1.1 Power Grid Company of Bangladesh

PGCB is the only power transmission company in Bangladesh. Power Grid Company of Bangladesh Ltd. (PGCB) was created under the restructuring process of the Power Sector in Bangladesh to bring about a commercial environment including an increase in efficiency, the establishment of accountability and dynamism in accomplishing its objectives. It was entrusted with the responsibility to own the national power grid to operate and expand the same with efficiency. PGCB completed taking over all the transmission assets on 31.12.2002. Since then, PGCB is operating those efficiently and effectively.

Table 3.2: Present transmission line infrastructure information

Transmission infrastructure Information	
Transmission Line as of December 2020	
400 kV	861 Circuit km
230 kV	3,658 Circuit km
132 kV	7,870 Circuit km
Total	12,389 Circuit

*Optical Fiber Ground Wire Network: 6,200 km

Table 3.3: Present substation number and information

Substation as of December 2020	
400 kV HVDC	1 Nos. 2*500 MW HVDC Back to the Back station
400/230 kV	4 Nos. 3,772 MVA
400/132 kV	2 Nos. 1,300 MVA
230/132 kV	28 Nos. 13,985 MVA
132/33 kV	145 Nos. 27,760 MVA

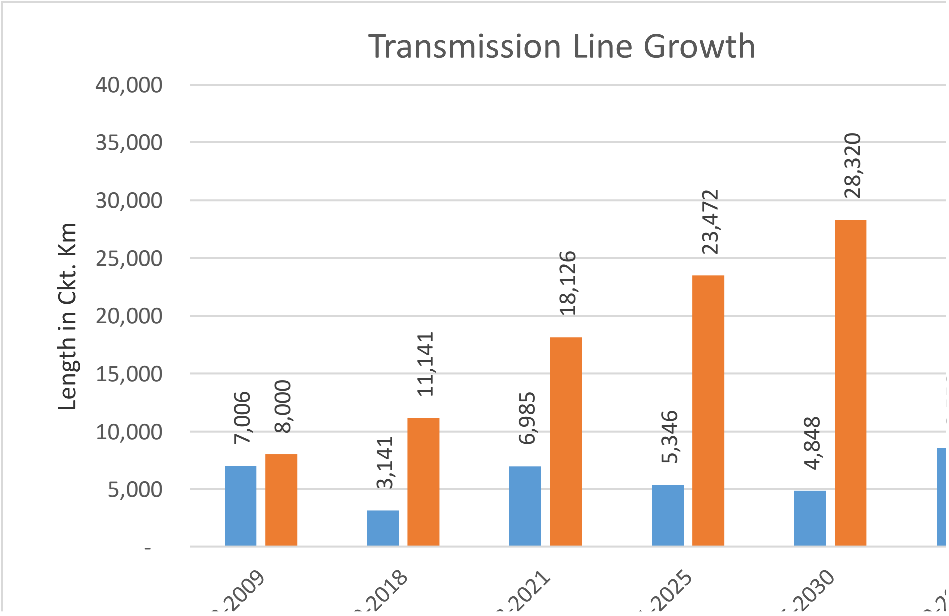

Chart 3.6: Transmission line growths

Table 3.4: Transmission Line projection plan

	2021 (Ckt. length in km)	2030 (Ckt. length in km)	2041 (Ckt. length in km)
765Kv	0	1380	1740
400Kv	3194	5530	7962
230Kv	5086	7783	9717
132Kv	9846	13627	17451
Total Circuit km=	18126	28,320	36074

Transmission Line projection plan in Circuit km

3.5.1.2 SCADA:

Since the start of its operation in 2010, the existing SCADA/EMS has been in service for about eight years. Although the service life of the hardware is already over, the policy on next generation SCADA/EMS has yet to be determined. Furthermore, considering the facility expansion plans in the future, PGCB also has many problems with its supervisory control system. Not having developed its specific policy on the supervisory control system, PGCB is unable to work out a facility replacement plan. Given this background, PGCB already planned and authorized the replacement of SCADA/EMS hardware this year or next year. It is expected that the service life of the existing SCADA/EMS will be extended by about 5 to 8 years because of this hardware replacement.

1) Hardware Configuration The equipment connected to RTU LAN is the RTUs of substations. The equipment connected to SCADA LAN includes each function server of SCADA, workstations for operational use, workstations for maintenance use, and a supervisory control terminal.
2) Applications the function for adjusting electricity supply and demand is currently disabled due to a connection problem with other pieces of equipment. However, this function will be enabled through the upcoming "Bangladesh Power System Reliability and Efficiency Improvement Project of the World Bank.

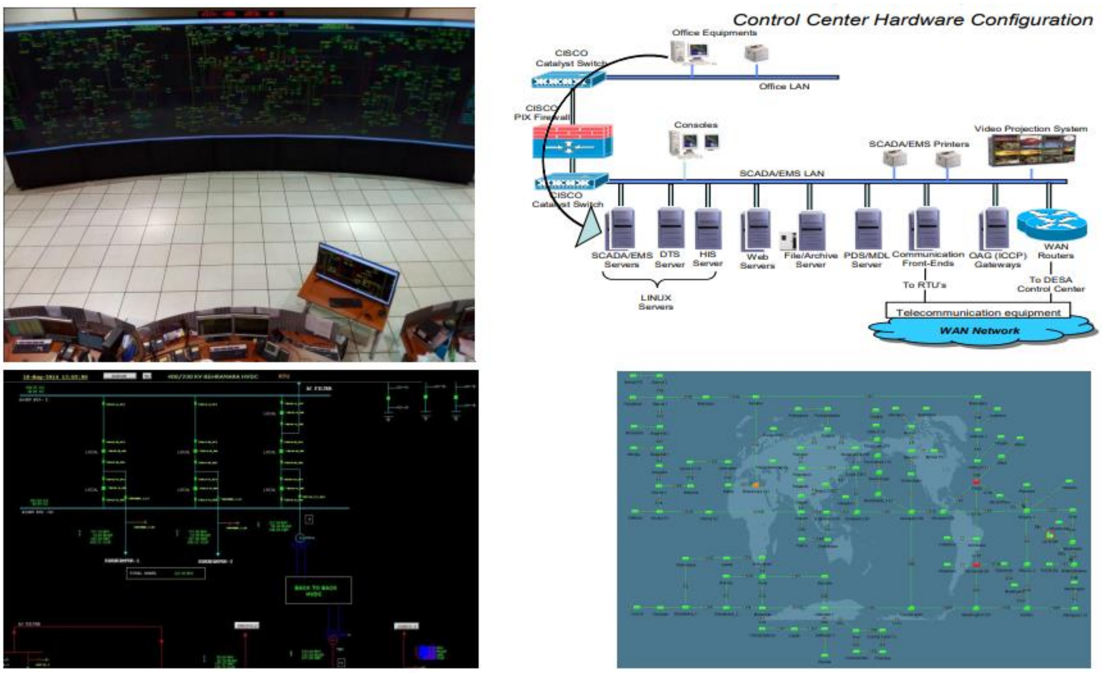

Figure 3.3: Control center hardware configuration.

Figure 4-6 shows the configuration of the optical fiber network PGCB owns. PGCB sets up optical ground wires (OPGW), a type of cable that mounts optical fiber cable inside the overhead ground wire designed to protect high-voltage transmission lines from direct lightning strokes. PGCB has its proprietary power line carrier (PLC) communication system in place. However, because the speed of its existing PLC communication equipment is not at a satisfactory level, PGCB is trying to improve its communication system by installing high-speed optical fibers using multiplexers.

As a result, the total length of the OPGW became 4,300km as of June 2012, and over 5,000km today (according to our hearing survey), covering most of the land of Bangladesh. Not just for PGCB itself, the optical fiber network has expanded rapidly enough to lease it to local telecommunications carriers and grow the country's communication infrastructure.

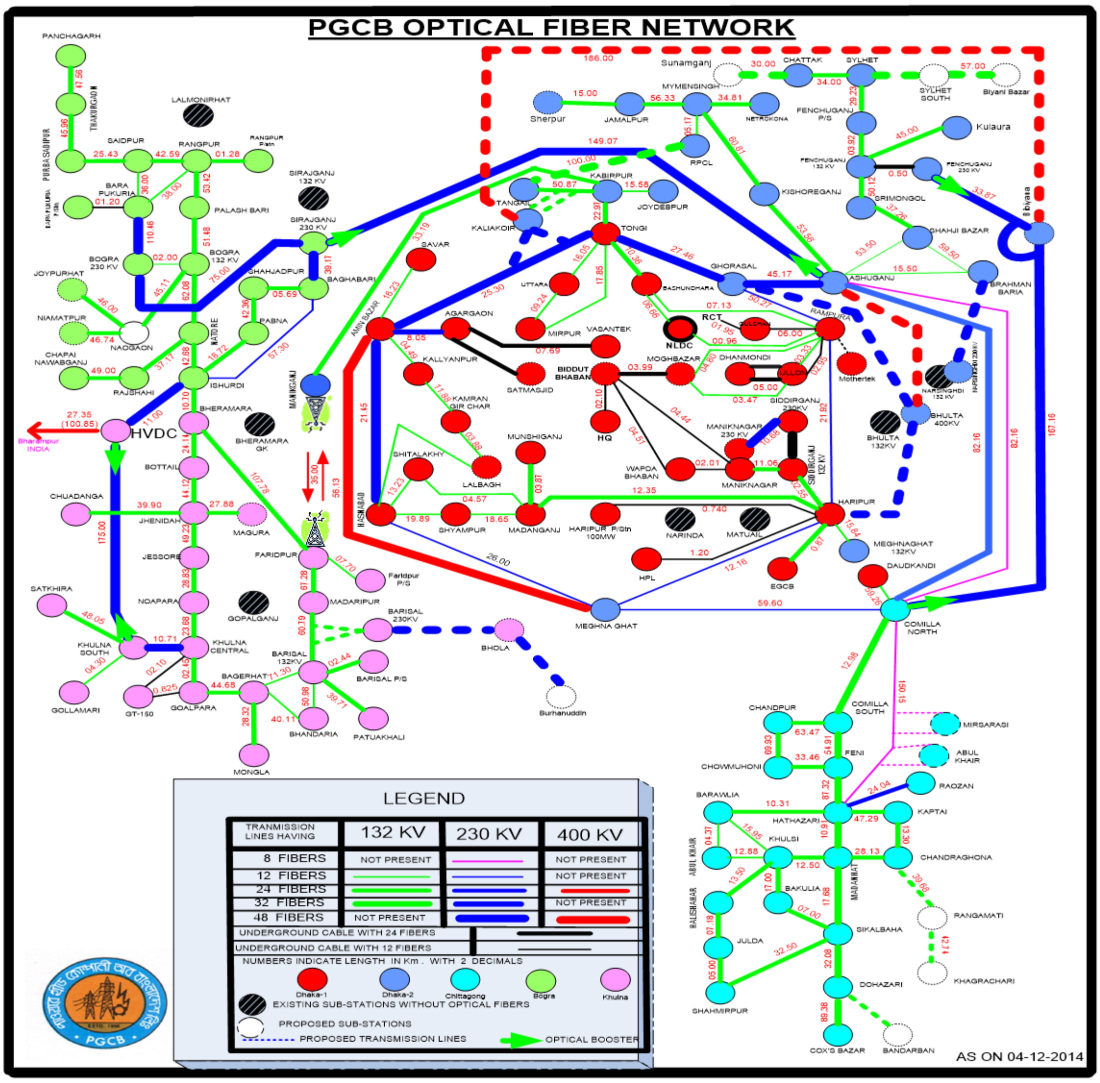

Figure 3.4: OPGW circuit map of PGCB

3.5.1.3 National Load Despatch Centre

National Load Despatch Centre (NLDC) under PGCB is entrusted with the responsibility to oversee voltage and frequency. Generation schedules, plant despatch, plant outage etc. are operated by BPDB (Single Buyer) through NLDC. There are six state-owned distribution entities including BPDB having a total of 401,000 kilometer distribution lines. The role of NLDC (PGCB's unit) is to play an independent role for plant operation and merit order dispatch between the public and private sectors. Sometimes conflict arises during load sharing at the grid level by the distribution entities. Under this context, the government intends to establish an Independent System Operator (ISO) by separating NLDC from PGCB. Accordingly, to establish ISO, a provision has been incorporated in the proposed Electricity Act, 2017 which is under enactment by the Parliament.

Picture 3.1: NLDC control room

3.6 Power distribution system of Bangladesh

BPDB is responsible for the distribution of electricity in most urban areas in Bangladesh except Dhaka Metropolitan City and its adjoining areas under DPDC and DESCO, areas under West Zone Power Distribution Company Limited (WZPDCL), Norther Electricity Supply Company and some of the rural areas under Rural Electrification Board (REB).

3.6.1 Dhaka Electric Supply Company (DESCO)

Dhaka Electric Supply Company (DESCO) Ltd. on November 03, 1996 became the first state-owned power distribution company in the country under the Companies Act 1994 to manage the power distribution system and improve financial management and change the quality of life under the ongoing restructuring activities of the very important power sector in Bangladesh.

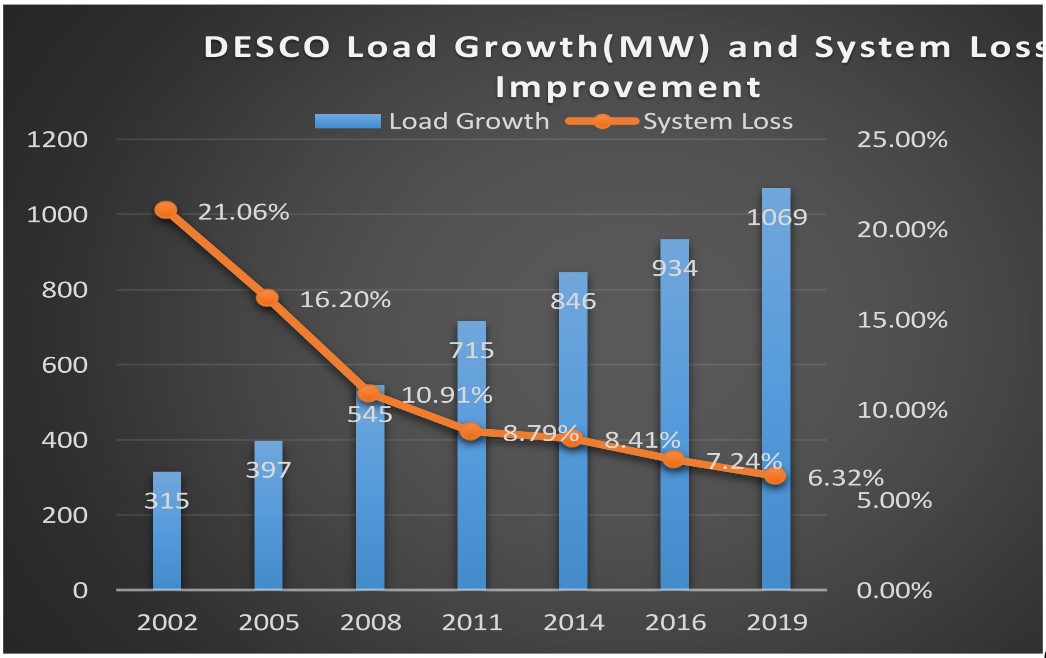

Chart 3.7: DESCO Load Growth and system loss improvement

3.6.2 Dhaka Power Distribution Company (DPDC)

Dhaka Power Distribution Company Limited (DPDC) is the largest power distribution company in Bangladesh. Dhaka Power Distribution Company Limited (DPDC) was formed on October 25, 2005 under the Companies Act, 1994. DPDC started its operations with 655,908 subscribers and now has 1404,613 subscribers (September 2020). DPDC distribution of electricity to the customers of the Dhaka City Corporation area.

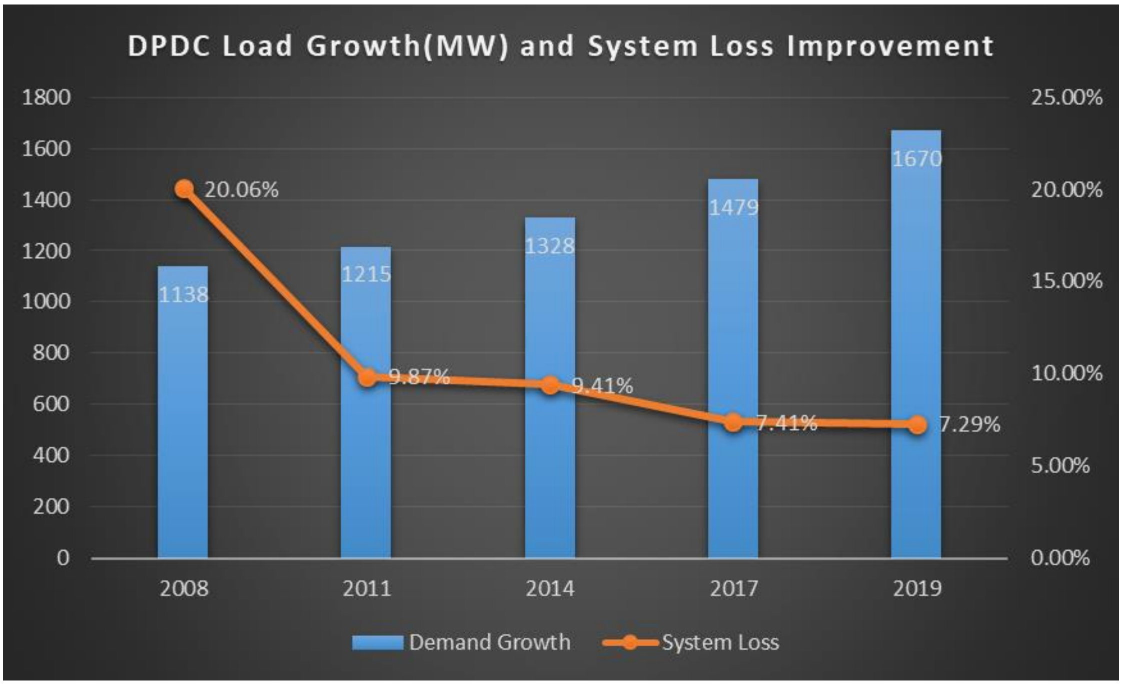

Chart 3.8: DPDC Load Growth and system loss improvement

3.6.3 West Zone Power Distribution Company (WZPDCL)

West Zone Power Distribution Company was formed with 21 districts and 20 Upazilas of Khulna, Barisal and Greater Faridpur Division. As part of the reform program, WZPDCL was formed as a power distribution company in November 2002 under the Public Limited Companies Act, 1994 to reduce system losses and strengthen the financial position in the power generation, management and distribution system, including the division of the power sector. The company took over the operations and distributions of the board in the Western zone.

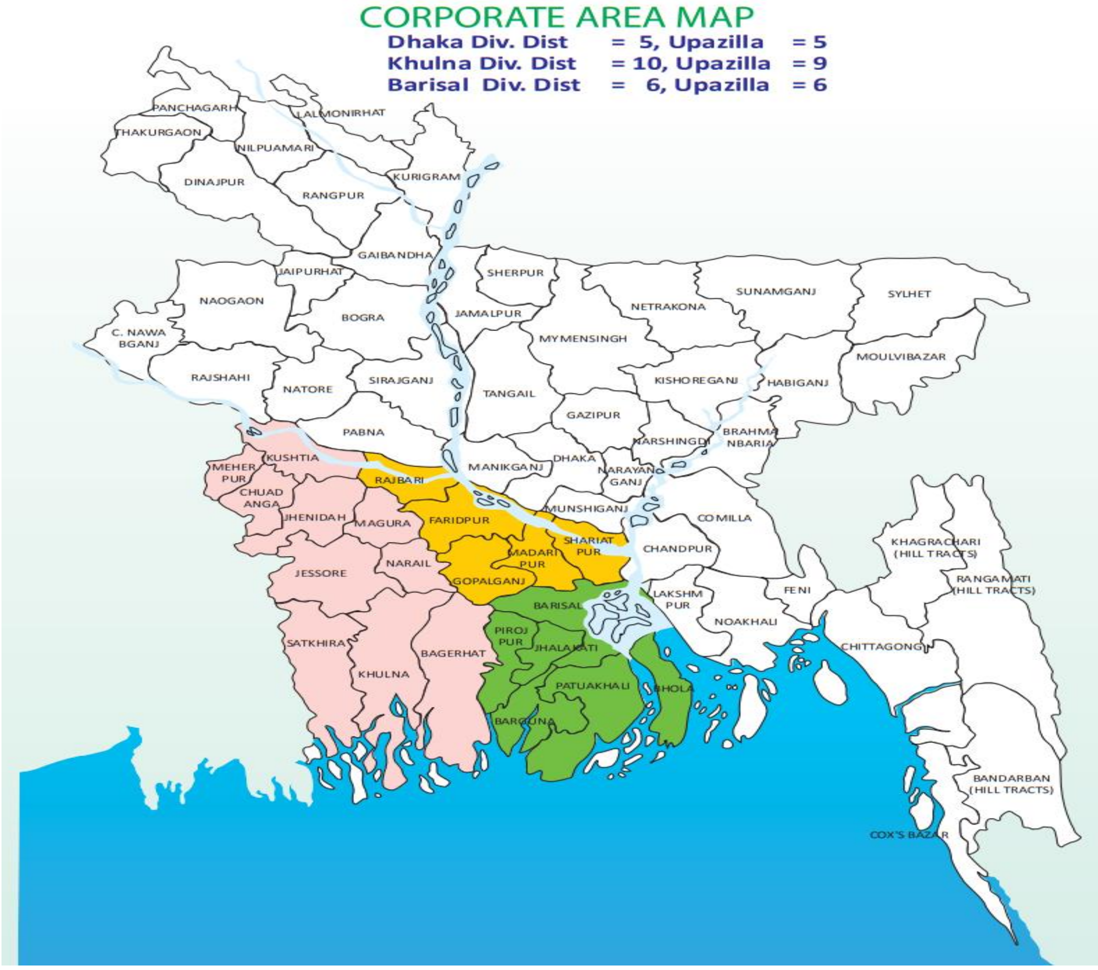

Figure 3.5: WZPDCL Power Distribution Area

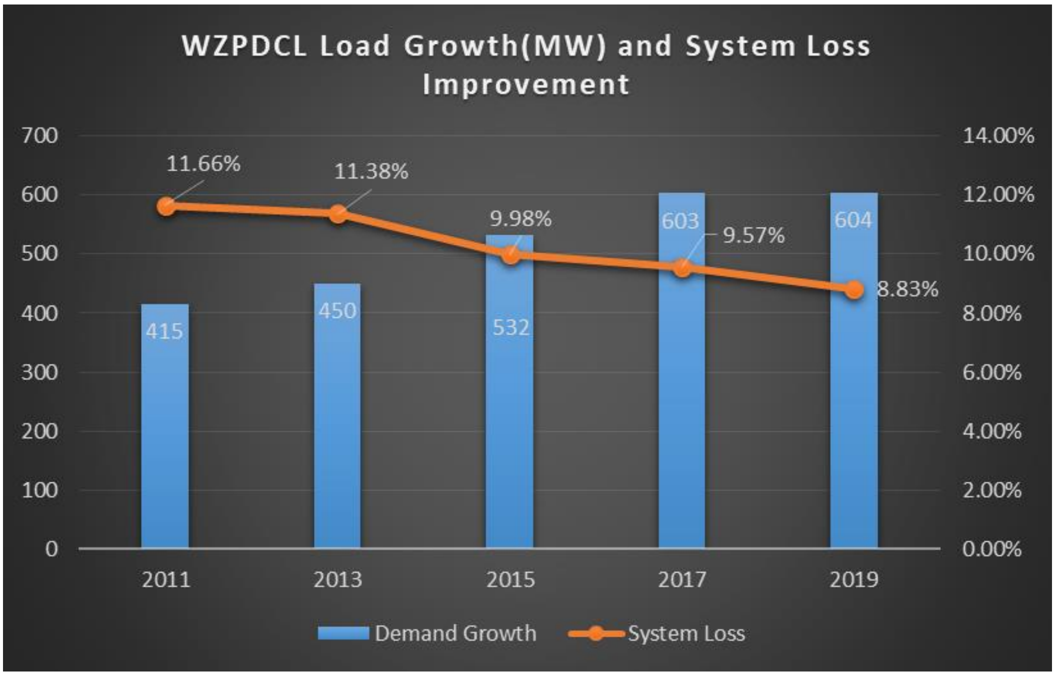

Chart 3.9: WZPDCL Load Growth and system loss improvement

3.6.4 Northern Electricity Supply Company Limited (NESCO):

Northern Electricity Supply Company (NESCO) Limited is an organization of Bangladesh Power Development Board. NESCO Ltd. is working to provide better customer service to about 1.5 million customers in 24 Upazila towns and urban areas under 16 districts of Rajshahi and Rangpur divisions of the northern region. Northern Electricity Supply Company (NESCO) Limited started commercial activities on October 1, 2017, taking all the assets and liabilities from Bangladesh Power Development Board.

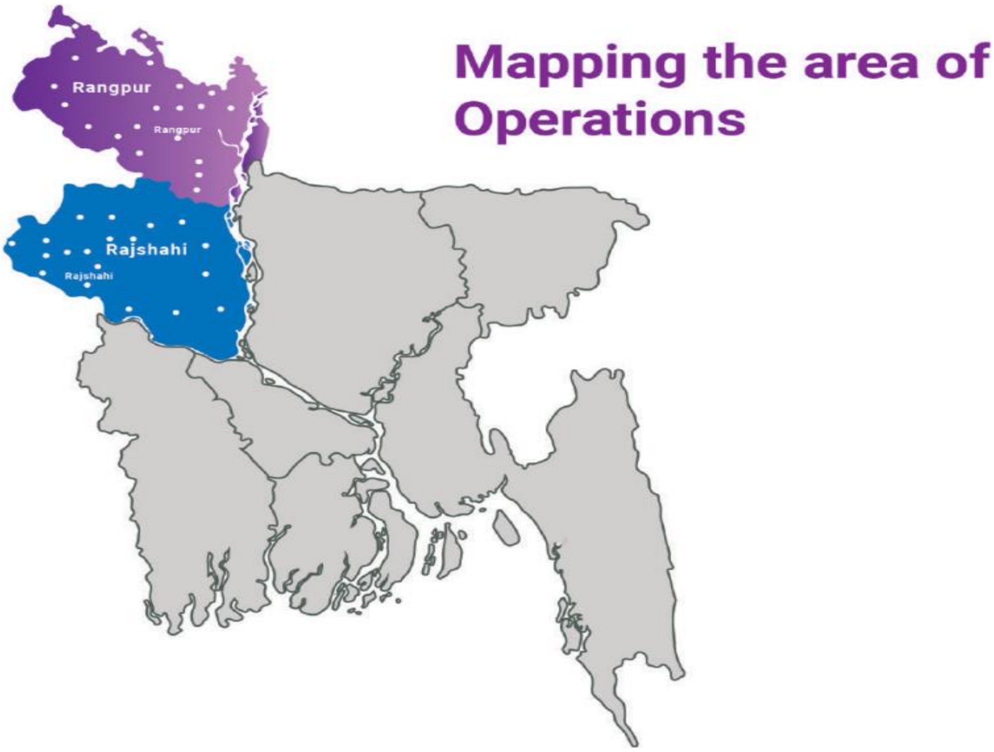

Figure 4.6: Area map of Northen Electricity Supply Company ltd.

Table 3.5: Technical report of NESCO

Particulars	2016-17	2017-18	2018-19	2019-2020
Energy Import (MKWh)	3429.28	3627.276	3916.51	3937.548
Energy Sales (MKWh)	3020.89	3214.368	3504.925	3517.668
Energy Import (MTk)	1360.86	1846.11	1870.99	1951.560
Energy Sales (MTk.) (Gross Billed)	18726.90	20752.61	23147.937	23878.965
System Loss (%)	11.91	11.38	10.51	10.66
Bill Collection Ratio (%)	96.49	96.89	98.48	97.79
C.I. Ratio (%)	85.00	85.05	88.13	87.36
Consumer Nos.(June)	1293256	1378258	1477886	1568982
Receivable/Sales (%)	30.34	30.91	25.94	26.63

3.6.5 Bangladesh Rural Electrification Board (BREB):

Bangladesh Rural Electrification Board or BREB is a government organization in Dhaka, Bangladesh and is responsible for rural electrification. Rural Electrification Board was established in 1977. It implements electrification of rural areas in Bangladesh and builds electrical lines and substations. Its counterpart Bangladesh Power Development Board manages electric distribution in urban areas. Palli Bidyut Samities (PBS) is a subsidiary of the board and acts as a consumer cooperative. The board has expanded rural electric connections rapidly. It has taken some market shares of solar energy.

Over the last 48 years, the program has reached about 461 Upazillas of the country, thus making it a core development program. The program has brought light to many families, hitherto remaining in complete darkness. It has given them enlightenment towards modern living, freedom from poverty, malnutrition and hunger. Electricity has brought many families close to rural homes. Some of them are thinking of taking new initiatives in the industrial and agricultural sectors.

Table 3.6: BREB technical report

1	Total PBSs	80 Nos.
2	Approved Projects	81 Nos.
3	The district included in RE program	61 Nos.
4	Upazillas included in RE program	462 Nos. (461 On-grid & 01 Off-grid)
5	100% Electrified Upazillas	288 Nos. (Opening Completed) 173 Nos. (Waiting to inaugurate)
6	Villages included in RE program	84,800 Nos.
7	Villages Electrified	84,409 Nos.
8	House Hold in Program Area	2,51,68,763 Nos.
9	Population in Program Area	10,68,93,673 Nos.
10	Line constructed	5,43,785 Km
11	Line energized	5,21,296 Km
12	Number of 33/11KV Sub-station & Capacity	1095 Nos. & 13,985 MVA
13	System loss (80 PBSs)	10.42% (12 Month Avg)
14	Monthly Sales	Tk 2000 Crore
15	Bill collection	96.73%
16	Peak demand	7100 MW

Information about REB in a nutshell

Chapter 4

Advanced metering Infrastructure Technology

4.1 Introduction

To achieve an intelligent grid, a succession of sub-systems should be realized. The solid establishment and functionality of each sub-system is instrumental in overall SG performance, as each layer's output serves as the feed for the next layer [4].

AMI is not a single technology. Rather, it is a configured infrastructure that integrates a number of technologies to achieve its goals. The infrastructure includes smart meters, communication networks in different levels of the infrastructure hierarchy, Meter Data Management Systems (MDMS), and means to integrate the collected data into software application platforms and interfaces [4]. The customer is equipped with an advanced solid state electronic meter that collects time-based data. These meters can transmit the collected data through commonly available fixed networks, such as Broadband over Power Line (BPL), Power Line Communications (P), Fixed Radio Frequency, as well as public networks such as landline, cellular and paging. The metered consumption data are received by the AMI host system.

Subsequently, it is sent to a MDMS that manages data storage and analysis and provides the information in a useful form to the utility service provider. AMI enables a two-way communication; therefore, communication or issuance of command or price signal from the utility to the meter or load controlling devices are also possible [5].

4.2 Advanced metering infrastructure definition

Advanced Metering Infrastructure (AMI) refers to systems that measure, collect and analyze and communicate with metering devices such as electricity meters, gas meters, heat meters and water meters as requested or scheduled. Advanced metering infrastructure two way communication system between the electricity distributor and the users. The heart of the model is the Smart meter. It's quite different from a normal metering device and will be installed in each user's house. It will maintain an overall record of the power being supplied as well as user's consumption [22].

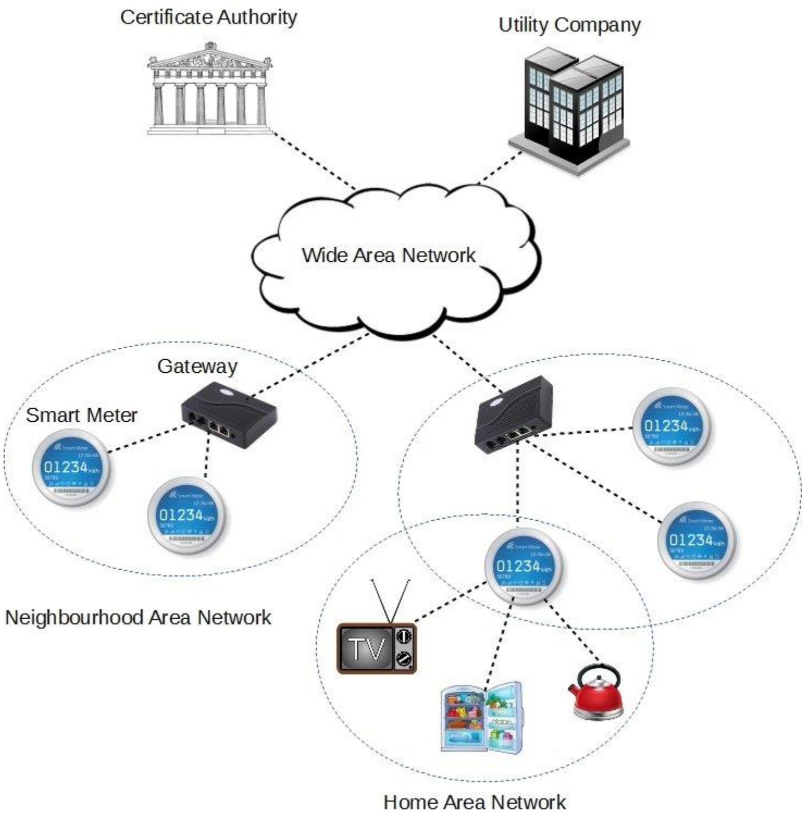

Figure 4.1: Advanced metering infrastructure (AMI) Basic diagram

These systems include hardware, software, communications, consumer power display and controllers, customer-related systems, meter data management software, and supplier business systems. Government agencies and utilities are moving towards improved metering infrastructure (AMI) systems as part of a larger "smart grid" initiative. AMI enhances automatic meter reading (AMR) technology by providing two-way meter communication, allowing time-based pricing information, demand-response action, or the sending of commands to homes for multiple purposes, including disconnecting remote services. Wireless technologies are critical elements of the neighborhood network, aggregating a mesh configuration of up to thousands of meters for back haul to the utility's IT control center. The network between the measurement devices and business systems allows the collection and distribution of information to customers, suppliers, utility companies, and service providers.

4.3 Benefit of AMI

- Consumer can sell electricity like rooftop solar or similar sources.
- AMI allows the user continuously monitor won meter data.
- Consumer can easily vending/recharge prepaid meter through on-line.
- Consumer can easily know the history of consumption & recharge.
- AMI will help keep to the consumer down utility costs by many customize feature of smart meter.
- If any meter tempering happens meter will send message instantly to the system and electricity will be disconnect.
- Meter control remotely from command center.
- Easy to prepare accurate Monthly Operational Data (MOD).
- With AMI the utility knows immediately when and where an outage occurs so it can dispatch repair crews in a more timely and efficient way.
- Using AMI there will be no dues of the unpaid bill because of prepaid billing system.
- Locate/ identify power quality issues by using AMI.
- Using AMI Optimize maintenance, capital and O&M spending.
- Using AMI can continuously monitor equipment health and send data computer center.
- The Advanced Metering infrastructure will be the part of Smart Grid in future.
- Advanced distribution management systems (distribution automation, integrated operation of DR (and DER), micro-grid operation etc.) [23].

Why Smart Meter is Necessary

- Online Vending from anywhere
- Customer can view meter status from home
- Utility can update meter firmware and new tariff immediately
- Meter temper event immediately displayed on prepaid software
- Automatic meter monitoring system and hence system loss may be reduced
- Customized meter data can be stored in MDM as per the schedule running in system and Reports on this data.
- Monitoring the transformer to protect overload
- Immediate Load management possible
- Smart meter is essential to go to smart grid

4.4 Essential Component of AMI

- Smart Meter
- Communication Network
- Data Concentrate Unit
- Head End System (HES)
- Meter Data Management System (MDMS)

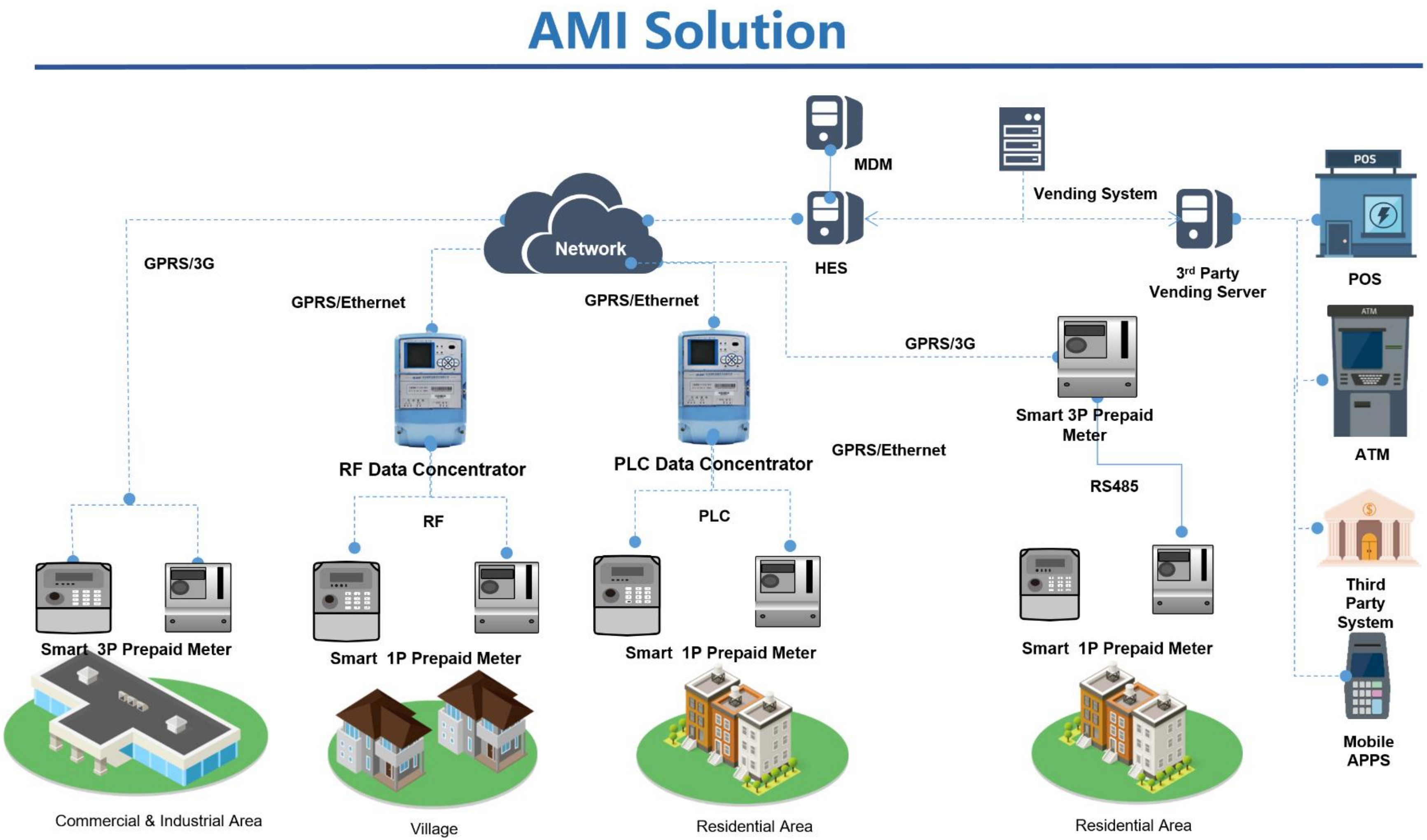

Figure 4.2: Advanced Metering Infrastructure Architecture

4.3.1 Smart Meter

A smart meter is an electronic device that records information such as electrical power consumption, voltage level, current and power factor. Smart meters communicate the information to the consumer for greater clarity of consumption behavior, and electricity suppliers for system monitoring and customer billing.

Photo 4.1 : Smart meter

Smart meters typically record power near real-time and report it regularly, with short breaks throughout the day [23]. Smart meters enable two-way communication between the meter and the utilities.

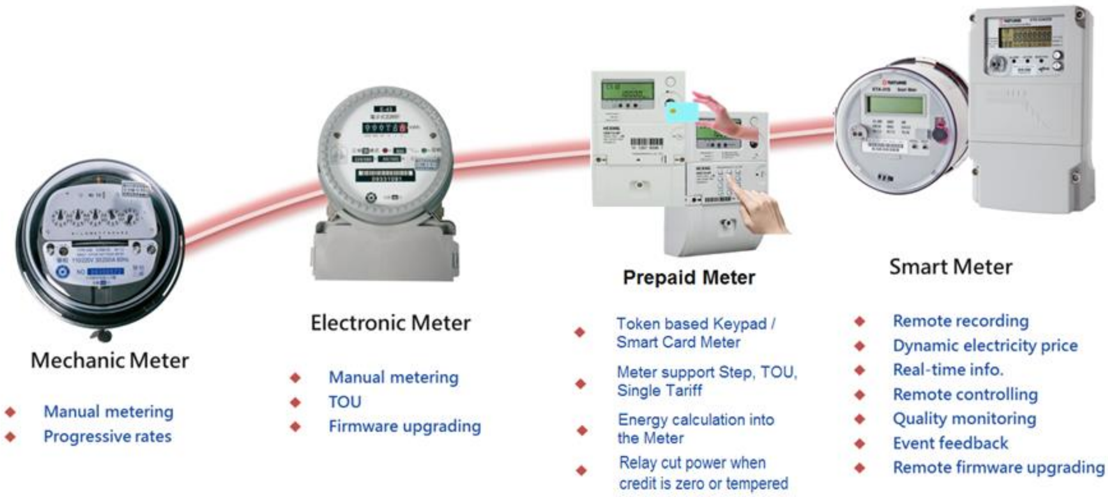

Figure 4.3: The Journey of Mechanical Meter to Smart Meter in Bangladesh

4.3.2 Communication Network

Three networks are commonly described when referring to the AMI.

- Home Area Network (HAN)
- Neighbor Area Network (NAN)
- Wide area Network (WAN)

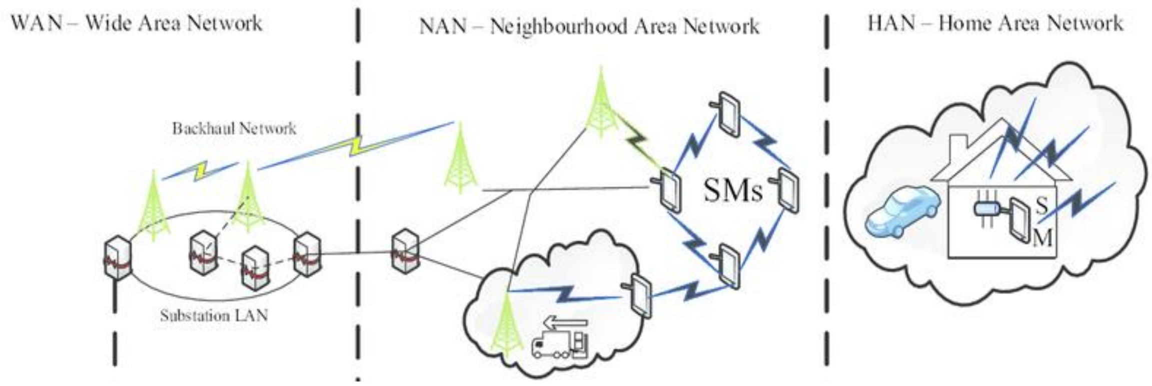

Figure 4.4: Various segments of the network (HAN, NAN, WAN) and the interconnectivity between them

Home Area Network (HAN)

A HAN is used to gather sensor information from a variety of devices within the home, and deliver control information to these devices to better control energy consumption.

Neighbor Area Network (NAN)

A NAN It is the communications network between Smart Meters and Data Concentrators of WAN. It collects information from many households in a neighborhood and relays them to WAN.

Wide Area Network

A WAN aggregates data from multiple NANs and conveys it to the utility private network. It also enables long-haul communications among different data aggregation points (DAPs) of power generation plants, substations, transmission and distribution grids, control centers, etc.

4.3.3 Data Concentrator Unit

Data Concentrator Unit (DCU) is the backbone of Advanced Metering Infrastructure (AMI) that helps in data acquisition, transfer of energy data to the central database, and automated meter reading in electronic energy meters. DCUs are primarily used in low voltage electric power systems.

Photo 4.2: Data Concentrator Unit

Data concentrators collect data about energy consumption and other customer management information from smart meters connected via a wireless or power-line communication (PLC) network in residential or commercial buildings and route this data in real time to a smart grid backhaul network, Advanced Metering Infrastructure (AMI) or customer center for further analysis and processing.

4.3.4 Head End System

A head-end system is a hardware and software that receives the stream of meter data brought back to the utility through the AMI. Head-end systems may perform a limited amount of data validation before either making the data available for other systems to request or pushing the data out to other systems. The processor is configured for receiving event signals from AMI meters. The event signals are indicative of events occurring at customer locations. The processor determines whether to transmit a command signal to a corresponding AMI meter in response to receiving an event signal from the corresponding AMI meter. The head-end system (HES), also known as meter control system, is located within a metering company network. The HES is directly communicating with the meters. Therefore, the HES is located in some demilitarized zone since services and functionality will be provided to the outside. The collected data will be managed within a metering data management system (MDM) which also maps data to the relevant consumer.

4.3.5 Meter Data Management System (MDMS)

Meter data management system refers to software that performs long-term data storage and management for the vast quantities of data delivered by smart metering systems. This data consists primarily of usage data and events that are imported from the head-end servers managing the data collection in advanced metering infrastructure (AMI) or automatic meter reading (AMR) systems. MDMS is a component in the smart grid infrastructure promoted by utility companies. This may also incorporate meter data analytics, the analysis of data emitted by electric smart meters that record consumption of electric energy.

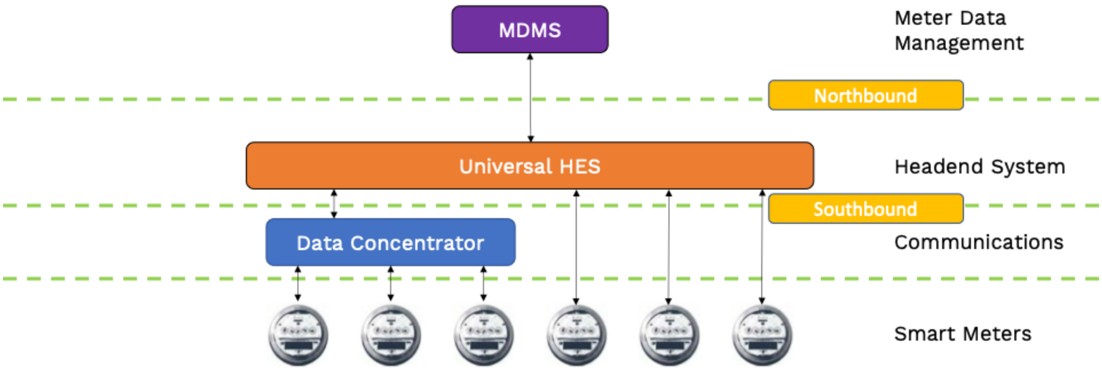

Figure 4.5: The Advanced Metering infrastructure Architecture

Chapter 5

Cost-Benefit Analysis of AMI Rollout

5.1 A pilot project of AMI Rollout

Northern Electricity Supply Company (NESCO) Limited is an organization of Bangladesh Power Development Board. NESCO Ltd. is working to provide better customer service to about 1.5 million customers in 24 Upazila towns and urban areas under 16 districts of Rajshahi and Rangpur divisions of the northern region. Northern Electricity Supply Company (NESCO) Limited started commercial activities on October 1, 2017, taking all the assets and liabilities from Bangladesh Power Development Board. Now we are going to cost analysis AMI installation for NESCO residential consumer. Following the company profile-

Table 5.1: Profile of NESCO

Sl. No.	Description	Expected Data
1	Total no. of consumers (Till June, 2020) NESCO area	1,500,000
2	Average Import Unit Per Month 2020	328 Mkwh
3	Average Sold Unit Per Month (FY 2019-20)	294 MKwh
4	System loss (FY 2019-20)	10.6%
5	Number of 11 kV feeder	330
6	33/11 kV Sub-station number and capacity	63 No. 1498/1990 MVA
7	Number of Distribution transformer	9072 No.
8	Highest Load (Upto June-2020)	Max. Demand 690 MW

5.2 Cost analysis of AMI Rollout

A) Cost at individual customer premises: Every customer's premises require smart meter with communication module. Every smart meter with module price BDT 4,000 [26]. Protect from external hazard its need meter box.

B) Cost of Communication Network: There are several communication system for AMI. We use Power Line Carrier (PLC). Data Concentrator Unit (DCU) is the backbone of Advanced Metering Infrastructure (AMI) that helps in data acquisition. We use DCU per distribution transformer. For AMI solution every single DCU price BDT 50,000 [25].

C) System Cost: Head End System (HES) with related software and Database & Application Server for DC and DR for 15 Lac smart meter. The License will be fully activated when smart metering system is commercially live. HES price BDT 20 million [27].

The Meter Data Management System shall support storage, billing (prepaid & postpaid), archiving, retrieval & analysis of meter data and various other MIS along with validation & verification algorithms. It shall act as a central data repository. MDM shall have capability to import raw or validated data in defined formats and export the processed and validated data to various other systems sources and services in the agreed format. It shall provide validated data for downstream systems such as billing (Postpaid & Prepaid), consumer Information system, customer care, analytics, reporting, Network planning & analysis, load analysis/forecasting, Peak Load Management, Outage management etc. The MDMS installtion cost 20 million [27].

D) Operation and Maintenance (O&M) Cost: This pilot project cost analysis about to 10 years.

5.2.1 Cost at individual customer premises:

Table 5.2: Cost of individual customer end

Item	Unit cost (BDT)	Quantity	Total Cost (BDT)
Smart meter with communications module	4,000	1,500,000	6,000,000,000
Meter box	500	1,500,000	750,000,000
Installation charges	300	1,500,000	450,000,000
Total	4,800	1,500,000	7,200,000,000

The cost at customer premises for deploying AMI for all 1.5 million customers covering 330 feeders is BDT 7.2 billion 7200 million (or INR 720 crore).

5.2.2 Cost of Communication Network

Table 5.3: Cost of Communication Network

Item	Unit cost (BDT)	Quantity	Total cost (BDT)
DCU (Data Concentrator unit)/ Data gateway	50,000	9,100 (DCU per DT)	455 million
Installation and setting up of Power line carrier (PLC)	7,000	9,100	63 million
Total			**518 million**

The cost of setting-p a Neighborhood Area Network for deploying AMI for all 1.5 million customers on 330 feeders in BDT 518 million

5.2.3 System Cost:

Table 5.4: Cost of System installation (Hardware & Software)

Item	Unit cost	Quantity	Total cost (BDT)
HES (Head End System)	20 million	1	20 million
MDM (Master Data Management) System	20 million	1	20 million
Computer Hardware & system software and networking system	50 million	1	50 million
System Integration	50 million	1	50 million
Total			**140 million**

The system cost for deploying AMI for all 1.5 million customers on 330 feeder BDT 140 million.

5.2.4 Operation and Maintenance (O&M) Cost:

Table 5.5: Cost of Operation & Maintenance

Item	Annual Cost (BDT)	Lifetime cost (BDT)	Remark
Annual Maintenance Charges (AMC) of Smart Meters @ 2.5%	150 million	1500 million	10 years
Annual Maintenance Charges (AMC) of DCU/Gateway @2.5%	11 million	110 million	10 years
Annual Maintenance Charges (AMC) of Head End System (HES) @ 20%	4 million	40 million	10 years
Annual Maintenance Charges (AMC) of Meter Data Management System (MDMS) @20%	4 million	40 million	10 years
Application Maintenance Support (AMS) of MDMS and HES @ 10%	4 million	40 million	10 years
O&M for attending to repairs/replacements/customer complaints/upgradation	100 million	1,000 million	10 years
Communication charges for WAN (leased lines/GPRS)	10 million	100 million	10 years
Total	**283 million**	**2830 million**	**10 years**

The O&M cost of the AMI system for all 1.5 million customers (spread over 330 feeders) is BDT 2830 million for a period of 10 years.

5.2.5 Total cost of Advanced metering Infrastructure

Table 5.6: Total cost of AMI Rollout

Item	Cost (BDT)	Remark
Cost of Neighborhood Area Network (NAN)	518 million	One- time cost
Cost of equipment at customer premises	7,200 million	
System Cost	140 million	
Sub Total **(a)**	7,858 million	
O&M Cost (including WAN communication) for 10 years **(b)**	2,830 million	items for 10 years
Total cost for 10 years **[(c)=(a)+(b)]**	1,0708	
Overhead, contingency and other unforeseen/contingency @ 10% of above, i.e.**(d) = 10% of (c)**	1,070.8 million	
Total [(e)= (c)+(d)]	11,778.8 million	

The system total cost for implement AMI for all 1.5 million customers on 330 feeder BDT 11,778.8 million.

5.3 Benefits of AMI

Table 5.7: Benefit calculation of AMI Rollout

Benefit	**Value**	**Annual benefits/ saving for 1.5 m customers (BDT)**
Annual saving on meter reading and bill distribution cost (salary, allowances and travel cost of meter readers, stationery etc.) **-(a)**	BDT 15* per customer per month considered (=15*12*11.5 million)	270 million
Annual savings on data entry cost and bill printing for bill generation (salary, allowances and travel cost of meter readers, stationery etc.)- **(b)**	BDT 15* per customer per month considered (=5*12*11.5 million)	90 million
Annual savings on cost for disconnections (DC)/ reconnections (RC) **-(c)**	Disconnections/reconnections considered for 1% customers every month and cost taken as INR 500* per visit (including cost of man hours) (=300*15,000*12)	54 million
Annual savings due to reduction in AT&C (Aggregate Technical & Commercial) losses (taking BDT 5* as average tariff) - **(d)**	Reduction in AT&C losses due to AMI considered as 10% monthly billed energy as 294 Mkwh and billing efficiency as 90% =((10% of (294/0.9))*12*5) million	1960 million
Annual savings from reduction in DT failure rate- **(e)**	Reduction in DT failure rate due to AMI considered as 5% (from 8% to 3%), cost of DT as BDT 200,000 and 9072 DTs for 1.5 million customers. =5% of 9072*200,000	90 million
Total annual benefit (BDT/Year) =a+b+c+d+e		**2442 million**

5.4 Payback Period

Payback period= (Fixed cost+ O&M cost for 10 years)/ Total annual Benefits

=11778.8/2442

=4.82 years

Chapter 6

Advanced Metering Infrastructure Rollout Strategy

6.1 Meter Standards and Specifications

All meters may be conforming to latest Standards as listed below:

a. Standards for smart meters and associated data protocol

- BIS Standard for Smart Meters (IS 16444) published in August 2015
- BIS Standard on Data Protocol (IS 15959 Part 2) published in February 2016

b. BIS Standard on Smart Meters (IS 16444) applies to:

- Single phase electricity meters
- Three phase electricity meters
- Single phase electricity meters with Net Metering facility
- Three phase electricity meters with Net Metering facility

6.2 Communication Technologies for AMI

A number of communication technologies are available for utilities to choose from for home, neighborhood and wide area networks. These are summarized in the table below.

Technology/ Protocol	Last Mile/NAN/FAN	Home Area Network (HAN)	Backhaul/WAN and Backbone
Wireless	➢ RF mesh ➢ ZigBee ➢ Wi-Fi ➢ Bluetooth	➢ RF mesh ➢ ZigBee ➢ Wi-Fi ➢ Millimeter Wave Technology	➢ Cellular ➢ Satellite ➢ LPWA ➢ Long Wave Radio ➢ TVWS ➢ Private Microwave Radio
Wired	➢ PLC ➢ Ethernet	➢ PLC ➢ Ethernet	➢ Ethernet ➢ PLC ➢ Optical Fiber

6.3 Retrofitting of Old Meters

According to IS 16444, the communication module must be a part of the smart meter (either built-in or pluggable unit). So it will not be possible to rebuild. The decision was taken by the technical committee at BIS as the concerned people have raised the following concerns regarding the reconstruction of the communication module in the respective meters:

- Theft of communication module
- Increased points of failure
- The unsuccessful use case of AMR in R-APDRP (where meter manufacturers were blaming the MODEM makers who in turn blamed the telecom network operators for poor bandwidth and vice versa)

Repeatedly sending engineers and technicians to customer premises to test and correct meter-modem-bandwidth problems is several times more expensive than the cost of new meters and communication devices. **Hence retrofitting communication modules on already-installed meters should not be considered.**

6.4 Rollout Methodology

Utilities can prioritize customers and locations for AMI deployments

- Most subscriber feeders with higher monthly subscribers (>1000 units, >500 units, >200 units in that order of priority)
- Feeders with high AT&C loss zones (>15% pockets/feeders)
- Feeders / cities with high annual power sales (above a certain million units/year)

AMI rollouts can be adopted for complete feeders that enable online energy auditing. All new meters will be purchased from July 2021 to Smart Meters to comply with the latest amendments to IS 16444 and IS 15959 compared to All other electrical technologies.

6.5 Manufacturing Capacity and Capability

As we know, all the major meter manufacturers in the country are working with smart meters in compliance with IS 16444 requirements. If they speed up, they can finish the test in 4-6 months. Several younger players claim that their meters have complied with IS 16444. The table below depicts a snapshot of the AMI rollout plans in other countries.

Table 6.1: Snapshot of AMI rollout plans in other countries

Country	No. of meters in the country by 2020 (in million)	Expected penetration rate by 2020 (%)	Total no. of smart meters expected to be installed by 2020 (in million)	Rollout timelines
Austria	5.7	95	5.4	2012-2019
Denmark	3.2	100	3.2	2014-2020
Estonia	0.7	100	0.7	2013-2017
Finland	3.3	100	3.3	2009-2013
France	35	95	33.2	2014-2020
Greece	7	80	5.6	2014-2020
Ireland	2.2	100	2.2	2014-2019
Italy	36.7	99	36.3	2001-2011
Luxemburg	0.26	95	0.24	2015-2018
Malta	0.2	100	0.2	2009-2014
Netherlands	7.6	100	7.6	2012-2020
Poland	16.5	80	13.2	2012-2022
Romania	9	80	7.2	2013-2022
Spain	27.7	100	27.7	2011-2018
Sweden	5.2	100	5.2	2003-2009
UK – Great Britain	31.9	99.5	31.8	2012-2020

Source: EU document on 'Country fiches for electricity smart metering'

6.6 Security challenges in AMI Rollout

Bangladesh will faces a number of challenges with respect to deployment of AMI:

Financial strength

Bangladeshi utilities are highly indebted and are undergoing financial restructuring as part of the UDAY reforms. The typically high upfront costs of smart meter projects can be prohibitive for utilities with limited access to capital.

Absence of skilled manpower

AMI is a new concept that includes thorough knowledge of three different domains: metrology, telecommunications and IT. The distribution companies are well versed with the electrical technologies of the electricity grid, but when it comes to telecommunications and IT, their expertise is limited. Furthermore, the fact that AMI is an evolving technology adds to the challenge.

Limited awareness

As AMI is new in Bangladesh, regulators and distribution companies are still trying to understand its nuances. As a result, regulators and distribution companies often find it hard to justify investments in AMI. Also, limited availability of information on successes in AMI deployments leads to an unclear picture in the minds of the decision makers.

Customer engagement

Many potential benefits of an AMI project rely on robust customer engagement. In Bangladesh, this is an often overlook aspect by most DISCOMs. Customers will take part in AMI and demand response initiatives only when they understand the importance and benefits to them.

Implementation of AMI

DISCOMs do not have one officer or business unit responsible for AMI. Instead, multiple officers and distinct working groups look after different aspects of smart meter projects. This leads to delayed and incorrect implementation of the technology.

Chapter 7

Conclusion

7.1 Conclusion

The 21st century brought great technological advancements in the field of electrical energy distribution and utilization. Advanced Metering Infrastructure is one such tool. This study's findings are following

Economic aspect:

- No average billing, no estimated billing
- No meter readers, bill distributors needed
- Advance revenue collection, no outstanding and improved cash flow
- No average billing, no estimated billing

Technical aspect:

- System loss reduction
- Tamper detection
- System loss reduction
- Budget better, reduced consumption

7.2 Future scopes of the study

- Feasibility study smart grid can be done using this thesis
- There is a significant shortage of skilled man-power for AMI amongst Bangladeshi utilities. To rectify this, Utilities must develop smart metering and smart grid training programs.
- While operational and economic benefits can be achieved by distribution companies that follow best practice, for customers to share in the gains requires widespread consumer awareness of the technology.

References

[1] V. M. &. R. Mehta, Principle of power system, New Delhi: S.Chand, 1982.

[2] D. M. •. P. H. •. V. O. K. L. •. R. Balme, Smart Grid Applications and Developments, New York: Springer, 2014.

[3] "http://www.answers.com/Q/What_is_power_grid_system," [Online].

[4] S. &. H. P. &. K. W. &. R. V. Hosein, "https://www.researchgate.net/figure/Power-Grid-Architecture_fig3_312562428 [accessed 4 Dec, 2020]," 2016. [Online]. Available: https://www.researchgate.net/figure/Power-Grid-Architecture_fig3_312562428. [Accessed 4 Dec 2020].

[5] X. Hu, "Smart Grid-A Development Trend of Future Power Grid, Power," *http://en.cqvip.com/* , pp. 33-14.

[6] M. A. I. S. M. Faysal Nayan, "Feasibility Study of Smart Grid in Bangladesh," *Scientific Research,* vol. 5, no. 10.4236/epe.2013.54B290 Published Online July 2013 (http://www.scirp.org/journal/epe), pp. 1531-1535, 2013.

[7] J. Polonestsky, "SmartPrivacy for the Smart Grid: embedding privacy into the design of electricity conservation.," *Researchgate.net,* pp. 278-279, 2010.

[8] "Smart Grid Information Clearing House.," [Online]. Available: http://www.sgiclearinghouse.org/learnmore.

[9] [Online]. Available: http://shaktifoundation.in/wp-content/uploads/2017/12/Smart-Grid-Handbook.pdf.

[10] [Online]. Available: https://www.saarcenergy.org/wp-content/uploads/2019/05/SEC-Smart-Grid-Study-2018-Draft.pdf.

[11] "How Secure Is Our Smart Grid?," www.govtech.com, [Online]. Available: https://www.govtech.com/blogs/lohrmann-on-cybersecurity/how-secure-is-our-smart-grid.html.

[12] M. Rokonuzzaman, "Blackouts in South Asia Perspective of Bangladesh: Observation and Recommendation," *Researchgate,* vol. 14, no. https://www.researchgate.net/publication/283495900_Blackouts_in_South_Asia_Perspective_of_Bangladesh_Observation_and_Recommendation, pp. 1-2, June-December 2014.

[13] v. kathera, "https://energycentral.com/," 28 October 2019. [Online]. Available: https://energycentral.com/sites/default/files/styles/article_body/public/ece/nodes/386964/20170816_135039.jpg?itok=1UZGP6JB.

[14] F. Energy, "Distributed Energy Resources: A How-To Guide".

[15] G. g. (. %. -. Bangladesh, "www..worldbank.org," [Online]. Available: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=BD.

[16] M. Masuduzzaman, "Electricity Consumption and Economic Growth," Dhaka, 2018.

[17] "https://www.bpdb.gov.bd/," [Online]. Available: https://www.bpdb.gov.bd/bpdb_new/index.php/site/page/124b-d18a-bf7f-0961-1a84-3ab0-b0ab-a409-3150-f305. [Accessed 28 December 2020].

[18] "https://www.mpemr.gov.bd/," [Online]. Available: https://powerdivision.gov.bd/site/page/e39dc904-f818-472e-bb72-46e225578877/%E0%A6%AA%E0%A6%BE%E0%A6%93%E0%A7%9F%E0%A6%BE%E0%A6%B0-%E0%A6%B8%E0%A7%87%E0%A6%B2.

[19] Sandeep Kumar Singh, Ranjan Bose, Anupam Joshi, "Energy Theft Detection in Advanced," p. 533, 2018.

[20] T. Wang, D. O'Neill and H. Kamath, "Dynamic Control and Optimization of Distributed Energy Resources in a Microgrid," *in IEEE Transactions on Smart Grid,* pp. 2884-2894, Nov 2015.

[21] A. Safdarian, M. Fotuhi-Firuzabad and M. Lehtonen, "Optimal Residential Load Management in Smart Grids: A Decentralized Framework," *in IEEE Transactions on Smart Grid,* pp. 836-1845, July 2016.

[22] "Advanced Metering Infrastructure Design and Installation," [Online]. Available: https://www.alibaba.com/product-detail/Advanced-Metering-Infrastructure-Design-and-Installation_1600107824547.html?spm=a2700.galleryofferlist.normal_offer.d_title.5ea9b762egE9vJ.

[23] Alibaba.com, "Smart energy meter DTS1661-R(7P) electricity billing meters," [Online]. Available: https://www.alibaba.com/product-detail/Smart-Meter-Meters-Meter-Electricity-Smart_1600151448987.html?spm=a2700.galleryofferlist.normal_offer.d_image.40902576O0pWoS&s=p.

[24] E. consultant, "National Electric BD," [Online]. Available: http://www.nationalelectricbd.com/.