AN OVERVIEW OF SMART GRID TECHNOLOGY AND ITS FEASIBILITY IN BANGLADESH

This project report/thesis/internship report is submitted in partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical and Electronic Engineering

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CERTIFICATION

This is to certify that this thesis entitled **"AN OVERVIEW OF SMART GRID TECHNOLOGY AND ITS FEASIBILITY IN BANGLADESH''** is done by the following students under my direct supervision. This work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering, 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 December 2022.

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Dedicated

To

Our Honorable Teachers & Parents

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LIST OF ABBREVIATIONS

kW- Kilo watt
kV- Kilo volt
GHG- greenhouse gas
CO_2- Carbon-di-oxide
DOE- Department of energy
DG- Distributed generation
PMU- Phasor measurement unit
FACTS- Flexible AC transmission system
SCADA- Supervisory control and data acquisition.
DMS- Demand management system
PCS- Process Control Systems
PV- Photovoltaic cell
RTU- Remote terminal unit
PLC- Programmable logic controller
PLC- Power Line Carrier
EMS- Energy management system
EHV- Extra High voltage
OPGW- Optical fiber ground wire
WAMS- Wide area monitoring system
PMU- Phasor Measurement Units
MRI-Magnetic resonance imaging
T&D- Transmission and distribution
IC- Internal-combustion
DSM- Demand side management
EV- Electric Vehicle
PMU- Phasor measurement unit
AMI- Advance Metering Infrastructure
HAN- Home Area Network
FGMO- Free Governor Mode Operation
AGC- Automatic Generation Control
NEM- Net Energy Metering
IPP- Independent Power Producer
BPDB- Bangladesh Power Development Board
NWPGCL- North West Power Generation Company Limited
APSCL- Ashuganj Power Station Company Limited
EGCB- Electricity Generation Company of Bangladesh Limited
BCPCL- Bangladesh-China Power Company(pvt.) Limited
SREDA- Sustainable Renewable Energy Development Authority
MWp- Megawatt peak
TPP- Thermal Power Plant
GT- Gas Turbine
GTPP- Gas Turbine Power Plant
CCPP- Combined Cycle Power Plant
TPP- Thermal Power Plant
PHEV- Plug in Hybrid Electric Vehicle

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ABSTRACT

Modern technology and advanced automation in the electricity system are what the term "Smart Grid Technology" refers to. The traditional electric grid system was developed roughly 50 years ago. Technology is updating day by day. There are several terminologies used in the power system, such as grid stability, system loss, renewable energy, dependability, quality power, energy security, and so forth. With regard to those concepts, smart grid is a complete package. While the current grid system is electro-mechanical, the smart grid will use automated technology in the next years. Although the idea of a smart grid is complicated, it is a more modern and stable grid system than the traditional grid system. The purpose of this thesis has been to present the idea of a "Smart Grid," the country of Bangladesh's current efforts to implement one, and the potential benefits of such an initiative for a developing economy. This thesis also emphasizes advantages, drawbacks, and other obstacles. Any equipment that has to be upgraded through technology can be updated rather than completely replaced, hence lowering costs. It was likewise narrowly targeted. The system design thinking also focused on how today's technologies might become conventional in ten to fifteen years. Although full automation cannot be achieved quickly, it can be partially automated before being fully automated step by step, day by day. It is an ongoing procedure. For regional cooperation, the idea of an inter-SAARC grid has been put out and discussions have also been had about cordial relations with neighboring nations.

CHAPTER 1
INTRODUCTION

1.1 Introduction

The first electricity system was established at Dhaka in Bangladesh in the first year of the 20th century. On 7th December 1901, British citizen Mr. Bolton turned on Ahsan Monjil's first electricity took all its financial measures Nawab Ahsanullah of Dhaka. In the 1930s, DEVCO, a division of Octavian Steel Company, started an electricity distribution system under private ownership. Dhanmondi Power House was established for commercial power distribution. When the British rulers left in 1947, Bangladesh's electricity system was completely isolated with no long-distance transmission system. This region of the nation's power production and delivery was under the control of a few private businesses in 1947. The township had a meager electricity supply that served the 17 provincial districts at the time. The 400-volt generating voltage. Most of the districts used to only have power during the night. The only exception was Dhaka City, where two 1500 kW generators were employed to supply power, with a generation voltage of 6.6 kV, the maximum supply voltage. With the development of people's living standards, the demand of electricity is constantly increasing. Electricity has been an effective driver of financial development and prosperity around the world. Power utilization alone is causing 25% of Green House Gas (GHG) outflows. Electricity is the pre-condition for social and financial improvement. But right now, consumers cannot be given with continuous and quality control supply due to inadequate era compared to the national request. To resolve the show shortfall and to meet the expanding request for power, the government has taken an activity to extend era (introduced) capacity to 25,700 MW by 2022 with 100% electrification. Bangladesh will need an estimated 34,000 MW of power by 2030 to sustain its economic growth of over 7 percent. Problems in Bangladesh's electric power sector include high system losses, delays in completion of new plants, low plant efficiency, erratic power supply, electricity theft, blackouts and shortages of funds for power plant maintenance. Overall, the country's generation plants have been unable to meet system demand over the past decade. Electricity demand proceeds to extend whereas fossil fuel assets are contracting and set to consistently gotten to be more costly. At the same time, climate alter and contamination have gotten to be issues of concern to

Bangladeshi citizens. The smart grid is praised by policymakers and business leaders as one of the most important chances to conserve energy and reduce CO_2 emissions, but many observers have noted that the implementation of the smart grid appears to be taking a long time. The smart grid is a complicated idea that includes complex management software, data generation, communication technologies and electricity distribution. Additionally, a wide range of entities are involved, including electricity producers, grid operators and electricity retailers as well as manufacturers of hardware and software, industry heavy-weights and upstarts, inventors, regulators, consumers and micro-producer. The majority of natural resources are currently out of date. Therefore, a worldwide need for an energy-efficient system exists to maximize the use of generated power. Such a productive system is possible with Smart Grid. In order to provide a sustainable power system with low losses high level of quality, supply security and safety, the smart gird integrates the behavior and actions of all users linked to it, including generators, consumers and those which do both. Most of the developed and developing countries are advancing to replace their conventional grid system with Smart Grid. To overcome the future impact in power sector, Bangladesh should switch to Smart Grid.

On the other hand, according to power system master plan-2016 Bangladesh has achieved the GDP growth of 7.4% within 2015-2020 and projection of GDP by 2025 is also 7.4%. For this reason, there many economic zones have been establishing. They need huge amount of electricity. According to this, the demand of electricity has increased rapidly. There is no better option than using smart grid technologies to manage the electrical system intelligently and for greater reliability. In addition, Bangladesh wants to meet the United Nations (UN)' Sustainable Development Goals (SDG) by 2030. The SDGs have 17 Goals. "Affordable and Clean Energy" is the seventh of these goals. Ensure access to affordable, reliable, sustainable and modern energy for all. The electrical system needs to be more intelligent in order to do that by 2030. By 2021, Bangladesh have entirely electrified. But there is a pressing concern regarding affordable, reliable, sustainable and modern energy. As a result, a significant number of inefficient captive power plants have emerged. The majority of such power plants are fueled by natural gas. They are wasting precious and valuable natural gas due to their low efficiency. Concerns have been raised regarding power security. After July 2022, Bangladesh experienced significant hardship due to the rise in LNG and oil prices. It occurs load-shed roughly 1.5-2.0 GW as a result. It has an impact on industrial production. It is a worrying development for both our economy and the security of our energy supply. We must make sure that our energy is used effectively. We must thus install the smart grid as soon as possible.

1.2 Conventional grid system

The modern world's most intricately constructed system is the electrical grid. Power plants, transmission lines, substations, distribution lines, and users are all connected to one another in this network. Delivering electricity from the sources of generation to the locations where it is needed is the entire purpose of the power grid. And now the power supply and conversion processes outlined above are used to do this:

1.2.1 Generation:

The main part of a power plant is power generation. There are multiple generators or alternators at a generating station and they may use multiple fuel sources. The majority of such power plants are located far from the load centers. They are commonly known as "Power Hub". The steam generated by the chemical burning of fossil fuels, such as coal, petroleum, natural gas, liquefied petroleum gas and liquefied natural gas is used to drive electromechanical generators in these power plants. There is a tradition of constructing numerous power plants in one area, which results in a significant increase in capacity there. After being generated, electricity is transferred to the national power grid or transmission line.

1.2.2 Transmission:

Power plants are placed far from consumers in remote, unpopulated areas, thus in order to transmit the generated electricity over long distances and with minimal loss, it is stepped up to higher voltages and sent along transmission lines to substations. The major reason for raising the voltage is to reduce transmission line loss.

1.2.3 Distribution:

When the power arrives at a substation which is typically close to the users, it must be stepped down from a transmission level voltage to a distribution level voltage. The distribution phase is where we are at right now and the distribution grid is where we are at right now.

1.2.4 Consumption:

The service site has now received power. As a result, it needs to be reduced once more from distribution voltage to the necessary service.

The electrical grid of today is a unidirectional network from the previous century. This indicates that the flow of energy from generators to substations via transmission lines and finally to consumers outlets is unidirectional. It should also be mentioned that the majority of the infrastructure including the lines and equipment of the traditional power system was established many years ago. They require significant investments. Therefore, their provisioning usually takes years. Because of their age, these grid components require periodic upkeep and supervision in order to keep the power on. Additionally fossil fuels are continually being used up due to this and other uses which makes them more expensive based on market prices.

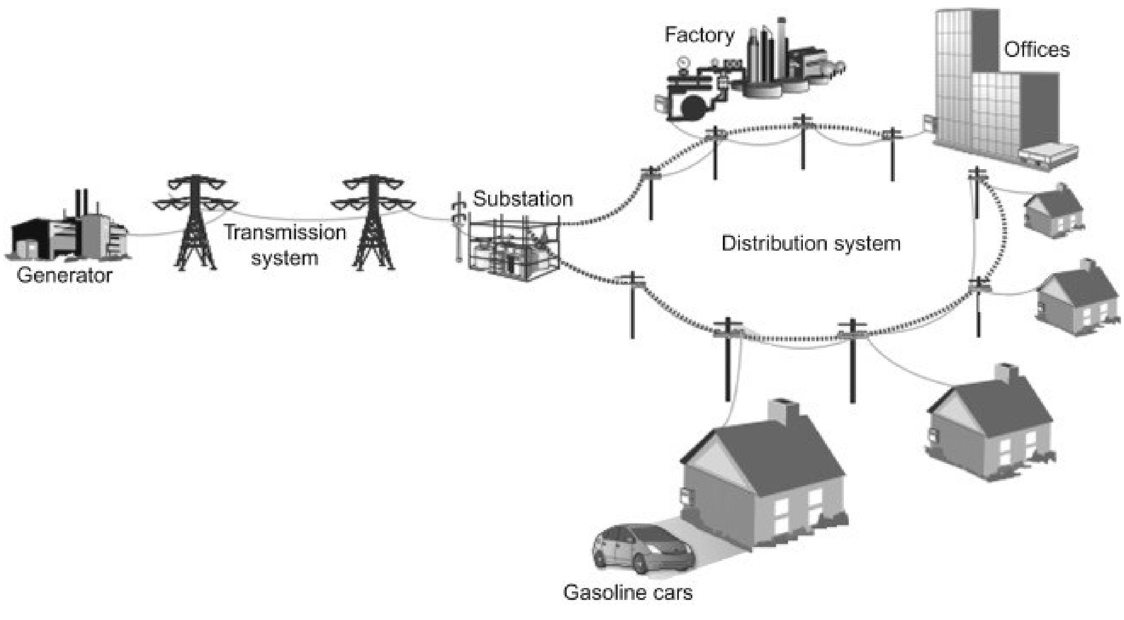

Figure 1.1 : Schematic diagram of conventional grid

1.3 Weaknesses of Conventional Grid System

The conventional grid or the electrical grid from the previous century is a unidirectional network and this needs to be noted. Accordingly, power travels in a single route from generators to substations then via transmission lines and finally into the outlets of users. It's also important to keep in mind that the majority of the traditional power grid's infrastructure including its wires and equipment was set up decades ago. Due to their size, they require significant investments and as a result provisioning usually takes years. Therefore, in order to keep the power flowing, these grid components must be regularly maintained and watched over. Fossil fuels are also continuously being depleted due to this and other usage, which makes them usually costlier depending on market prices. But there are issues with the traditional grid. They are-

i. Our ability to predict future needs for the capacity of the delivery system is hampered by the fact that conventional power producing units are grouped and built up around settlements, making it difficult to provide electricity to remote locations while maintaining growth (the transmission and distribution lines).
ii. In many situations, installed grid components were created to accommodate historical energy demands rather than the requirement that exists now.
iii. The architecture of the current grid may be challenged by increased energy consumption at times of peak demand.
iv. In a traditional grid, power and communication travel from the point of generation to the users. This implies that the conventional power grid may not be able to adapt to the rising energy demands, suffers difficulties in identifying grid breakdowns, is unable to switch electricity on and off at will, and may experience power line overheating.
v. Observing power flows is still primarily done manually.
vi. Natural disasters, bad weather, and technological problems with the grid's operations all frequently cause outages, which raise the possibility of harm and financial loss.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Introduction

A smart grid integrates advanced sensing technologies, control methods, and integrated communications into the current electricity grid.

Smart grid technology is an extension of analog technology that allows for two-way communication to control the operation of appliances. The majority of homes now have access to the internet, making the smart grid more feasible to install. Ordinary users, operators and automated devices can immediately react to changes in the condition systems of the smart grid thanks to the information transmitted by smart grid devices. Enterprises, retail establishments, hospitals, universities, and international businesses can all benefit from smart grid technology. The entire smart grid system is automated to keep track of how much electricity is used everywhere. Energy management software and grid architecture are also used together to estimate an enterprise's energy use and costs. In general, demand drives up electricity rates. Smart grid energy management systems assist in reducing consumption during high-cost, peak-demand periods by giving consumers information about current energy usage and energy costs.

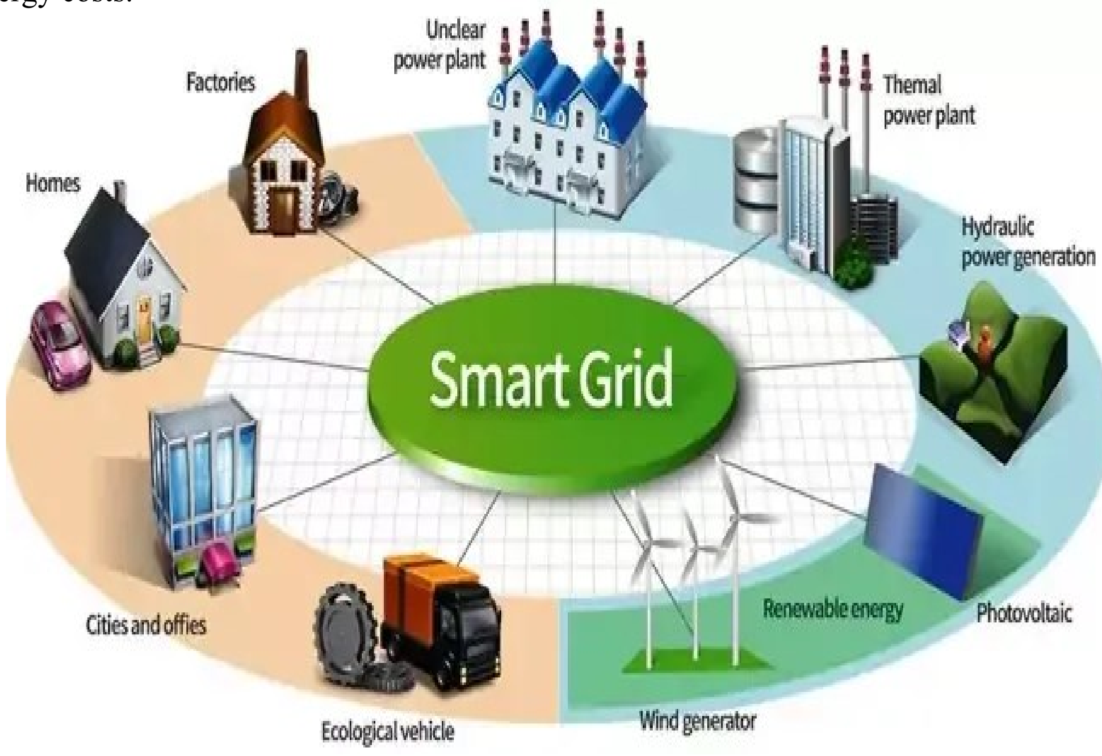

Figure 2.1: Schematic diagram of smart grid

2.2 Capabilities of a modern smart grid system

i. It is self-healing.
ii. It promotes customer involvement in grid operations.
iii. It guarantees a reliable, high-quality power supply
iv. It enables the electrical markets to expand and generate revenue.
v. It can be run more skillfully.

2.3 Objectives of the study

The mature energy and power industry's biggest and most recent technology breakthrough has been the idea of a "smart grid." With billions of dollars invested in smart grid technology, it has become a significant concern in the age of globalization and climate change. It will take a coordinated effort from wireless sensors, the internet, and two-way communication protocols and technologies to effectively use smart grid technology for bi-directional power flow, the integration of renewable energy generation sources, and improving the quality and reliability of power supply. Additionally, to effectively prevent and restore power outages, sophisticated sensing and switching technologies with increased redundancy in the power delivery sector are essential. This focuses on the electric power network of Bangladesh. The main objectives of this thesis are -

i. To determine the advantages and drawbacks of a smart grid over a conventional grid from Bangladesh's standpoint.
ii. To determine the potential of smart grid technologies in light of Bangladesh's situation.

Global demand for Smart Grid technologies is growing, and Bangladesh has the potential to lead the way in this field of technological advancement. Bangladesh's energy demand is rising every year, making it impossible to construct power plants quickly. This issue can be reduced by using smart grid technology. In the event of load shedding brought on by a countrywide electrical energy deficit, the smart grid can instantly recalculate and fairly distribute electricity to all consumers. Currently, the majority of natural resources are decreasing. To enhance the usage of generated power, an energy-efficient system is therefore required globally. An effective system can be ensured via smart grid. The main focus of this thesis is to find the necessity of Smart Grid system in Bangladesh.

2.4 Conventional Grid System vs Smart Grid System

Table 2.1: Comparison between Conventional Grid and Smart Grid

Method	Conventional Grid System	Smart Grid System
Communication way	Unidirectional	Bi-directional
Communication technology	Analogue	Digital
Power Generation	Centralized	Distributed
Outage recovery	Manual Restoration	Self-Healing
Monitoring	Manual	Remote
Metering System	Analogue	Smart & Advance Metering
Sensor System	Unavailable of few	Advance sensor system
Electricity Market type	Single Buyer	Open Market
DSM system	Feedback not from consumer end	Feedback from consumer end
Efficiency	Less	More
Green energy	Less	More

2.5 Need for Smart Grid System

2.5.1 Power Quality

Power quality represents an equipment's capacity to use the power being supplied to it as well as the ability of a power grid to efficiently supply power to consumers. Technically speaking, sinusoidal waveform measurement, analysis and improvement at the rated voltage and frequency constitute power quality. Harmonic distortions, a major problem with power quality, can harm operational digital electronic control systems and overheat transformers and other equipment. Pressure on the authorities to impose severe regulations on power quality issues is growing as the density of sensitive technology on the electric grid increases.

Smart meters installed at end user locations in a smart grid system have the capacity to calculate the THD (Total Harmonic Distortion) of the supply voltage. The utilities will be able to identify the harmonic distortions' source with the use of this information. On the feeder, the area with the highest THD can be assumed to be the source of the harmonics, and corrective action can then be taken in that area.

2.5.2 Peak Demand Reduction

When demand for electricity is at its peak and per unit cost are at their highest, this is when it happens. Utility operators are obliged to run peaking plants longer than necessary to meet demand and sustain power availability because they were unable to predict the timing and nature of peak demand at a specific time. The cost of operating the generating units that handle peak demand is typically high because the fuel for these facilities is typically purchased on the erratic "spot" market and is a major contributor to greenhouse gas emissions. From the website of Power Cell of Bangladesh, we can see that our maximum generation 14,782 MW was occurred on 16th April 2022 at 9 P.M.

Peak demand will significantly decrease as a result of the implementation of smart grids, sophisticated metering infrastructure, demand response, and increasing user engagement. By implementing a smart grid, utilities might save costs and, in certain situations, even stop using these plants, protecting the environment from carbon emissions. By enabling dynamic pricing, consumer will be aware. They can do their daily necessaries at off-peak time like washing cloths by washing machine. Because at off-peak time, the price of electricity is low as the per unit cost of electricity production is low just because of using the base load power plant. Smart grid introduces consumers to the active participation. As a result, consumers will also aware and will try to do the necessaries at off-peak time. This will help the power system very much and reduce to burn the limited fossil fuel.

2.5.3 Integration of Renewable Energy

Due to worries about global warming, the integration of renewable energy generation technologies is becoming more and more significant. The current electric system can reasonably handle the very low penetration of renewable energy sources at this time. To accept and incorporate fluctuating (stochastic) generation, however, significant changes and alterations would be required as penetration increased. Through the utilization of communication and information, a smart grid makes use of possible advancements that can be made to conventional operation. Because the current power system is unable to anticipate and identify such fluctuation, it cannot support or regulate it. Renewable energy sources like solar and wind energy could make the power system unstable. Therefore, reliability is a key issue right now. In order to adopt a smart grid, a sensitive control system is needed which will include effective transmission, demand response and intelligent energy storage. To use renewable energy sources, you need an energy storage system. While it is not always possible to run renewable energy conventionally, it is possible to forecast its behavior and a smart grid must use this information to increase system efficiency. So, it is clear that the Smart Grid benefits from renewable energy.

2.5.4 Technological Development

There is a major lack of automation in the current electric grid, particularly on the distribution side. Although the existing system uses approximately real-time load monitoring, it is unable to combine data from a wide variety of sources and equipment, which reduces situational awareness. Furthermore, there is a critical lack in the capacity to comprehend and act on the gathered data as energy efficiency programs expand. As a result, "Smart Grid" is a solution for technological development. It can make the current grid smarter than present. Consequently, "Smart Grid" is a technological advancement. It might enhance the current grid's intelligence. Besides this, in current distribution infrastructure is too old. It needs automation in the distribution sector for more reliable power supply. In addition, the infrastructure for distribution today is outdated. For a more dependable supply of power, the distribution industry needs automation.

CHAPTER 3

SMART GRID TECHNOLOGY

3.1 Definition of smart grid

There is no single definition by which a ‘Smart Grid’ can be expressed properly.

According to The U.S. Department of Energy (DOE) Definition:
A smart grid integrates advanced sensing technologies, control methods and integrated communications into the current electricity grid.

“A smart grid uses digital technology to improve reliability, security and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers”.

“Smart Grid” refers to the computerization of the traditional distribution grid.

Smart grid puts ‘information’ and ‘communication’ technology into electricity ‘generation’, ‘delivery’ and ‘consumption’ system with dynamic pricing, demand response, bidirectional power flow with distributed generators (DG) and enabling two-way communication up to consumer level with an aim of making the power systems cleaner, safer, more reliable and efficient.

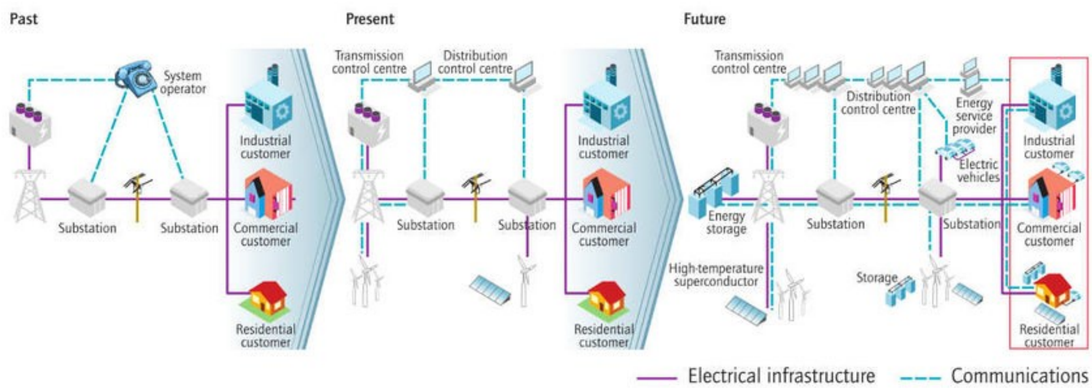

Figure 3.01 : Evolution of the electric power grid.

A smart grid is a digitally-based power network that uses two-way digital communication to deliver electricity to customers. To increase efficiency, lower energy consumption, costs and increase the transparency and dependability of the energy supply chain, this system enables monitoring, analysis, control and communication throughout the supply chain. By utilizing smart net meters, the smart grid was created with the intention of addressing the flaws in traditional electricity grids. Smart grids have received support from many governmental organizations throughout the world because to its capacity to manage and address global warming, emergency preparedness and energy independence scenarios.

3.2 SMART GRID CONCEPT

i. Target for increasing level of entrance of Renewable Energy resources and advanced technologies such as online monitoring of transformers and cables, phasor measurement units (PMU), Flexible AC transmission system (FACTS), super conductive transmission lines, fast chargeable batteries, multi-purpose smart meters, smart appliances (to adjust their consumption and communicate with the smart meters or consumer energy management system).

ii. Rapid restoration process due to mobilization of consumer's resources and adjusting their demands and creating islands.

iii. Improve efficiency and make the system as green as possible.

3.3 Key features of smart grid

i. Active participation of consumer like consumer level energy management system with software having adaptability.

ii. Bidirectional power flow with accordance with distributed generation.

iii. Two-way communication even with retail consumers for complete sharing of their information such as real-time demand profile, historical data, power quality requirement, appliances system etc.

iv. Real time motivation of the consumers in adjusting their demands in response to the situation and to avoid blackouts and ensuring power quality.

v. Online price signals the consumers commensurate with their varying requirements.

vi. Smart demand side management up to consumer level.

3.4 Smart Grid Networks

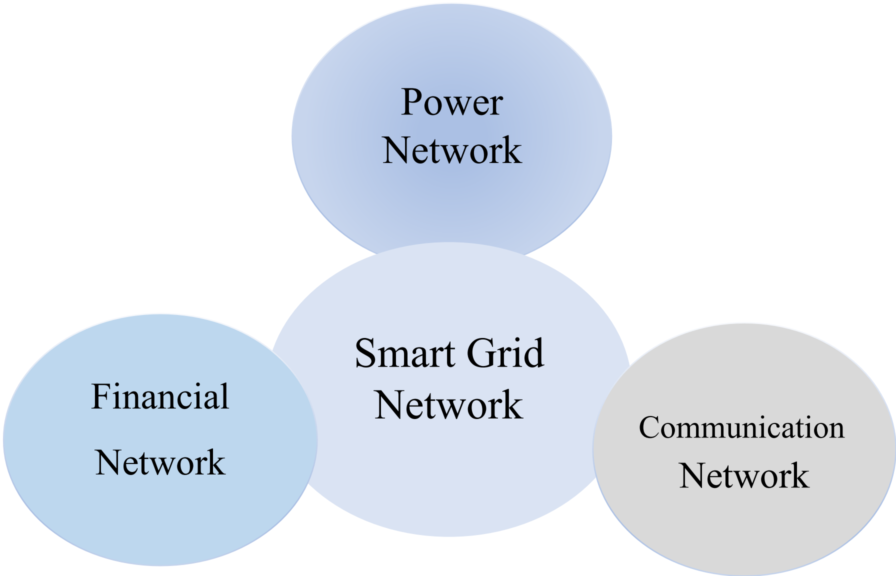

Figure 3.02 : Smart Grid Network

3.5 Conceptual Model of Smart Grid Network

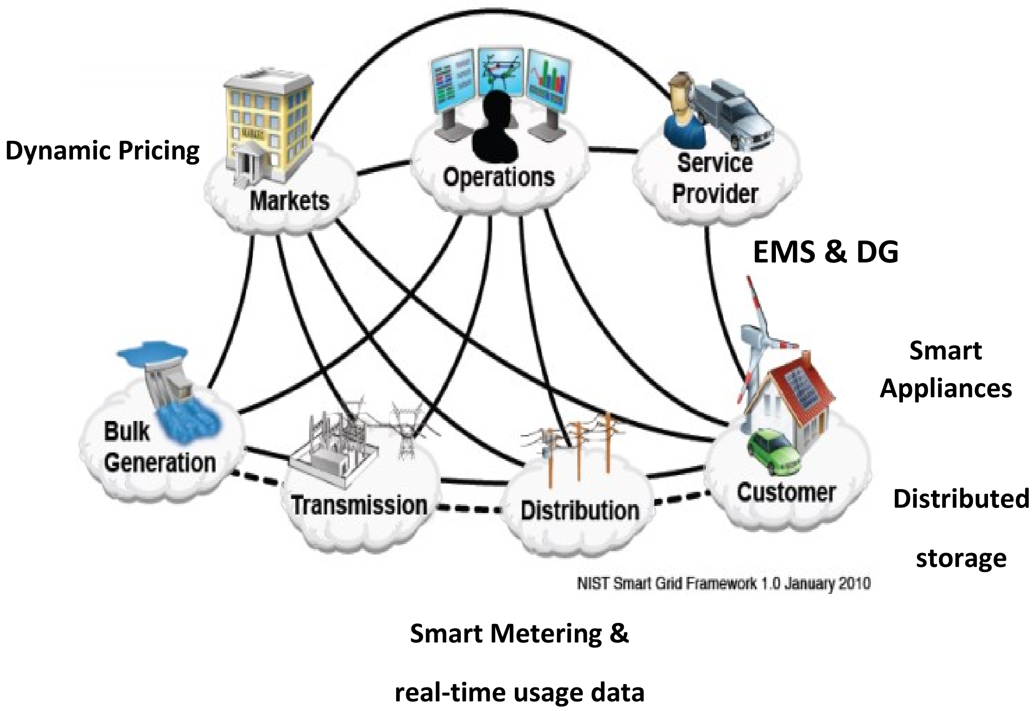

Figure 3.03: How smart grid look like

3.6 Major components of smart gird and the function of smart grid:

3.6.1 SCADA

SCADA stands for supervisory control and data acquisition. A SCADA system is one that gathers information from multiple sensors in a factory, power plant, transmission system, or other remote places and then delivers that information to a centralized computer for management and control of the system. SCADA can operate with comparatively little human interaction and has the capacity to monitor an entire system in real time. Data collection from numerous sensors and meters makes this possible. SCADA gathers all data on the operation of the grid from numerous sensors positioned at various points and feeds it to a central computer where the data is immediately examined. The infrastructural components necessary to enable both the higher-level applications of a DMS and the varied nature of distribution automation should be present in a SCADA system. The primary purposes of a smart grid SCADA system are remote monitoring and control of outstation field equipment, alarms, telemetry, event logging, and recording. For gathering, monitoring and analyzing real-time environmental data from a straightforward residential building or a sophisticated large-scale PV or wind power plant, SCADA systems are essentially Process Control Systems (PCS). On the basis of a specified set of data and situations, such as generated/consumed energy or power grid management, PCSs are developed for micro grid automation or power distribution systems. Some PCSs are made up of one or more RTUs (remote terminal unit) and/or PLCs (programmable logic controller) that are coupled to a variety of actuators and sensors and relay data to a master data collective device for analysis. Dedicated and dependable communication channels between diverse field devices (RTU) and the Master Station are necessary for SCADA. Electric utilities have historically employed Power Line Carrier (PLC) communications. Limited bandwidth may be supported by the analog PLC. There are still many locations using PLC-based SCADA. Firewall is used for this system security like as to prevent unauthorized access. The SCADA system assists with overall electrical network monitoring and control which gives the user a steady supply of electricity. It keeps track of system activity, which helps to provide a clear picture of the system's overall condition. Since the whole network state of the system can be understood in a matter of seconds, the daily load demand may be determined in accordance with the requirements. The use of SCADA has made it easier to manage the energy network with the least amount of human involvement.

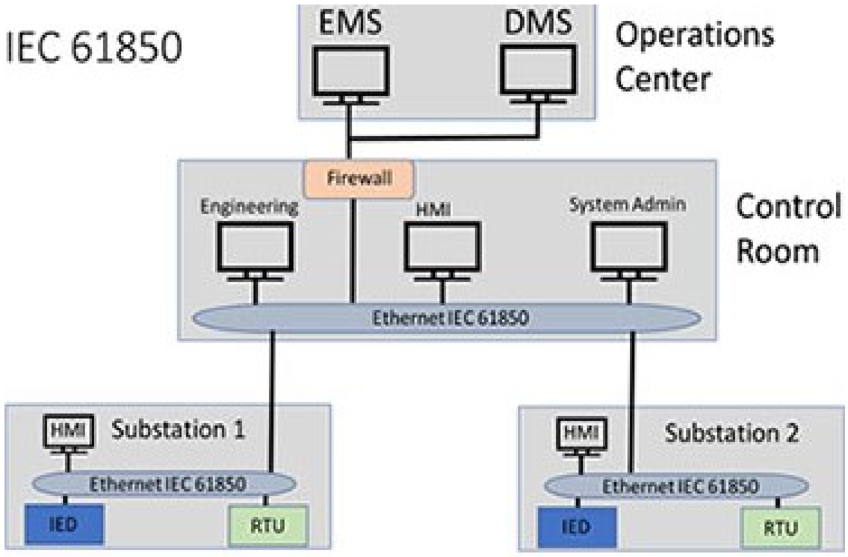

Figure 3.04: Substation SCADA with RTU

3.6.1.1 Additional SCADA connection channels include

i. On EHV lines, optical fiber ground wire (OPGW) can be used as the earth wire. (Most commonly used in Bangladesh).
ii. Wireless Communication by Microwave.
iii. Communication by satellite.

3.6.1.2 Main functions of SCADA

i. Data collection from RTUs and online database storage.
ii. Data processing to transform raw values into engineering values and ensure quality.
iii. Storing and retrieving historical data.
iv. Order of things recording, re-creating, and playing back occurrences.
v. Power system equipment should be tagged to be both protective and instructive.
vi. Providing operators with a user interface.
vii. Connection between control centers.
viii. Trends in both the present (real time) and past.

3.6.2 WAMS

WAMS stands for wide area monitoring system. A quick and precise measurement of grid equipment is achievable with the deployment of Phasor Measurement Units (PMU). Applications for real-time wide-area monitoring must adhere to strict latency requirements between 100 milliseconds and 5 seconds. To handle the massive amounts of data from PMUs, a quick communication infrastructure is required. Applications for the smart grid are created to take use of these high throughput real-time measurements. PMU data is gathered in milliseconds, while SCADA data is gathered in 1 to 5 seconds. PMU data is accurately time-stamped but SCADA data lacks a timestamp. PMU Data is like an MRI scan of the grid, whereas SCADA is like an X-Ray. Based on real-time data fed from phasor measurement units, WAMS offers visibility (PMU). This information is used by a variety of WAMS software programs to deliver information that is specific to a certain situation and is shown through a simple user interface. In order to handle the complex difficulties of contemporary power systems, GE's WAMS technology complements conventional SCADA-based energy management by providing quick and proactive grid stability management.

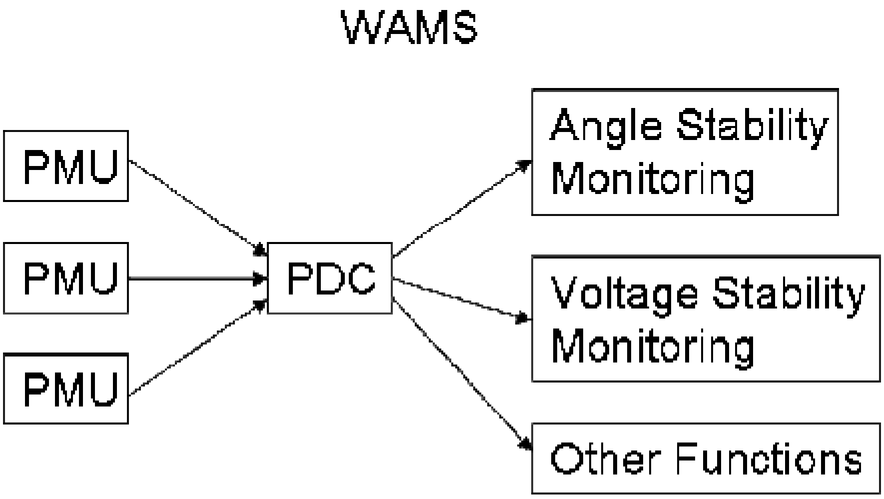

Figure 3.05: Wide area monitoring system

Based on real-time data fed from phasor measurement units, WAMS offers visibility (PMU). This information is used by a variety of WAMS software programs to deliver information that is specific to a certain situation and is shown through a simple user interface. In order to handle the complex difficulties of contemporary power systems, GE's WAMS technology complements conventional SCADA-based energy management by providing quick and proactive grid stability management.

3.6.3 DISTRIBUTED GENERATION

Distributed generation is also known as Embedded Generation. Central plants, which are big producing facilities that are intentionally situated either close to resources or otherwise placed far from crowded load areas, have historically been a crucial component of the electric grid. The traditional transmission and distribution (T&D) grid, which delivers bulk electricity to load centers and then to consumers, is fueled by these. These were created when the price of building T&D facilities and tariffs was significantly higher than the price of transporting fuel and integrating generating technologies into populated regions. Typically, central plants are created in a way that is site-specific in order to benefit from existing economies of scale. Compared to centralized generation, distributed generating systems are subject to a varied combination of local, state & federal policies, regulations and markets. The financial attractiveness of a distributed generation project fluctuates, just as policies and incentives differ significantly from one location to the next. There may be chances to more reliably and economically deploy distributed power as electric utilities incorporate information and communications technologies to update electricity delivery networks.

3.6.3.1 Traditional Power System

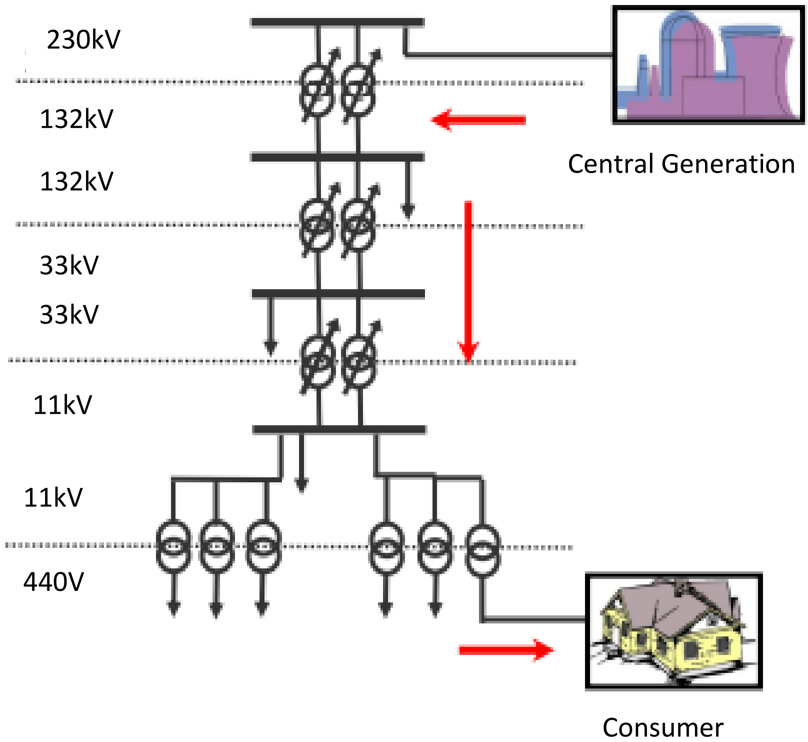

Figure 3.06: Traditional Power System

3.6.3.2 Power System with distributed generation (DG)

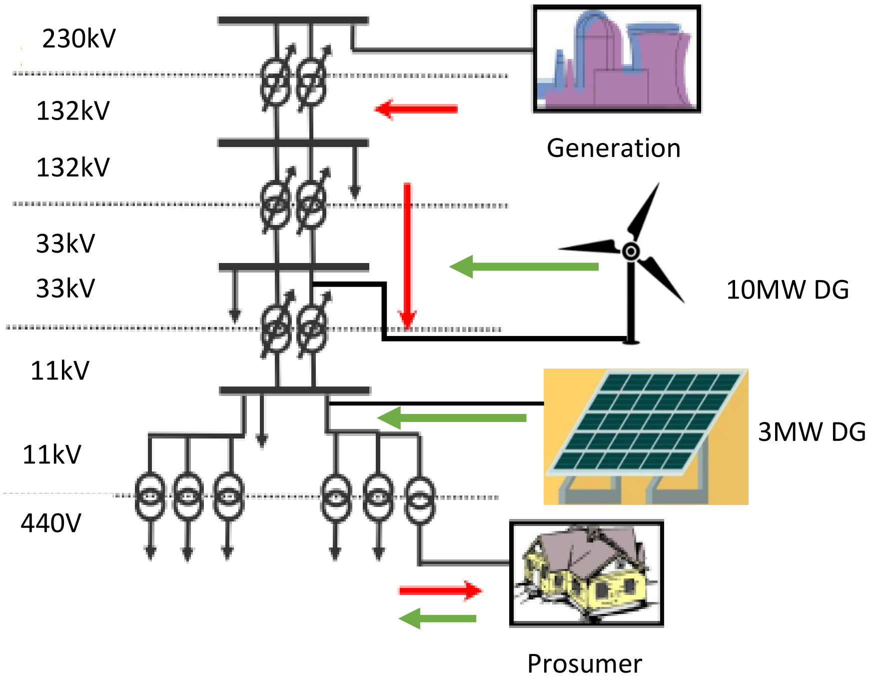

Figure 3.07: Power System with distributed generation

3.6.3.3 Typical characteristics of distributed generation

i. Not centrally planned (by the utility).

ii. Not centrally dispatched.

iii. Usually, these types of generation are less than 100MW.

iv. Normally these are connected to distribution network.

3.6.3.4 Different types of distributed generation plants

i. Wind

ii. Solar

iii. Hydro

iv. IC Engines

v. Combined heat and power

vi. Landfill gas

vii. Micro gas turbines

3.6.3.5 Common distributed generation systems in the residential sector

i. Photovoltaic solar cells.
ii. Small-scale windmills.
iii. Fuel cells powered by natural gas.
iv. Generators for emergencies that are typically powered by gasoline or diesel fuel.

3.6.3.6 Necessity of Distributed Generation

i. For reduction of CO_2 gas emissions.
ii. Rational use of energy and energy efficiency.
iii. Deregulation and competition policy.
iv. Increasing the variety of energy sources.
v. National need for energy.
vi. Modular generating plant availability.
vii. Finding locations for smaller generators is simple.
viii. Short construction times and lower capital cost of Distributed Generations.
ix. Closer location of the generation could result in lower transmission costs.

3.6.3.7 The Effects of Distributed Generation on the Environment

By reducing the amount of electricity that must be produced at centralized power plants, distributed generating can lessen the negative environmental effects of centralized generation. Specifically:

i. Renewable energy sources like solar and wind can be used to create electricity at homes and businesses utilizing existing, cost-effective distributed generation systems.
ii. Energy that may otherwise be squandered can be captured by distributed generation, such as through a combined heat and power system.
iii. Distributed generation lowers or eliminates "line loss" (wasted energy) that occurs during transmission and distribution in the electricity delivery system by utilizing local energy sources.

3.6.3.8 Distributed generation though may potentially have detrimental effects on the environment:

i. Due to their "footprint" (the amount of space they occupy) and proximity to the end user, certain distributed generation systems may be unsightly or raise issues with land use.

ii. Combustion-based distributed generating methods, particularly those that burn fossil fuels, can have many of the same negative effects as bigger fossil fuel-fired power plants, including air pollution. These effects could be less drastic than those from a big power plant, but they might also be closer to populous areas.

iii. Water may be needed for steam generation or cooling in some distributed generation methods, including waste incineration, biomass combustion and combined heat and power.

iv. Due to economies of scale, combustion-based distributed generation systems may be less effective than centralized power plants.

3.7 SMART DSM SYSTEM

DSM stands for demand side management. Demand Side Management (DSM) is the process of changing, lowering, or managing the load rather than the production of the power plant in order to balance the supply of electricity on the network with the electrical load.

Demand Side Management is a method for influencing customer's capacity and willingness to cut back on their use of electricity.

DSM is crucial in addressing the difficulties in the power networks by balancing supply and demand. To smooth out the peak demand, which has a significant impact on system reliability and generation costs, on the provider side of the power system and to motivate users (electricity consumers) to shift their noncritical power consumption to periods of off-peak hours in order to reduce their bills, DSM includes management in the consumer side of the power system.

Demand-side management (DSM), also known as energy demand management or demand-side response (DSR), is the process of reducing a client's energy use through a variety of tactics, such as behavioral modifications (through awareness) and financial rewards. DSM aims to prevent consumers from using less energy during peak hours or from transferring their energy use to off-peak hours like the weekend or at night. This might not actually result in less energy being used overall. Instead, it emphasizes minimizing the need for unnecessary investment in power plants or networks to meet the best demands, such as by saving energy storage during off-peak hours and using it during peak hours. The most recent method used by DSM to reduce power usage is to help grid operators stabilize intermittent solar and wind generation, particularly when the quantity and timing of energy demand do not match that of renewable energy supply.

3.7.1 Types of Demand side management system

i. Energy efficiency: This kind of DSM involves replacing outdated equipment with more energy-efficient models in order to permanently reduce demand while still accomplishing the same functions.

ii. Demand response: Any proactive or defensive methods to lessen or change demand are included here. Demand response (DR) programs help to change the net load structure, which is the amount of wind and solar power production subtracted from the total load, while integrating all forms of renewable energy. Reducing peak consumption to postpone high supply costs is one of the main goals of DR programs. The term "DR" refers to all intentional adjustments made to a utility customer's historical electricity consumption patterns with the goal of altering the timing, overall power consumption, or intensity of spontaneous demand. A variety of activities are taken out on the client's end of the electric meter during high charges or network congestion during peak hours as part of DR techniques.

iii. Load shifting: The practice of "load shifting" involves moving demand from peak to off-peak hours. It can lower the peak demand during particular times, lessen the need to build additional power plants and lower the cost of running power plants. It is a method that allows for direct control over machinery or through tariffs. One of the oldest methods of load control is load shifting. Using special tariffs to influence consumer behavior.

iv. Peak load management: Peak load management is the process of lowering the demand for electricity during the busiest times, which can save a lot of money. Peak load management techniques include both capital-intensive initiatives like battery storage and low-cost operational ones like pre-heating and cooling to avoid peak hours. The best approach will rely on your budget, usage kind and territory. As a grid user, you are charged for both the energy you actually use (measured in kilowatt hours) and the energy that must be available to serve your account depending on your peak load (kW demand). Depending on the market, this peak kW, also known as a peak load contribution, capacity tag, or cap requirement, may account for up to 50% of your supply bill and more than 30% of your total power bill (supply plus delivery). You can trim these peaks by carefully managing your load, or Peak Load Management (PLM), which will dramatically lower your electricity expenditures both now (distribution) and in the future (supply). Read on to learn how your peak load contribution is determined, why you should care, how to completely capture the value of PLM and how you can start actively managing your peak load.

3.7.2 Common Smart DSM implementation strategies

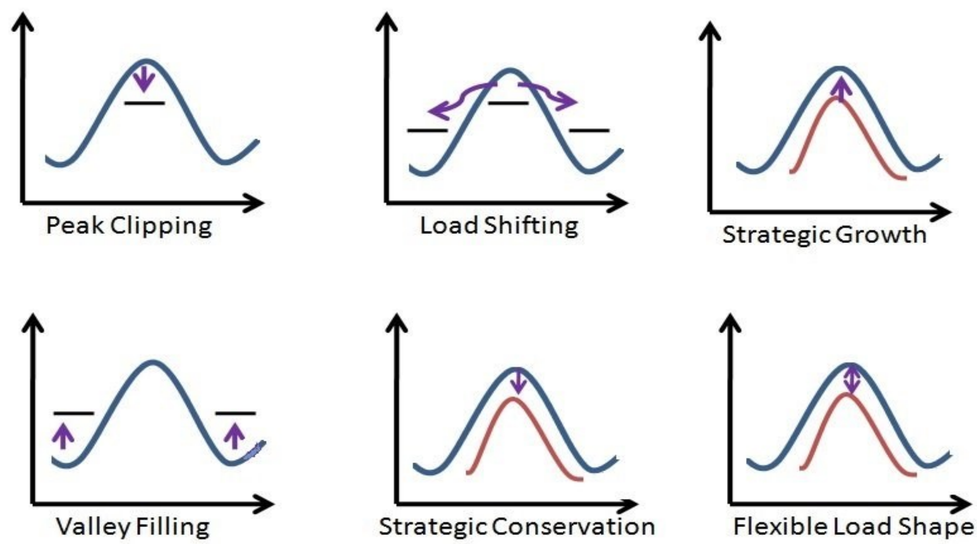

Figure 3.08: Common Smart DSM implementation strategies

There are six basic load shaping methods which are peak clipping, valley filling, load shifting, strategic conservation, strategic load growth and flexible load shape. Peak cutting and valley filling are the direct load control techniques among them. The load shifting approach, which may be put into practice with the aid of manageable loads at the consumer side, includes the peak cutting and valley filling combination. The controllable loads are moved from peak slots to off peak slots in the load shifting scenario without affecting energy usage. Because of this, this approach is overwhelmingly preferred among all load control strategies. The following three strategies, which are considered sophisticated, use system design and operation to either extend or reduce the total load demand shape.

3.7.3 Advantages of Smart DSM

i. Through load control, existing generation, transmission and distribution equipment can be used more effectively.
ii. Boost system dependability.
iii. Reduced capital expenditures for new machinery.
iv. Reduced demands for spinning reserves.
v. Decreased operating expenses.
vi. Increasing off-peak energy use will result in higher system load factors.
vii. In an emergency, immediate selective load shedding.
viii. Use of natural resources to the fullest.
ix. An improvement in energy efficiency.
x. Lowering carbon emissions.

3.8 PMU

A PMU also known as a synchro-phasor or a phasor measurement unit is a crucial device used in electric systems to increase operator's awareness of what is happening across the extensive grid network. A PMU is a tool that measures something referred to as a phasor. The magnitude and phase angle of the AC voltage or current at a specific point on a power line are indicated by a phasor. This data is helpful for recognizing and assessing system conditions and can also be used to calculate frequency. As opposed to the customary one measurement every 2 to 4 seconds supplied by traditional SCADA systems, PMUs can deliver up to 60 measurements per second. This indicates that PMU can provide real-time data. PMUs provide a significant advantage over conventional methods of data collection because all PMU data is time-stamped using GPS data. This indicates that the data gathered across a grid is synchronized using the same precise technique for tying time to the data. PMUs are sometimes referred to as synchro-phasors because of this. At specific transmission system stations, phasor measurement units (PMUs) measure current and voltage by amplitude and phase. By comparing measured values (synchro-phasors) from several substations located far away, high-precision time synchronization (through GPS) enables inferences about the system state and dynamic events like power swing situations. PMUs offer a thorough and precise picture of the power quality across a large geographic grid. The system operator can determine from the data gathered whether the voltage, current and frequency are remaining within predetermined tolerances. In transmission grids all throughout the world, tens of thousands of PMUs have recently been installed. They are occasionally used in distribution networks as well. PMU provide the opportunity to switch out the conventional manual adjustments required by SCADA systems with an autonomous system that makes judgments and delivers control signals.

Figure 3.09: Phasor measurement unit

3.8.1 Reasons for using PMU

i. To increase the precision of system conditions modeling.
ii. To anticipate and identify grid stress and instability.
iii. After a disturbance has occurred, to provide details for event analysis.
iv. In order to spot inefficiencies.
v. Predicting and controlling line congestion.

3.9 Advance Metering Infrastructure

AMI enables the use of technology, such as smart meters and other advanced metering devices, to enable a two-way flow of information between consumers and utilities and to give customers and utilities access to data on consumption, including time, amount of energy spent, and electricity price. As a result, the smart grids will be equipped with a wide range of functionalities, including remote consumption control, time-based pricing, consumption forecasting, fault and outage detection, remote user connection and disconnection, theft detection and loss measurements, as well as efficient cash collection and debt management. By achieving these objectives, the grid will become smarter and have better control over the quality of the power coming from various angles. The power quality index in grids with AMI will be raised by quickly logging and reporting any form of disturbance or outage. AMI has been a buzzword in the energy sector in recent years. Energy utilities are now accepting and implementing this more frequently to increase the system's energy efficiency. With the use of AMI, two-way communication is made possible, allowing for communication between utility and metering end points on fixed networks. AMI keeps track of energy use patterns and promptly notifies customers about their budgets and bills. This keeps customers always aware of the need to manage their energy effectively. AMI appears to be a fantastic tool for energy conservation, which is something that is desperately needed in this day and age. Both budget billing and rating can be done with AMI. AMI is created when power, communication, and IT are combined. In order to inform its customer on energy consumption, AMI provides a framework for automatic, bilateral communication between a utility and consumer. This suggests that AMI is a system that, in coordination with metering devices like electricity meters, gas meters, heat meters, and water meters, records, gathers, and analyzes energy usage on a regular basis. The Head End System (HES), Meter Data Management (MDAS) software, Customer Associated Systems, Consumer Energy Displays and Controllers, Communications, and Supplier Business Systems are all included in the AMI architecture. An AMI's primary goal is to provide utilities with real-time data about power usage and to inform consumers about typical patterns of energy use and the best options based on current market prices (ToU).

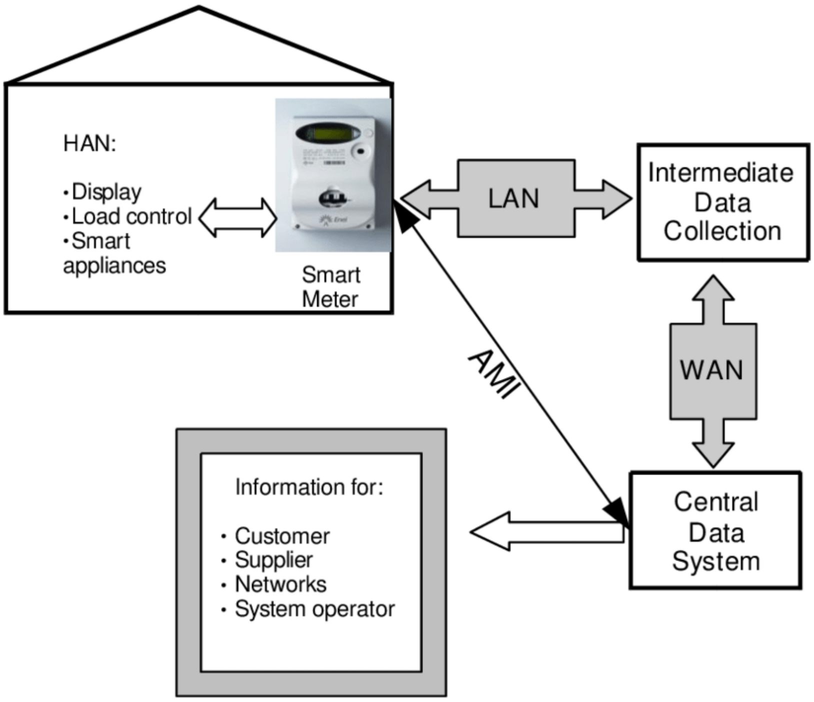

Figure 3.10: Typical architecture of AMI

3.10 Smart Home System

Smart home system is an important part for the smart grid system. Smart home system can be deployed by using smart home appliance. The smart appliance will be connected to the consumers smart meter and it will sense when the appropriate time comes for doing daily necessaries. Once the dynamic pricing system can be deployed in the grid network for regulating the market competition then the smart home system will be a vital thing in the context of smart grid. Smart home can sense the peak time, off-peak time and the dynamic pricing. When the price of electricity is low, the smart home system will operate the smart home appliances to operate. At dynamic pricing system, the tariff system will be changed according to the demand and the cost of electricity production. When the cost and demand will increase, the price of the electric power will increase too. But at the off-peak time the tariff system will be different and it should be low price in the off-peak time. At that time smart home can do the daily necessaries by using advance sensing technology and can control the load and smart home appliances.

CHAPTER4

PROSPECT OF SMART GRID IN BANGLADESH

4.1 Present Power System scenario in Bangladesh

Bangladesh is a developing country. It is now working to develop as a country. According to Worldometer's elaboration of the most recent United Nations data, Bangladesh had 168,340,936 people living with the growth rate of 1.08% there as of Sunday, September 25, 2022. Bangladesh's land area is 148,460 square kilometers, according to Wikipedia. Bangladesh has undertaken various development initiatives in order to thrive economically. From here, a lot of the projects are in under progress and a lot of them have come to a conclusion. The need for electricity as a result is growing daily. Currently, 100% of the population has access to power, including off-grid networks and renewable energy sources. The installed capacity currently stands at 25730 MW including captive and renewable energy and per capita generation has increased as well, reaching 608.76 MW. The power sector has always been a top priority for the current administration in terms of development. Power System Master Plan (PSMP) 2016 states that the government has set a goal to enhance installed power generation capacity to 40,000 MW by 2030 and 60,000 MW by 2041.

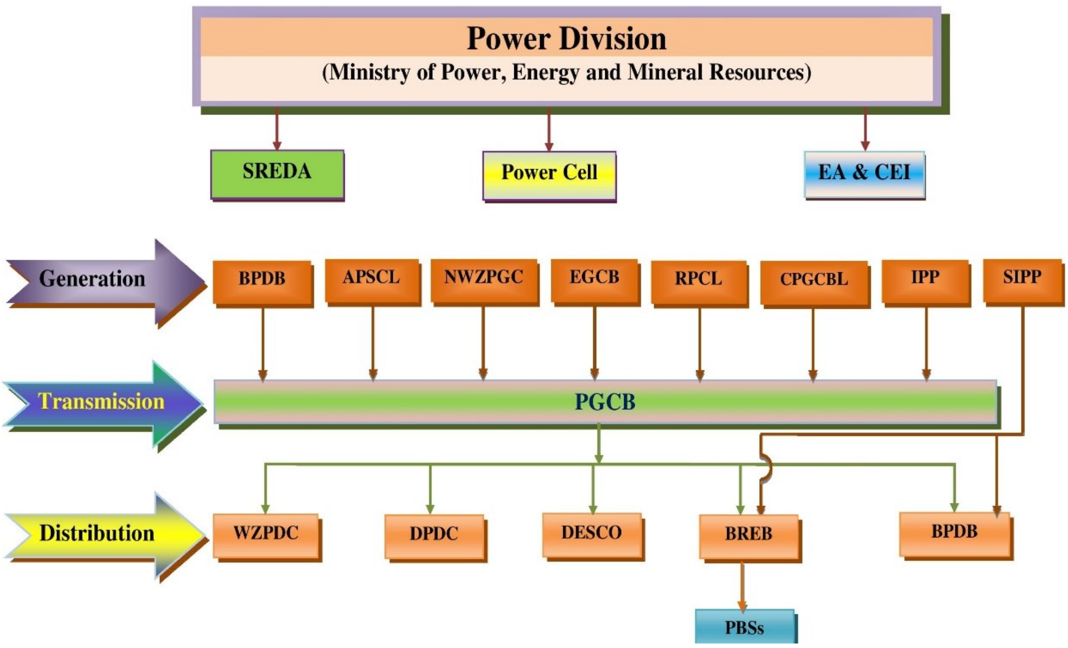

Figure 4.01: Power Sector Structure

We can see the current structure of Power Sector in Bangladesh. From there Power Division is a division of Ministry of Power Energy and Mineral Resources (MPEMR).

4.1.1 Power Generation in Bangladesh

Bangladesh now has 25730 MW of installed capacity. About half of this capacity comes from the private generation sector (including captive power). Only seven (07) Utility/Company is producing power from public sector. They are-

i. Bangladesh Power Development Board (BPDB)
ii. Rural Power Company Limited (RPCL)
iii. Electricity Generation Company of Bangladesh Limited (EGCB)
iv. North-West Power Generation Company Limited (NWPGCL)
v. Ashuganj Power Station Company Limited (APSCL)
vi. Coal Power Generation Company of Bangladesh Limited (CPGCBL)
vii. B-R Powergen Limited

From their CPGCBL has not come into operation. The plants of this company are under construction. Besides this there is an under-construction nuclear power plant named “Nuclear Power Plant Company Bangladesh Limited” with an installed capacity of 2*1200 MW under Bangladesh Atomic Energy Commission. It will be come to operation by 2024 as expected. Normally the generating voltage of the power plants in Bangladesh vary from 11kV to 22 kV. Then after converting it to very high voltage level, the power has been handed over the national grid.

Power division has taken the initiative for fuel diversification in this area. According to PSMP-2016. Bangladesh now has more than 150 power plants. Bangladesh also imports 1160 MW of power from India. The Bheramar (Kushtia) HVDC center, commonly known as Bangladesh India Power transmission center, imports 1000 MW power from Bahrampur (India). At Cumilla, Bangladesh imports the remaining 160 MW of power from Tripura, an Indian state. According to Power System Master Plan 2016, looking to increase power import from neighboring counties up to 9,000 MW.

4.1.1.1 Power Generation Units (Fuel Type Wise):

Table 4.1: Installed Capacity of BPDB Power Plants as on September 2022

Fuel Type	Capacity (Unit)	Total (%)
Coal	1768.00 MW	7.85 %
Gas	11476.00 MW	50.98 %
HFO	6278.00 MW	27.89 %
HSD	1341.00 MW	5.96 %
Hydro	230.00 MW	1.02 %
Imported	1160.00 MW	5.15 %
Solar	259.00 MW	1.15 %
Total (excluding Captive)	22512 MW	100 %

4.1.2 Power Transmission in Bangladesh

There is only one utility for power transmission of Bangladesh. The utility is Power Grid Company of Bangladesh (PGCB) Limited. PGCB is in charge of managing, developing, and maintaining the nation's transmission infrastructure. Currently PGCB is operating the national grid through 400kV, 230 kV and 132 kV transmission lines to transmit power from power plant to the distribution utility. Additionally, a 400 kV HVDC Back-to-Back station (fitted with two blocks) has been put in place via which 1,000 Megawatts of power have been being imported from India. Moreover, there are grid substations with voltages of 400/230 kV, 400/132 kV, 230/132 kV, 230/33 kV and 132/33 kV. PGCB was formed in 1996. PGCB is increasingly placing more emphasis on the work to construct a strong grid network in order to implement "Vision 2041" in light of the government's Master Plan for the power sector. For this reason, PGCB is increasing its transmission capacity by taking many developments project. Currently PGCB is aiming to construct 765kV transmission line and sub-stations. From 2010 it has completed about 44 development mega projects. Now about 17 development projects are ongoing and about 7 mega projects are pending for clearance from power division to start these. PGCB working on quality and reliable power transmission. These projects are for this reason. And in recent years the transmission loss is reducing. At present transmission loss is about 3%. It also can be reduced too. As power plants or power hubs are far away from load center, it can’t be reduced from 3%. But they are performing well in the power sector. They are operating the transmission system and National Load Dispatch Center (NLDC) very well and the management system of PGCB is well organized. PGCB is aiming to implement 765kV transmission.

4.1.2.1 Transmission Infrastructure Information at a glance

4.1.2.1.1 Transmission Line:

Table 4.2: Existing Transmission Line

Voltage Level	Length
400kV	1397 Circuit km
230kV	4,022 Circuit km
132kV	8190 Circuit km

4.1.2.1.2 Substation:

Table 4.3: Existing Sub-Station

Voltage Level	Capacity
400kV	1 Nos. 2x500MW HVDC Back-to-Back station
400/230kV	4 Nos. 4,680 MVA (PGCB)
	2 Nos. 1170 MVA (Others)
400/132 kV	3 Nos. 1,950 MVA
230/132kV	27 Nos. 15,225 MVA(PGCB)
	3 Nos. 7,50 MVA (Others)
230/33KV	1 Nos. 280 MVA (PGCB)
	3 Nos. 910 MVA (others)
132/33kV	125 Nos. 24,775 MVA (PGCB)
	40 Nos. 6,851.6 MVA (Others)

4.1.2.1.3 Present transmission scenario of Bangladesh:

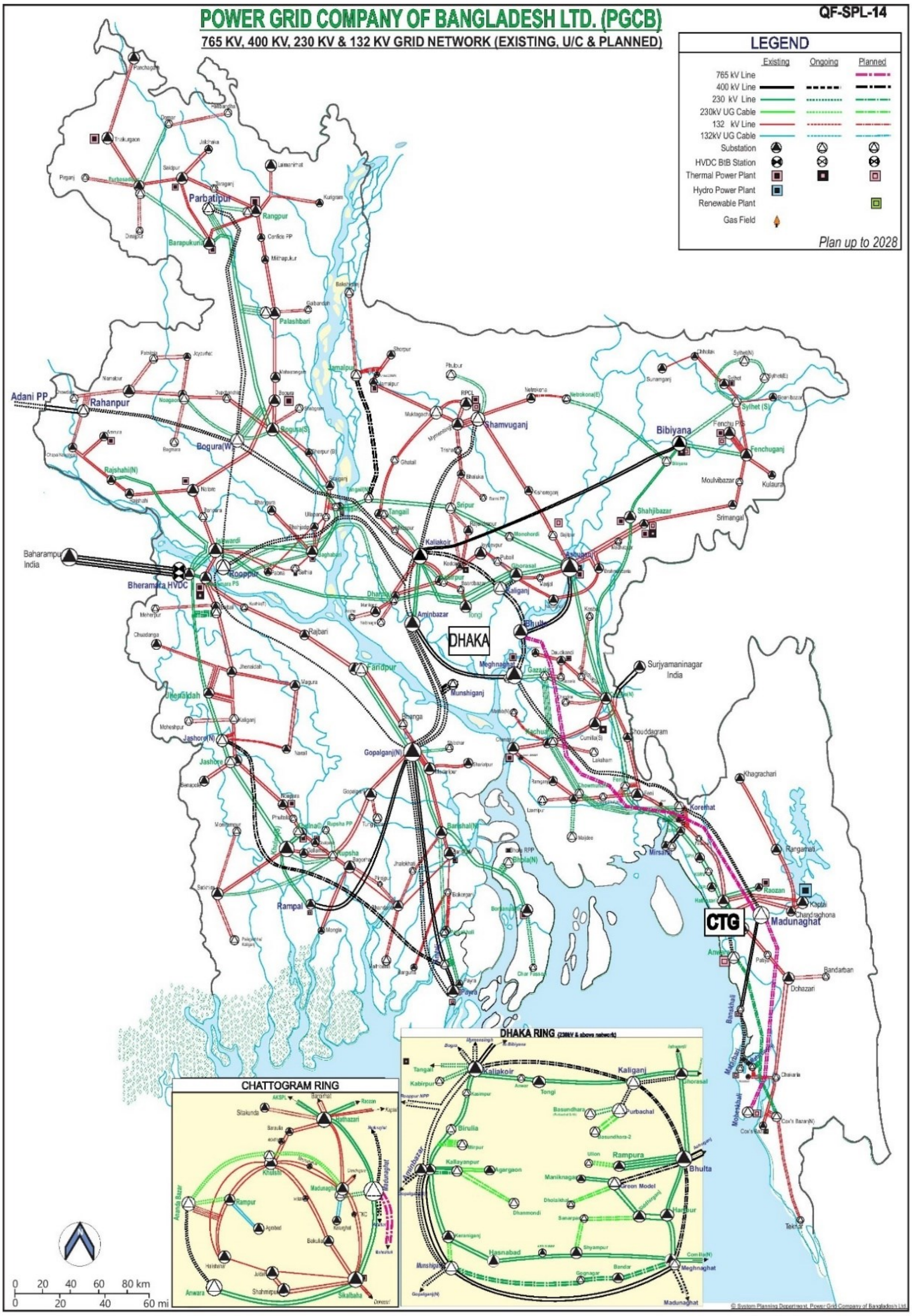

Figure 4.02: Present Power Transmission Scenario

4.1.3 Power Distribution System of Bangladesh

PGCB transmit the electric power to the distribution utility. Currently there are six (06) distribution utility and one (01) more utility is waiting to come into operation. The six (06) utilities are-

i. Bangladesh Power Development Board (BPDB)
ii. Bangladesh Rural Electrification Board (BREB)
iii. Dhaka Power Distribution Company Limited (DPDC)
iv. Dhaka Electric Supply Company Limited (DESCO)
v. West Zone Power Distribution Company Limited (WZPDCL)
vi. Norther Electric Supply Company Limited (NESCO)

Another utility, which is waiting to come into operation is South Zone Power Distribution Company Limited (SZPDCL). Bangladesh Power Development Board is a single buyer of electricity. They buy the electricity from the power generation company as a single buyer and sells this electricity to the distribution utility according to the rate of Bangladesh Energy Regulatory Commission (BERC). From the above utilities DPDC & DESCO are distributing power in the Dhaka city and partial part of Narayanganj and Gazipur city. BREB is responsible for distributing power in the rural area of Bangladesh. WZPDCL is distributing power to the Khulna and Barisal division. NESCO is distributing power in Rajshahi and Rangpur division. BPDB is distributing power in Chattogram, Cumilla, Mymenshing and Sylhet region. Another company SZPDCL will distribute power in the Chattogram and Cumilla region. Every utility is working under Power Division, Ministry of Power Energy and Mineral Resources (MPEMR). Before forming PGCB, the distribution loss of Bangladesh was abnormal. A huge amount of power was out of billing as non-technical loss. But after forming PGCB, the distribution loss has started to decrease as there are metering infrastructure at generation, transmission and distribution side. Now the distribution loss is about 7.74% by June 2022. Government is working for improving this sector as there are very old infrastructure. As a result, there are many mega-projects for upgrading the distribution system in Bangladesh. Already power division is working for creating underground distribution network in the cities like Dhaka, Sylhet. As a piloting of this type of project there are an under-ground distribution line at Sylhet. Besides this, there are ongoing projects for underground distribution network of Dhaka city under DPDC & DESCO area. On the other hand, to improve the distribution system in rural area

BRER is also working according to the instruction of Power Division. The distribution utilities are distributing power in the voltage level from 220V. Here are the distribution voltage levels of Bangladesh-

Table 4.4: Service Voltage according to demand

Range of Demand	Voltage level of supply	Category
Less than 50 KW	230 to 440 volts	LT
50KW to maximum 5MW	11 kV	MT
5MW to maximum 30MW (Must be Double circuit for above 20MW)	33 kV	HT
20MW to maximum 140 MW (Single or double circuits in technical consideration)	132 kV	EHT-1
Above than 140 MW	230 kV	EHT-2

Source: https://dpdc.gov.bd/site/page/27e77af7-1187-436c-9f80-b579d3493a46/-

4.2 Feasibility of smart grid technology in Bangladesh

Currently Bangladesh has a huge installed capacity and producing about half of the total generation from natural gas. We have limited fuel sources and we have to depend on the import of the fuels. Recently we are facing a huge crisis and as a result production of electricity has been decrease. In spite of having a huge amount of install capacity, we can’t produce electricity according to the demand of the consumers. As a result, daily about 1500 MW load shed occurs on average. It hampers the economy of Bangladesh. As Bangladesh has a rising economy, so it an alarming matter for the economy of Bangladesh. The main reason for this crisis is the “Energy Security”. We’ve mentioned earlier that we have limited source of fuel, so it is very much important to implement “Smart Grid” system as early as possible. It can optimize the losses and can make sure the proper use of electricity and can reduce fuel crisis.

4.2.1 Current scenario for smart grid implementation in Bangladesh

Bangladesh strives for dependable and high-quality electricity. According to the Power Division of Bangladesh's mission statement is “Ensuring quality and Uninterruptable electricity for all by 2030 through integrated development of power generation, transmission and distribution system”.

4.2.1.1 Generation Infrastructure:

At the moment, Bangladesh has 154 power plants. In the previous 13 years, the power system has incorporated about 127 power plants. We must regulate the system voltage and frequency in accordance with the standard to ensure the stability of the power system and the quality of the electric power. There are some methods for regulating these parameters as a result. There are various methods used on the generating side. They are-

i. Primary Control (FGMO)
ii. Secondary Control (AGC)
iii. Tertiary Control

The Primary control system (FGMO) is used by about 36 of the 154 power plants to balance between generation and distribution. We require all three techniques for demand and generation balancing in order to implement smart grid technologies and guarantee high-quality power. On the other hand, there should be some spinning reserve for emergency situation to avoid blackout and to adopt more renewable energy like solar and wind power plant as it can't be predicting the actual generation of power or we can't control the generation. Because solar power generation is fully dependent on the light of sun and the surrounding weather. For smart grid implementation, we need a number of the spinning reserve to integrate more renewable energy in the grid network. We can see the fluctuation of the solar system of Bangladesh at 29th September 2022 below-

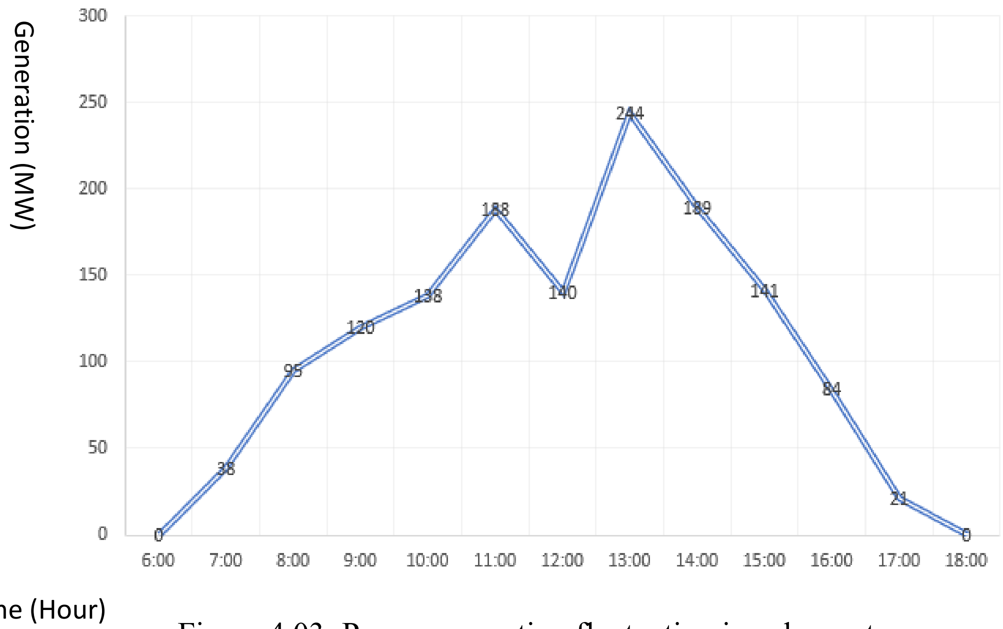

Figure 4.03: Power generation fluctuation in solar system

On the other hand, numerous power plants, including the nuclear power plant at Rouppur and the thermal power plants at Rampal and S. Alam, are coming to operate. The stability will improve after they are put into use. Our electricity system cannot currently support the operation of the nuclear power plant. The system frequency can vary by 49-50.5 Hz in compliance with Bangladesh's current power system as permitted by the international norm for running nuclear power plants. Therefore, we ought to put the smart grid technologies in place as quickly as possible. A smart grid system can increase the stability of the current power system. There are under voltage protection relays, over voltage protection relays, over frequency protection relays, under frequency protection relays, over frequency protection relays, over current protection relays, etc. for protection systems. From those power plant whose are gas turbine power plant, they have nice inertia and they can handle the instant fluctuation of generation and demand. As most the consumer of our country is residential consumer. Newly constructed power plants have the ability to spin up a reserve, a FGMO control system, and the ability to combine secondary and tertiary control systems. The majority of the power plants can be operated through the SCADA system, and they feature advanced metering systems. So, we may conclude that both new and some older power plants can use the smart grid. As a result, integrating a smart grid system into the current generation system will be simpler. Here are the FGMO controlled power plant given below (source from the Monthly Operational Report of PGCB) –

Table 4.5: FGMO controlled power plants

Sl. No	Plant Name	Owner	Installed capacity (MW)
1	Bibiana-II 341 MW CCPP (Summit)	IPP	341
2	Shahjibazar GTPP Unit 8 & 9	BPDB	70
3	Sirajgonj 400 MW CCPP Unit-4	IPP	414
4	Chandpur 150 MW CCPP	NWPGCL	220
5	Sirajgonj 225MW CCPP Unit-2	NWPGCL	220

6	Meghnaghat CCPP(Summit)	IPP	335
7	Ashuganj 450 MW CCPP(North)	APSCL	360
8	Ashuganj 225 MW CCPP	APSCL	221
9	Bheramara 410 MW CCPP	NWPGCL	410
10	Haripur 412 MW CCPP	EGCB	412
11	Fenchugonj CCPP Phase-1	BPDB	97
12	Chandpur 150 MW CCPP	BPDB	163
13	Siddhirganj 2x120 MW GTPP	EGCB	210
14	Shikalbaha 225 MW CCPP	BPDB	225
15	Shikalbaha Peaking GT	BPDB	150
16	Shahjibazar 330 MW CCPP	BPDB	330
17	Ashuganj 450 MW CCPP(South)	APSCL	360
18	Fenchugonj CCPP Phase-2	BPDB	104
19	Bhola 225 MW CCPP	BPDB	194
20	Ghorasal 365 MW CCPP Unit-7	BPDB	365
21	Sirajgonj 225MW CCPP Unit-1	NWPGCL	210
22	Siddhirganj 335 MW CCPP	EGCB	335
23	Bibiyana-III 400 MW CCPP	BPDB	400
24	Sylhet 225 MW CCPP	BPDB	231
25	RPCL 210 MW CCPP	IPP	210
26	Khulna 225 MW CCPP	NWPGCL	230
27	a) Baghabari 71 MW GTPP	BPDB	71
	b) Baghabari 100 MW GTPP	BPDB	100
28	Karnaphuli Hydro PP Unit: 1	BPDB	40
	Karnaphuli Hydro PP Unit: 2	BPDB	40
	Karnaphuli Hydro PP Unit: 3	BPDB	50
	Karnaphuli Hydro PP Unit: 4	BPDB	50
	Karnaphuli Hydro PP Unit: 5	BPDB	50
29	a) Ghorasal Repowered CCPP Unit-3	BPDB	416
	b) Ghorasal Repowered CCPP Unit-4	BPDB	410
30	Bibiyana South 400 MW CCPP	BPDB	383
31	Barapukuria 275 MW TPP Unit-3	BPDB	274

32	Shajibazar 100 MW PP	BPDB	100
33	Payra 1320 MW Unit-1	BCPCL	622
34	Kushiara 163 MW CCPP (KP)	IPP	163
35	Haripur 360MW CCPP(HPL)	IPP	360
36	Meghnaghat 450 MW CCPP(MPL)	IPP	450
Total (MW)			10396

From the table we can see that about 40% of the installed capacity have the FGMO control system.

Additionally, at the very beginning of the thesis, the term "prosumer" was mentioned. Prosumers are a subset of consumers who also generate their own electricity. They utilize this power to suit their needs, and any excess power can be distributed to the grid system via a bi-directional metering system, also known as a net metering system. Because of this, they are able to change the final bill to reflect the power sent to the grid as well as the electricity received. A policy mechanism known as net energy metering (NEM) enables prosumers to link their renewable energy sources to the distribution grid. As a result, any excess electricity produced from renewable sources after self-consumption is supplied to the distribution grid. In return, the prosumer can either import an equal amount of electricity from the grid or receive payment for the net amount of exported electricity at the end of the settlement period in accordance with the Net metering guideline-2018. Bangladesh has also this infrastructure.

A bi-directional meter allows power to flow in both ways during the net metering process. Thus, provided all the requirements outlined in this recommendation are satisfied, the consumer has the option to modify both the amount of electricity consumed from the grid and any excess electricity left over after self-consumption that is generated by rooftop solar systems or any other renewable energy sources. The measured data may be sent to a central aggregator service or retained in the meter itself. The net energy recorded on the meter i.e., the total energy drawn from the network less the total energy supplied to the network for the designated billing period is used to determine the customer's charge. The consumer is responsible for paying the net consumption bill if the amount of power used from the grid exceeds the amount of electricity provided to the grid by the rooftop solar PV system. On the other hand, the distribution utility must permit the consumer's entire credit (measured in kWh) to carry over to the following billing period if the amount of electricity generated and exported from a solar PV system or other renewable energy system to the grid is greater than the amount of electricity imported. The consumer gets compensated for all kWh credits at the conclusion of the defined rolling cycle or settlement period by the distribution utility at a rate outlined in this policy, and on July 1 of each year, the credit account is reset to zero. The design of a typical net metering setup is shown in the diagram below using solar PV as an example of a distributed renewable energy system.

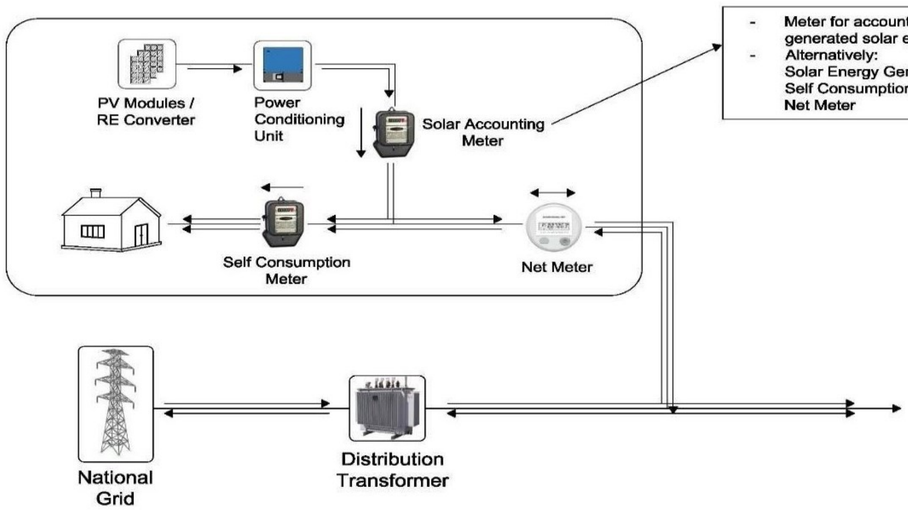

Figure 4.04: Typical Net Metering System

The consumer tariff class, the type of renewable energy technology, installed capacity, and export restrictions are only a few of the variables that are taken into account when determining the rate at which the customer is paid. The prosumer must also follow the safety rules and connectivity technical specifications established by the relevant government while installing such connections. The interconnection procedure, which provides a legal and secure means of connecting net metered distributed energy systems to the electrical grid, is essential to the success of net metering initiatives. Although interconnection standards are frequently described independently of the specifics of a net metering policy, they are crucial to the formulation of the NEM policy. As the regulations only permit the renewable energy system in the net metering system, it can be a tremendous opportunity to incorporate renewable energy. There is a directive regarding the net metering system's tariff system. There is a massive potential of renewable energy which is green and it will be helpful to reduce CO_2 emission. As a result, both consumer and the utility will be benefitted and it will be a blessing for the whole power system and can be a great potential to implement the smart grid system. According to the E-service desk for solar of SREDA, there are 1702 systems of net metering system. Here is the statistic of net metering system below in the table-

Table 4.6: Existing Net-Metering System

Utility Name	Installed Capacity	Quantity
BPDB	16.085 MWp	360
BREB	22.083 MWp	318
DPDC	2.75 MWp	293
DESCO	2.582 MWp	398
WZPDCL	1.157 MWp	260
NESCO	1.763 MWp	73
TOTAL	46.42 MWp	1702

It won't be too difficult to implement smart grid technology at the generation side of the current situation in Bangladesh, as we have previously mentioned that the majority of power plants, including power plants that are still under construction, have the capability of adopting with the advanced technology.

4.2.1.2 Transmission Infrastructure:

Bangladesh has the most advanced transmission system out of the three systems (Generation, Transmission, and Distribution). The only utility PGCB is updating the transmission infrastructure is updating day by day. It is aiming to establish 765kV transmission system. Modern systems include the operating, monitoring, regulating, protecting, and communication systems. At order to increase dependability, they are installing Gas Insulated Switchgear systems in their key sub-stations. A number of transmission lines and sub-stations are what PGCB plans to build. They are accepting several development projects as a result. They have a SCADA system in most of their sub-stations. The SCADA technology allows them to remotely monitor and control these sub-stations. PGCB has the modern National Load Dispatch Center (NLDC) and they have more than one NLDC. For better performance, they have many ALDC also. To control and monitor their system, they have RTU. For communication system PGCB has OPGW over the transmission line. They use their sky wire for both protection and communication. Optical fiber is deployed inside the sky wire whole over Bangladesh.

PGCB is using the OPGW and also leasing the optical fiber to the telecom operators and internet service provider. So, there is a huge potential at the transmission system to integrate the smart grid technology in Bangladesh. PGCB is also working to integrate the smart grid in full scale in the transmission system. The NLDC has the latest infrastructure to control and monitor the transmission system. NLDC is situated at Rampura, Aftab Nagar, Dhaka. PGCB has backup NLDC at Biddut Bhaban, Abdul Gani Road, Dhaka and one more backup NLDC at Shiddhirganj. Here is the organizational chart of NLDC(PGCB)-

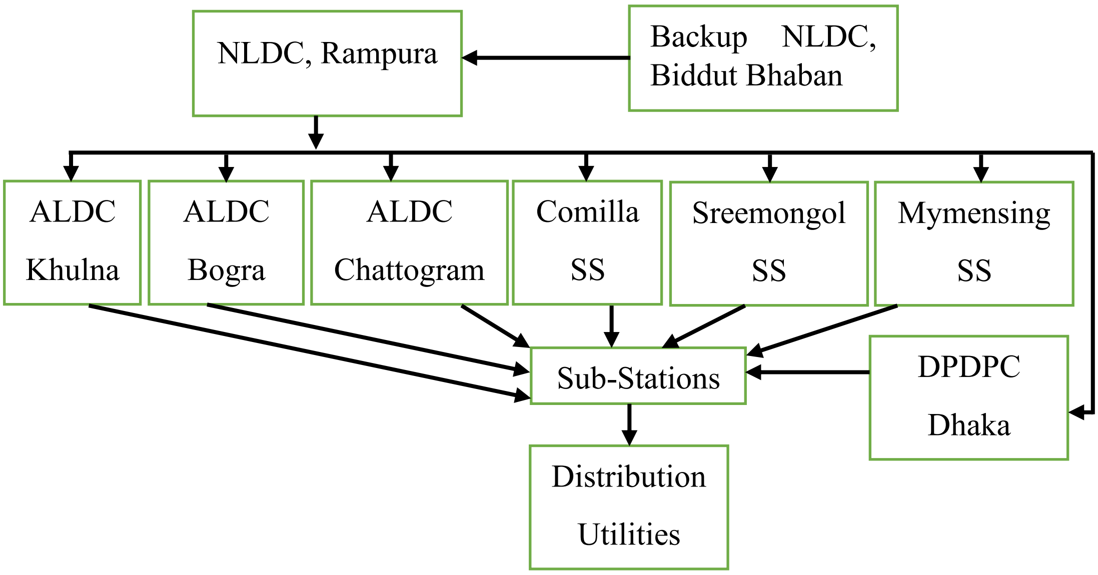

Figure 4.05: Organizational Chart of NLDC

The ALDC is organized according to the area zone. NLDC commands to the ALDC and ALDC control the sub-stations according to the command/instruction of NLDC. Now the ALDCs according to the area zone is given below-

Table 4.7: Area wise ALDC or Control Center

ALDC/ Control Center	**Area/Zone**
Khulna ALDC	Khulna+Barishal
Borga ALDC	Rajshahi+Rangpur
Comilla S/S	Comilla
Sreemongol S/S	Sylhet
Mymensing S/S	Mymensingh
Chattogram ALDC	Chittagong
DPDC (Dhaka Base)	Dhaka

4.2.1.2.1 Features of the NLDC-

i. Coordination among generation, transmission & distribution
ii. Load forecasting
iii. Unit commitment
iv. Contingency analysis
v. Economic dispatch
vi. Optimum power flow
vii. Load flow analysis

SCADA supported National Load Dispatch Center at Rampura and Back-up Center in Biddyut Bhaban provides a central point from wchich whole power network of Bangladesh is visible in respect of monitoring and controlling the lines, sub-stations and a number of generators (at present monitoring only).

As the control center is distributed according to the area/zone, it becomes easier to handle the whole system which is a step to the smart grid. Transmission infrastructure is moving forward to the smart grid system. Current infrastructure has the ability to adopt with the smart grid system. PGCB has the advance communication network with RTU which is shown the given below figure –

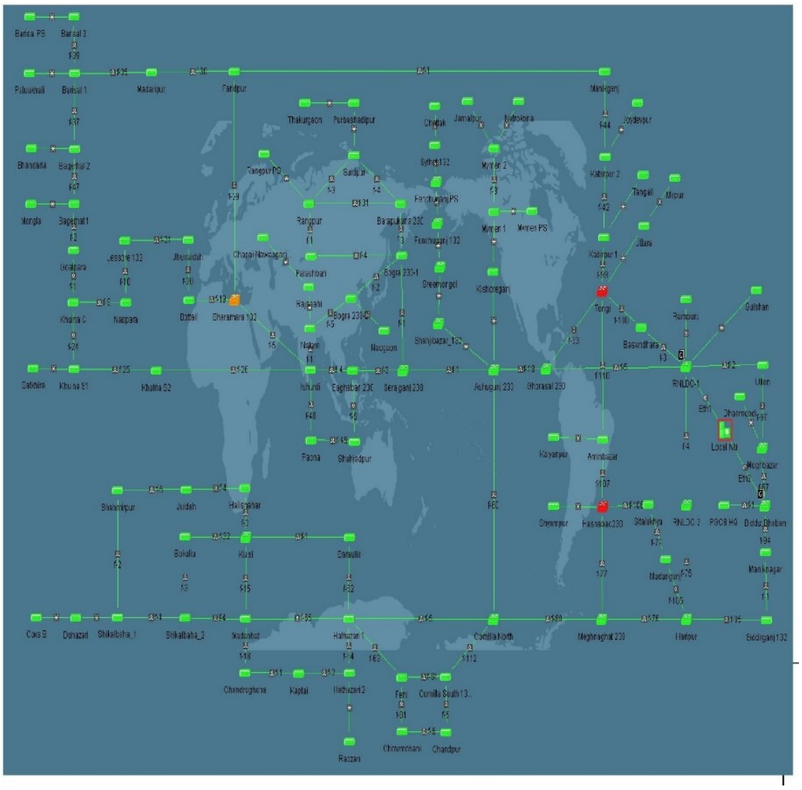

Figure 4.06: Communication Network & RTU Locations

PGCB has the largest optical fiber communication network, which is a fundamental thing for the Smart grid system. The current optical fiber network whole over the country is shown in the below-

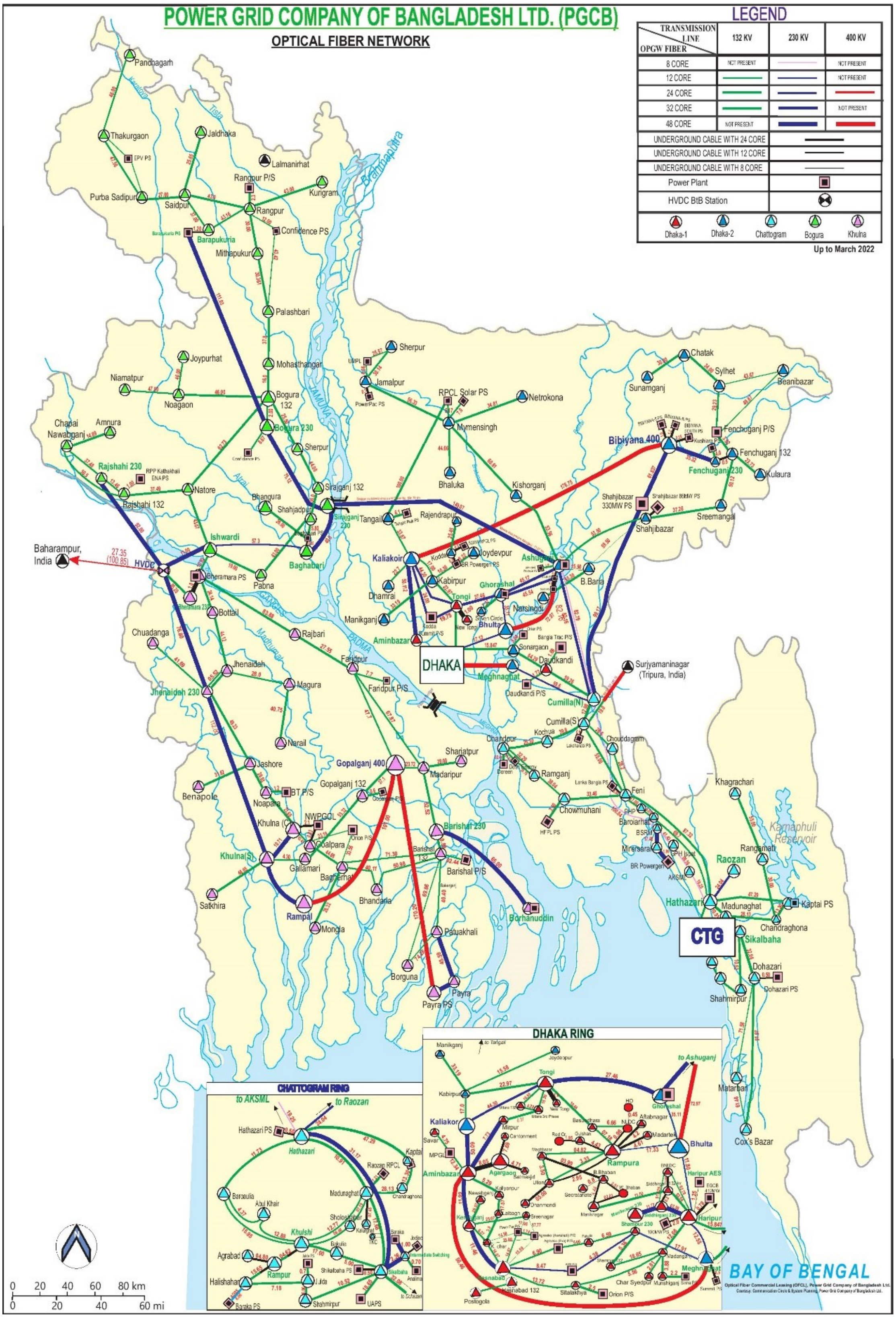

Figure 4.07: Optical Fiber (OPGW) Network in transmission line

The transmission system's performance has improved along with the infrastructure's updating and adoption of new technology. SAS technology is included in several existing and newly constructed substations. The substation operator and the operator of NLDC can easily operate and monitor the system with the help of the substation automation system, and they can carry out the operation without making any mistakes thanks to SAS's intelligent interlock system. As soon as the operator attempts to carry out a mistaken command, the SAS system can identify the error and reject the operation by suggesting a potential workaround. It keeps the system as stable as possible and minimizes accidents and physical harm. Here is the consolidated statement of Sub-Station performance and the consolidated statement of Transmission Line's performance shown below-

4.2.1.2.2 Consolidated statement of Sub-Station performance

Page: 1/1 QF-LDC-29

POWER GRID COMPANY OF BANGLADESH LTD.

Information Management Division, LDC, Dhaka.

Consolidated Statement of Sub-Station performance

Month:August 2022

A) Power Interruption

SL. No	Name of the Circle	Total Capacity of the Sub-Station MVA	No of Power Interruption			Power Interruption Up to 30Mins	Power Interruption Up to 01Hrs	Power Interruption Above 01Hour	Amount of Interrupted Energy MWH	Remarks
			Forced	Scheduled	Total					
1	2	3	4	5	6	7	8	9	10	11
1	Dhaka (North)	8801.60	10.00	1.00	11.00	7.00	1.00	3.00	343.37	
2	Dhaka (South)	5031.60	4.00		4.00	2.00	1.00	1.00	186.03	
3	Chattogram	2042.00	6.00	2.00	8	2.00	1.00	5.00	429.72	
4	Khulna	2434.00	8.00	9.00	17.00	3.00	5.00	9.00	869.11	
5	HVDC	5954.30	3.00	1.00	4.00	1.00	2.00	1.00	110.40	
6	Bogura	3145.60	12	11.00	23.00	4	2.00	17.00	844.10	
7	Cumilla	2981.00	7.00	9.00	16.00	4.00	3	9.00	517.45	
8	Others	-	-	-	-	-	-	-	0.00	
	Total	30390.10							3300.18	

B) Availability of the Sub-Station

SL. No	Name of the Circle	Availability of the S/S
1	2	3
1	Dhaka (North)	99.99%
2	Dhaka (South)	99.95%
3	Chattogram	99.90%
4	Khulna	99.87%
5	HVDC	99.98%
6	Bogura	99.89%
7	Cumilla	99.94%

Executive Engineer
Information Management Division
LDC, PGCB, Dhaka.

Figure 4.08: Sub-Station availability and performance

4.2.1.2.3 Consolidated statement of Transmission Line's performance

Page: 1/1 QF-LDC-30

POWER GRID COMPANY OF BANGLADESH LTD.

Information Management Division, LDC, Dhaka.

Consolidated Statement of Transmission line's performance

Month:August 2022

A) Power Interruption

SL. No	Name of the Circle	Total length of Transmission line (Ckt-KM)	No. of Section in the Transmission Line	No of Power Interruption			Power Interruption	Power Interruption	Power Interruption	Amount of Interrupted	Remarks
				Forced	Scheduled	Total	Up to 30Mins	Up to 01Hrs	Above 01Hour	Energy MWH	
1	2	3	4	5	6	7	8	9	10	11	12
1	Dhaka (North)	2254.47	-	4		4	4				163.983
2	Dhaka (South)	990.29		3		3	1.00	2.00			**107.7**
3	Chattogram	917.00	-	2	-	2	2	-	-	-	26.95
4	Khulna	1238.40	-	4		4	3	1	-	-	38.13
5	HVDC	1325.00	-	1	1	2	-	1	-	1	169.65
6	Bogura	1803.30	-	-	-	-	-	-	-	-	-
7	Cumilla	1648.16	-	3		3	3.00				**119.53**
8	`	-			-	-	-	-	-	-	-
	Total	10176.62									**625.95**

B) Availability of theTransmission Line

SL. No	Name of the Circle	Availability of the Transmission Line
1	2	3
1	Dhaka (North)	99.94%
2	Dhaka (South)	99.95%
3	Chattogram	99.97%
4	Khulna	99.91%
5	Bheramara (HVDC)	99.96%
6	Bogura	99.88%
7	Cumilla	99.92%

Executive Engineer
Information Management Division
LDC, PGCB, Dhaka.

Figure 4.09: Transmission line availability and performance

From the both of the table, we can see that the current transmission system is much better as we can see the availability of both sub-stations and the transmission line is about above 99%. It could be about 99.99% if the distribution system would more developed, as we can see that most of the fault occurred at the distribution side and it effects at the transmission system of the current situation. PGCB is also working to improve the stability and reliability of the current transmission system of Bangladesh. They are working to integrate the giant base load power plants in the system. Although there are some laggings in this sector, they are doing well to operate the power plant most economically. The power plants can be controlled from the NLDC. Once it could be happened, then Bangladesh would move forward to the smart grid. PGCB has some equipment, which are the components of a modern smart grid system. Transmission system just need a few modernizations only.

4.2.1.3 Distribution infrastructure

Outdated of the three sectors is distribution. The transmission system has not yet been able to evolve as the distribution system can. Six distribution utilities are present in

Bangladesh. The nation's infrastructure is being updated, but they are still distributing power in many areas. An enormous number of faults therefore develop at the distribution network. The majority of the distribution lines are antiquated. Despite the utilities' best efforts, they were unable to surpass the mark in this area. Despite the massive amount of newly constructed distribution lines, the outdated infrastructure makes it impossible to guarantee a continuous supply of power. As soon as possible, the distribution system should have updated infrastructure such as GIS distribution sub-stations and automation. Although the utilities are making an effort to upgrade the system, it is extremely minimal compared to the existing system. Only DPDC and DESCO are moving toward cutting-edge technologies, including subsurface distribution systems, SCADA integration, and GIS sub-stations. But it is not enough. DESCO and DPDC will incorporate smart grid technologies into some distribution areas on the distribution side. They have chosen the projects for incorporating the smart grid technologies because of this. Both DPDC and DESCO have pre-paid meters in addition to smart meters. But it's also not enough. They are attempting to integrate pre-paid meters and smart meters also. However, their distribution mechanism is also pretty outdated. As soon as feasible, a replacement ought to be made. The city of Dhaka experiences power outages every day as a result of this infrastructure.

Construction of contemporary Grid Substations, Distribution Substations, renovation or upgrade of the Distribution Network, installation of Supervisory Control and Data Acquisition System (SCADA), Smart Metering System, application of Geographical Information System (GIS), Underground Distribution Network, development of human resources and adoption of State-of-the-Art Information Technology, etc. are some of the initiatives DESCO has taken to improve its electrical infrastructure. By June 2023, it's anticipated that all consumers will have access to SMART Prepaid Meters via AMI (Advanced Metering Infrastructure).

DESCO, on the other hand is very interested in and focused on the contemporary underground electrical distribution network due to the aesthetic beauty of the capital city and dependable power supply. Byucksan Power Co. Ltd., an international consultant, performed a Feasibility Study of Underground Electric Distribution Network in RAJUK Purbachal New City, RAJUK Uttara 3rd Phase, and Existing Gulshan, Baridhara, and Uttara area in 2018 for DESCO (S.Korea). It should be noted that all 132kV and 33kV wires are currently underground in the DESCO region.

The SCADA system has already been implemented by DESCO in its jurisdiction. It is planned to support 69 stations, 2 control centers, and around 70,000 DB points, with 50% of the planned capacity allocated for expansion up to 2041. All of the equipment will be monitored and managed by this SCADA system up to the 132kV, 33kV, and 11kV levels. The project includes designing and building a redundant back-up SCADA center (BCC) and a SCADA control center (MCC) at DESCO sites. At DESCO substations, supply, installation, and upgrade of the SCADA system, including RTUs and SAS Gateway Servers, are also provided.

The establishment of a Master Information Center for data interpretability is the next stage of modernization. To store, process, and distribute data and applications, DESCO intends to construct a MIC that unifies the company's shared IT operations and hardware. DESCO makes sure the MIC has a secure setting that reduces the possibility of a security breach for information security.

Smart grids are being installed by Dhaka Power Distribution Company (DPDC) in the capital's Dhanmondi, Azimpur, Green Road, Lalmatia, and Asad Gate neighborhoods. They are piloting the smart grid technology in the Dhaka city. For this reason, they have taken a huge project to implement the smart grid. In this project, their smart grid will have some interface like- GIS, SCADA, AMI etc.

On the other hand, many homes in Bangladesh now have access to power thanks to the Bangladesh Rural Electrification Board. Now, it must be made sure that all consumers receive the electricity without any system losses. Because of this, BREB will also need to be automated.

Distribution side needs a massive automation. Generation and transmission system is up to the mark in accordance with the smart grid technology. Transmission system is almost like smart grid. Main things to do that the distribution system needs an update to adopt smart grid technology and Bangladesh is far away from automation in the sector without DPDC and DESCO.

4.2.1.4 Others Infrastructure

4.2.1.4.1 Communication system & IT-

i. As we have mentioned before PGCB owns an optical fiber network known as OPGWS which is connected whole over the country with the transmission line.

ii. The Bangabandhu Satellite-1 launched on 11th May 2018. Note that it is the 1st Bangladeshi Geostationary Communication and Broadcasting Satellite.
iii. Six (06) mobile phone operators have wireless connectivity all over the country, which indicates the internet availability.
iv. Distribution Network Operator offers online/online bill payment facility, different information and answers of queries from consumers end which indicates the consumers participation.
v. Pilot projects for Big Data analysis has taken for few industrial zones.

4.2.1.4.2 Metering System-

i. Meters with AM/RM (automatic/remote metering) already installed for a significant number of bulk consumers at 11 kV and 400 volts level.
ii. Pre-payment meters are installed at many areas for single phase consumers.
iii. Net-Metering system for grid connected solar home system is under implementation.

4.2.2 Advantages of smart grid technology in Bangladesh

In the perspective of the current situation of Bangladesh power sector, smart grid can be a blessing for this sector. Government is using a huge amount of investment in this sector to develop this power sector. Here are the advantages shown below-

4.2.2.1 Reducing system loss by using smart grid components

Bangladesh has been successful in terms of reducing system loss by using smart grid components. We can see a graphical presentation of the reduction of smart grid below-

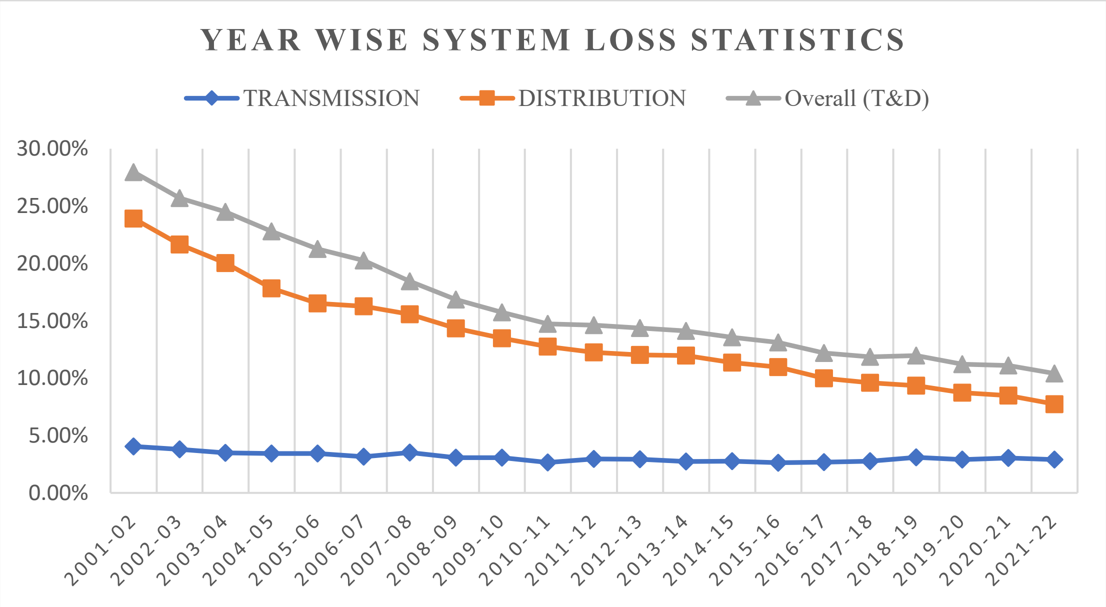

Figure 4.10: System Loss

We can see the data table of the system loss below-

Table 4.8: Financial Year Wise System Loss

Year wise System Loss Statistics			
Fin. Year	**TRANSMISSION**	**DISTRIBUTION**	**Overall (T&D)**
2001-02	4.05%	23.92%	27.97%
2002-03	3.79%	21.64%	25.69%
2003-04	3.48%	20.04%	24.49%
2004-05	3.42%	17.83%	22.79%
2005-06	3.44%	16.53%	21.25%
2006-07	3.15%	16.26%	20.25%
2007-08	3.51%	15.56%	18.45%
2008-09	3.06%	14.33%	16.85%
2009-10	3.08%	13.49%	15.73%
2010-11	2.66%	12.75%	14.73%
2011-12	2.96%	12.26%	14.61%
2012-13	2.94%	12.03%	14.36%
2013-14	2.74%	11.96%	14.13%
2014-15	2.76%	11.36%	13.55%
2015-16	2.63%	10.96%	13.10%
2016-17	2.67%	9.98%	12.19%
2017-18	2.75%	9.60%	11.87%
2018-19	3.10%	9.35%	11.96%
2019-20	2.91%	8.73%	11.23%
2020-21	3.05%	8.48%	11.11%
2021-22	2.89%	7.74%	10.41%

The table above shows that the system loss is gradually decreasing day by day. It is encouraging. According to system loss data from the most recent fiscal year, the maximum generation was 14,782 MW for that fiscal year. We may determine from that information that the transmission loss is 427.2 MW, the distribution loss is 1144.12 MW, and the total loss is 1538.8 MW. It is a substantial sum. Transmission is below

3%, which complies with international standards, however distribution loss does not. It only occurred as a result of the smart grid architecture and the nearly automated transmission side. So, we can conclude that implementing a smart grid can reduce system loss. If it can be reduced at minimum like about 8%, then the amount would be about 1182.6MW and about 356.3 MW can be saved. Annually 3121188 MWh energy can be saved in terms of reducing the system loss. It will save fuel and also save the valuable foreign reserve as we have to import the fuel from abroad.

4.2.2.2 Others Advantages

i. Systems for smart grids contribute to universal access to reliable electricity. They enable more effective management of the energy network by facilitating the exchange of information between electricity providers and consumers and adjusting the flow of electricity in real time.
ii. Improved grid performance brought about by advanced automation will enable the electricity supplier to optimize energy distribution without making excessive investments.
iii. The diesel generators that are utilized as a backup during grid failures will no longer emit pollution as a result of the smart grid's improved grid performance.
iv. More renewable energy sources can be integrated to the system by implementing smart grid. It will save the fossil fuel and can reduce the greenhouse gas emission.
v. Smart grid can introduce with the electric vehicle as a distributed storage. It will run by the electricity and can be a distributed storage while dynamic pricing appears. This will reduce the air pollution of the mega cities like Dhaka city.
vi. By integrating smart grid technology, the captive power can be reduced also and Bangladesh can save huge amount of natural gas as the captive power plant uses natural gas to produce their electricity with the low efficient engines. As smart grid can ensure reliable, quality and uninterrupted power.
vii. Power plant can be decentralized by implementing smart grid technology in the perspective of Bangladesh.
viii. Can be come out from the single buyer policy as there is BPDB is the single buyer of the bulk electric power. If once smart grid can be implemented, there a regulated market can be introduced and it will increase the customer participation and satisfaction.

ix. As everything can be monitored and controlled of electric power, so the system will be clear crestal, can be improved the system performance and can make sure the accountability of the system related manpower also.

4.2.3 Disadvantages of smart grid technology in Bangladesh

Everything has advantages and disadvantages too. There are some disadvantages also. But the advantages are higher and more effective than the disadvantages. The disadvantages are-

i. The main disadvantage is that the advance technology is not available in our market & it is very costly and Bangladesh will have to import the technology, technology support, integration service, technology expert from the abroad. As a result, a huge capital needs to implement the smart grid technology which is quite difficult to manage it at the context of present situation.

ii. Bangladesh has a huge population and unemployment is a major problem. But by implementing the smart grid technology will make more people unemployed as there is a huge automation in the smart grid technology like advance metering infrastructure will unemployed the meter readers etc.

4.2.4 Challenges to implement Smart Grid system in Bangladesh

Future electrical networks could benefit from the smart grid platform. On the route to putting it into practice, there are many obstacles to overcome. As a result, various market players must coordinate their efforts and concentrate on developing the technologies and infrastructure necessary for the deployment of the Smart Grid as well as identifying the sources of funding and returns. It is now appropriate for utilities to use Smart Grid technologies and inform customers of the advantages of lowering peak electricity demand. The fact that the utility is already old and in need of renovation (the majority of the network's 30-40 years lifespan has passed) presents a good opportunity for the utility companies to not only replace the outdated equipment with brand-new equipment but also to test-drive the brand-new, exciting Smart Grid technology platform. They will receive aid from electricity users. A consumer will start altering his behavior if he has greater knowledge about what he is consuming. It concerns not just the kinds of gadgets he purchases but also the amount of energy he consumes. However, to implement smart grid technology there are some challenges. They are given below-

4.2.4.1 Technological Challenge

4.2.4.1.1 Coverage of communication in distribution grid network

The administration of Smart Grid systems will necessitate the employment of an extremely capable communications network that can deliver assured standards of performance in terms of bandwidth and latency. Various distribution automation functions, such as the control of switch gear to achieve rapid restoration and self-healing capabilities, can be supported by an expansion of communications coverage to the distribution network. It is now feasible to actively manage feeder voltage profiles with automatic tap adjustments or VAR assistance, as well as to thoroughly monitor assets like distribution transformers. Today, nearly every distributor must overcome the difficulty of creating a cogent communications solution that will support their Smart Grid ambitions and enable simple integration of Smart Grid activities inside their business processes. For many years to come, how they respond will determine how effective their organizations are. Key concerns include open communications standards, cyber security, and equipment and jurisdictional interoperability.

Numerous distributors already have projects in place to increase the level of automation of distribution assets, largely for the goal of enhancing reliability.

4.2.4.1.2 Security of Information

Since practically everyone has access to the Internet nowadays, we are in the digital age. Terrorist attacks are very likely to target modern electrical infrastructure. These days, remote access to SCADA systems is possible. Given that a SCADA system regulates the power flow on the bus, an attack on the SCADA system has the potential to disrupt the functioning of the existing electrical infrastructure. The grid system is a burning question for national security. The grid system should be secure from any threats. Otherwise, there will likely be a national emergency and a blackout could happen. This calls for a robust security system for both the data and the system. There should be restricted access for controlling the system, and access should be adequately screened, in order to protect it from any attack. For the security of the information, powerful firewalls, anti-virus software, and advanced security systems can be deployed.

4.2.4.1.3 Integration of Distributed Energy Resources

With the aid of sensors and two-way metering, more intelligent integration of dispersed energy generation will be possible thanks to advanced metering technologies and improved communications. In the event that they have excess energy, this will allow customers to act as energy suppliers. On the other hand, unscheduled and weather-dependent distributed energy generating (in case of wind or solar generation). Because of this feature, managing the fluctuating energy flow presents certain difficulties. The power system needs to be controlled at a higher level in order to ensure dependability as distributed generation becomes more prevalent. Improved transmission efficiency, demand response implementation and energy storage are a few examples of these controls. The development of an acceptable load modeling and forecasting is necessary for the integration to happen. For instance, analysis of long-term wind patterns can be done to determine the time of day when a wind farm will be available and how much electricity it will be able to produce. Forecasts of upcoming needs are necessary for the real functioning of smart grids in order to be able to get the flexible systems ready for the right behavior. The already challenging balancing act is made even more difficult by non-scheduled renewable energy sources. The inability of the renewable energy generation to be dispatched in the usual sense may make it difficult for the conventional system to operate. A smart grid makes use of future advancements made possible by the application of communications and information technology. One of the most important steps in putting a Smart Grid in place is the use of precise renewable energy forecasting.

4.2.4.1.4 Automation of Distribution

Given that distribution networks serve as a hub for many participants in the electrical market, the planning of the Smart Grid platform will have a significant impact on how these networks operate. The one-way power flow idea was taken into consideration when designing the traditional distribution network. As a result, power travels from a big generation node to consumers. Power will flow in both directions on the new Smart Grid. As a result, the distribution network needs to undergo some changes in order to take use of the new opportunities provided by cutting-edge communication and information technologies. Distribution automation is a big challenge to implement the smart grid system. There is a huge distribution network whole over the country and most of the distribution network are in the rural area. So, it would be quite difficult for the automation of the distribution system.

4.2.4.2 Economical and Business Challenge

For the smart grid ideas to be successfully implemented in the real world, the business case for a smart grid must be built. A business case offers the fundamental justification for investing in initiatives for business change in the broadest sense. Network operators, potential power retailers, and newly emerging businesses like demand and generation aggregators are the main entities in the smart grid space that are investigating establishing business cases. The main business problem the utility industry is facing is justifying the high initial capital cost of a fully implemented smart grid rollout with benefits that can be seen at specific sites. Consumers are also dubious about the cost-benefits of such an investment because those rewards seem insignificant in comparison to the initial outlay. Additionally, the electricity sector must conform to macro-level policy criteria that include resource conservation, environmental protection, adaptation to climate change and confirmation of a sustainable environment. The cost-benefit ratio for each application in an integrated system will be more accurate for a complete rollout beyond the pilot stage if the expense of common infrastructure is shared among the benefits generated from different applications. Given the significant expenditures made in the smart grid scenario, it is crucial for the utilities to recoup their costs. However, it is important to keep in mind that, from a larger perspective, smart grids can result in potential savings by improving the dependability of the electric power grid. Smart grids are typically connected with cost reductions at the consumer end. Consumer concerns about plug-in hybrid electric vehicles (PHEVs) in terms of cost, benefits, technical requirements, and dependability must be addressed. Currently exceedingly expensive and regarded as a luxury rather than a means of saving money and lowering carbon emissions, plug-in hybrid vehicles will be crucial components of future smart grid networks. In order to support this new technology, there is currently a lack of charging infrastructure and a significant cost associated with converting a hybrid vehicle to a plug-in hybrid electric vehicle. Since the fossil fuel base load plants are the ones that power these vehicles, PHEVs have also not yet attained widespread acceptability as a contributor to lower greenhouse gas emissions. To achieve widespread adoption of its technology and consequently, economic and environmental benefits, all these PHEV-related difficulties must be tackled.

CHAPTER 5
PROPOSED MODEL OF SMART GRID FOR BANGLADESH

5.1 INTRODUCTION

Bangladesh is a developing country. For forwarding to the developed country, Bangladesh needs accurate planning. To be a developed country, we have to be more careful. Because we have a limited natural resource and limited foreign earning. The main sources of foreign currency are the readymade garments and the remittances. On the other hand, we have a few exporting products and services only. So, we need to be more careful while choosing the development projects. For this reason, we shouldn't follow the foreign expert opinion blindly. Because most of the foreign country will try to export the new technologies in like our country to expand their publicity, their business and to earn foreign currency. Most of the foreign consultants can't provide actual forecasting, actual feasibility study, actual things according to the perspective of our country. For example, like Power System Master Plan-2016. According this master plan made by JICA, the growth of electricity demand has not increased. As a result, we have a huge installed capacity but we can't use this capacity to provide reliable and uninterrupted power supply to the consumer. Government is paying up a huge amount of capacity charge without buying a single unit of electricity. We need to plan which is reasonable and sustainable. Bangladesh has very few industrial loads in respect of industrial country. They are not following the Grid-code properly. As a result, there is a huge problem in the power system. Bangladesh is aiming to import power from SAARC country. As a result, we have to change the existing technology to adopt with them. We can't change our system over night, but we can make it possible by changing gradually. Technologies of today are evolving quickly. After ten to fifteen years, the current technology may become conventional. So, it should be designing a technology, which can be modified easily so that it can be adopt the new technology. As Bangladesh is a developing country, it has a rising economy and it after covid effect has started so Bangladesh have to choose that kind of way to develop a smart grid. A technology should be reliable and sustainable in the context of current situation. So Bangladesh should follow the proper way.

5.2 Proposed model of Smart Grid

Smart grid is a conceptual thing. It can be described in many ways. We have proposed a simple way for developing smart grid.

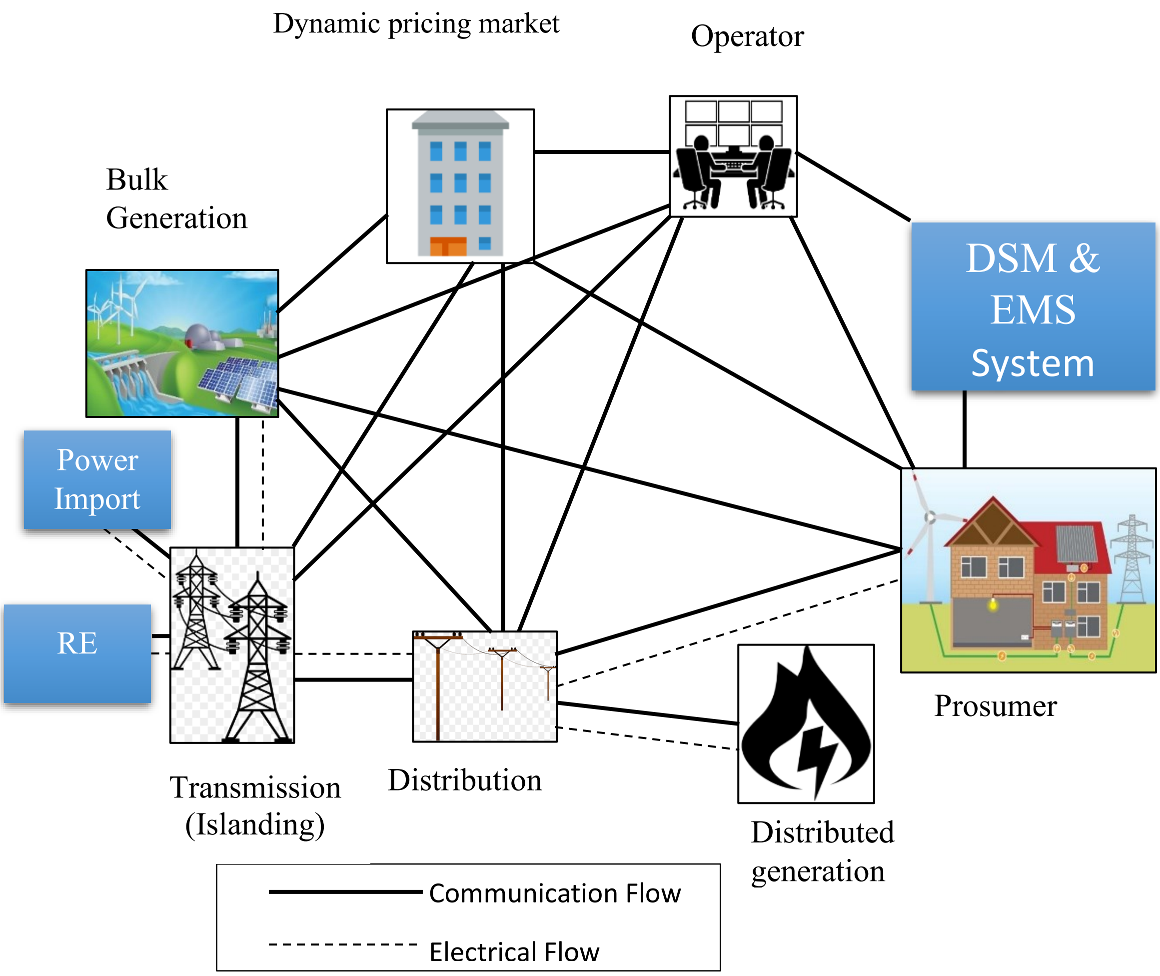

Figure 5.01: Proposed model for smart grid network in Bangladesh

In the above figure we have shown very much essential things in the context of Bangladesh. Most of the things of them are well established from generation end to distribution. Most of the grid sub-stations are SCADA based, which is essential for smart grid. On the other hand, PGCB has a well-established OPGW, which can establish communication network from the generation end to the distribution. Some important sub-stations are gas insulated switchgear system, which ensure the reliability of the grid system. Day by day grid sub-stations are upgrading gradually. Which sub-stations are very old, they have been upgrading for the new technology like SCADA & GIS system. Some of them are being converted from conventional to semi-automated like including RTU in the old substations and as a result those substations can be monitored in the central SCADA system for the whole grid system. BPDB, DPDC and

DESCO has SCADA system in a small scale. They are also covering the whole system in the SCADA. Other distribution utilities are also moving forward to the SCADA system. We can establish SCADA system in the upcoming new sub-station but which are established, those can be integrated in the central SCADA system by using RTU. PGCB can be the example for implementing this. Because we have to ensure the proper use of the existing equipment. Already world is facing a huge crisis. Fuel and energy is a crying need for the development of any country. So smart grid can be the only solution for the country like Bangladesh. In our proposed model only, dynamic pricing is absent in Bangladesh. On the other hand, rest of the model are available in Bangladesh. It just needs to expand gradually. We can use Bangabandhu Sattelite-1 for establishing communication network to the consumer end by using smart meter. Everything except dynamic pricing and power import has been described before. So, we can now discuss about Dynamic Pricing and Power Import.

5.2.1 Dynamic Pricing

Dynamic pricing system for electrical energy is a crying need in the context of Bangladesh. By establishing dynamic pricing system, many problems of current power system can be solved. Like demand side management and energy management system can be done easily. Which enables reliable and uninterrupted power supply to the consumer. Besides this people will also aware of using electricity. Waste of electrical power and also production cost of power can be decreased. Now government has to run IC-engine based power plant to meet up the peak demand. Which is not eco-friendly and production of electricity is also increased. Oil based power plant have to come into production to meet the extra peak demand at peak hour. Fuel price is also increasing day by day. On the other hand, liquid fuel-based power plant is not eco-friendly. It produces a huge amount of greenhouse gas. So, it can also be reduced by establishing dynamic pricing. In dynamic pricing system, people can sell electricity to the market when price is high and can buy electricity from the market when price is low. They can also use distributed storage for that. People can do the daily work in the off-peak time as the price of electricity will be low. It can establish consumer participation to the market. On the other hand, rooftop solar system will increase due to dynamic pricing which can reduce the burden in the national power grid and can reduce the burden to the fossil fuel. As a result, green energy use will increase rapidly. At present most of the net-metering system is not working properly as there is no dynamic pricing system to the current grid system. By enabling dynamic pricing system, people will be aware of electricity usage. As a result, electricity waste will decrease rapidly. So dynamic pricing system can be a blessing for power and energy sector if it can be established properly.

5.2.2 Power Import

Power import can be another blessing for Bangladesh. The SAARC (South Asian Association of Regional Co-operation) country can establish a SAARC inter-connected grid system like European grid. It will create regional co-operation between the SAARC country. Bangladesh is already importing 1160 MW power from India at Kushtia Bheramara Back-to-Back HVDC station and Comilla. It is also aiming to import Hydro power from Nepal and Bhutan also. According to the Power system master plan-2016, Bangladesh is aiming to import 9000 MW power from neighboring country under cross-border co-operation. For this reason, power system should be updated for synchronizing to the SAARC interconnected grid or cross-border grid. It should keep sufficient up to date to cope up with the other countries development. The main advantage would be that the stability of the system will increase and regional co-operation will increase. As a result, the people of those SAARC country will be benefitted and the developing economy will arise. There will be no war or anything else like that. It could be quite difficult to implement the SAARC grid. But the result will be impressive for the country like Bangladesh. We repeat that European Grid can be the great example in that case. But power import can be a great solution of fuel crisis. Like Nepal and Bhutan has a huge resource for Hydro power and there is no noticeable demand of power in those country. So, it can be a great source of clean energy as well as cost of unit price will also decrease and overall system will be more reliable.

5.2.3 Transmission (Islanding)

The existing transmission system is nearly following the international standard. But the system is updating day by day and system is also increasing. As a result, the transmission system became more complex. To avoid grid failure like 1st November 2014 and 4th October 2022, the existing transmission system should be like Island. By creating Island, if any fault occurred in any Island, then it can be isolate the other island easily and the system can be restored as early as possible. At present, there is only 2 islands in the transmission system. Eastern grid and western grid of Bangladesh.

CHAPTER 6
IMPACT ASSESSMENT OF THE THESIS

6.1 Economical, Societal and Global Impact

There are some impacts of any project or development work like economic, social and global impact. In this part it will be tried to show some impacts of implementing the smart grid technology.

6.1.1 Economic Impact

Every technological development has some economic impacts. Today's world is fully depended on the economy. After implementing the smart grid in Bangladesh there will be also an economic impact in the economy of Bangladesh. Bangladesh is developing country and it has a rising economy in the south Asia. One of the benefits of smart grid is reducing system loss. From the table 4.8 shows that the system loss. The system loss is gradually decreasing day by day. It is encouraging. According to system loss data from the most recent fiscal year, the maximum generation was 14,782 MW for that fiscal year. We can determine from that information that the transmission loss is 427.2 MW, the distribution loss is 1144.12 MW, and the total loss is 1538.8 MW. It is a substantial sum. Transmission is below 3%, which complies with international standards, however distribution loss does not. It only occurred as a result of the smart grid architecture and the nearly automated transmission side. So, we can conclude that implementing a smart grid can reduce system loss. If it can be reduced at minimum like about 8%, then the amount would be about 1182.6MW and about 356.3 MW can be saved. Annually 3121188 MWh energy can be saved in terms of reducing the system loss. It will save fuel and also save the valuable foreign reserve as we have to import the fuel from abroad. On the other hand, DG can reduce transmission loss. In this case only distribution loss will be remaining. So, it would be very economical for the whole power system and a huge economic impact can be done.

6.1.2 Societal and Global Impact

There are societal and global impact also after implementing the smart grid in Bangladesh. By implementing smart grid, the system can be designed more green than the present condition. As a result, greenhouse gas emission will also can be reduced. As a result, global warming problem can be reduced also. Because, greenhouse gas is the main reason for global warming. On the other hand, it will also keep the environment as green as possible. The air quality index of Dhaka is very poor and a number of people died due to air pollution. Rooftop solar can be a very impressive thing in the smart grid for green energy. It can reduce CO_2 emission. This has a global impact also. The developed countries are the top contributor of green house gas and air pollution also. As renewable energy can be integrated in the system, then contribution amount of green house gas will be reduced in the environment.

6.1.3 Other Concerns

There are some other concerns also besides this impact. Dynamic pricing system can play a vital role in the existing power system of Bangladesh. When dynamic pricing system, the consumer will be conscious about their own power consumption. Abuse of energy will be reduced also. As a result, proper utilization can be done.

CHAPTER 7

PROJECT MANAGEMENT

7.1 Task, Schedule and Milestones

To implement any development work in large scale, it should be piloting. Just because of that the project will sustain or not. Smart grid implementation needs a huge investment and it is not easy for piloting. This is why before piloting it needs a large feasibility study for successful implementation. First it needs technical assessment and then financial assessment. As there is no piloting, it can’t be defined the actual technical and financial assessment properly. After completing the technical and financial assessment, first it needs to do the civil works and then it needs to do the technical works.

7.2 Resources and Cost Management

We are suggesting not to replace the whole system by smart grid. Rather we are telling that, the newly planned system can be designed and implement by following the smart grid technology and the existing system can be replaced or modified to the semi-automated system also. AS a result, a huge financial save can be done. On the other hand we can implement the technology by our local technology rather to import the technology from abroad according to the suggestion of the foreign expert. They may be best expert in the situation of their own country but our local expert will know better than the foreign expert. We can see the example of power system master plan-2016. According to the power system master plan-2016, the demand of electricity didn’t increased properly. So, it needed to revise the power system master plan-2016. So, resource and cost management should be done according to the perspective of our present condition. So, it will be wise not to follow the suggestion of foreign expert blindly. Rather we can follow the suggestion of our local expert and implement the system according to the perspective of our own country.

CHAPTER 8

CONCLUSIONSION & RECOMMENDATION

8.1 Conclusion

Smart grid a huge concept and the technology of electric grid system is updating day by day. Bangladesh has a big opportunity in the power system as it has a rising economy. The power system of Bangladesh is increasing day by day and the system is going to be more complex. In recent years, grid failure occurs in several time. On the other hand, fuel and energy crisis is a matter to think about future. Besides this natural fuel and energy resources is going to be finished. Renewable energy can be a rising sector in the power system of Bangladesh. To ensure quality power, uninterrupted power supply and reliable system, smart grid can be a great solution. Grid stability is a vital thing in power system as well as national power grid security. Last grid failure at eastern part of power grid network was very crucial. Smart grid can reduce this kind of grid failure. Which can increase the reliability and security of the electric grid system. Smart grid can reduce the system loss and ensuring the proper use of the energy. Most of the infrastructure are available in our country, we just need to expand in proper way. This thesis is the concept of the smart grid and the feasibility of smart grid in Bangladesh. There huge scope for future research and development of smart grid in not only Bangladesh but also in the sub-continent.

8.2 Recommendation

The most important thing for the power system of Bangladesh is the stability of the system. The system is very unstable for few causes. It should be solved as soon as possible without any delay. According to Bangladesh Power System Reliability and Efficiency Improvement Project Final Report, the system frequency of Bangladesh power system to operate nuclear power plant should be like as below-

Table 6.1: Nuclear power plant operating requirement

Frequency, Hz	Voltage, relative units	Operating time, min
47.5-49.0	0.9-1.05	Max. 30 min. every 10 years
49.0-50.5	0.85-0.95	Max. 30 min. every 5 years
49.0-50.5	1.05-1.075	Max. 30 min. every 10 years

49.0-50.5	0.95-1.05	No Limitation
50.5-52	0.9-1.05	Max. 30 min. every 5 years

From the above, we can see that to operate the Rooppur Nuclear Power Plant the power system of Bangladesh should be more stable. Otherwise, a manmade disaster may come in. Although Bangladesh is aiming to operate the nuclear power plant by 2024. But without ensuring the stability of the current grid system, it will be a suicidal decision for the power system of Bangladesh. Not only to operate the nuclear plant but also power system stability should be done to ensure quality power and the security of the power system also. The generation and distribution utility should follow the grid code properly. For ensuring the stability, grid code is a vital thing. So, it shouldn't be violated.

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