EAST WEST UNIVERSITY

INTERNSHIP REPORT

ON

PROSPECTS & CHALLENGES OF PHOTO VOLTAIC (PV) POWER GENERATION IN BANGLADESH

SUPERVISED BY:

SARWAR JAHAN
ASSISTANT PROFESSOR
DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING
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CO-SUPERVISER:

QUAZI ASHIQUR RAHMAN
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RENEWABLE ENERGY & RESEARCH, DPDC

SUBMITTED BY:

SHARITA SULTANA
ID: 2014-1-55-025
MAJOR IN ELECTRONICS & TELECOMMUNICATION ENGINEERING
DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING
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AUGUST 25, 2019

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AN INTERNSHIP REPORT PRESENTED TO THE FACULTY OF ECE IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF B.SC. IN ETE

DATE OF SUBMISSION:
AUGUST 25, 2019

DISCLAIMER

This is to declare that this internship report is based on “Prospects & Challenges of Photo Voltaic (PV) Power Generation in Bangladesh”. This is also certified that this report is prepared as per the requirement of the course ETE 498 (industrial Training). It has not been submitted elsewhere for the requirement of any undergraduate or graduate program.

Sharita Sultana
ID: 2014-1-55-025
Major in ETE
Department of Electronics & Communication Engineering
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ACCEPTANCE

This internship report presented to the department of Electronics & Telecommunication Engineering, East West University as a partial fulfillment of the course ETE 498 (Industrial Training) as well as for the Bachelor of Science Degree in Electronics & Telecommunication Engineering (ETE).

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ACKNOWLEDGEMENTS

Most importantly, I would like to express my heartiest gratitude to almighty Allah for keeping in good health and giving me the strength, ability and opportunity to accomplish the report within the schedule time successfully.

I convey my deepest appreciations to my Academic Supervisor Sarwar Jahan, Assistant Professor at Department of ECE, East West University, for his valuable suggestions, advice, support and important guidance while preparing this report. For sure, I am appreciative to all the Faculty Members of Department of ECE, East West University from whom I have been learning and inspired in different courses.

Additionally, my graceful admiration goes to Mr. Quazi Ashiqur Rahman, Executive Engineer, Renewable Energy & Research, DPDC who has provided guidance that enabled me to learn the functions of DPDC, especially Renewable Energy. Moreover, I am grateful to the Head of Renewable Energy & Research Mr. Abdur Rouf Khan, Superintending Engineer, who paved the way for me to have my internship completed in such a great platform. The experience I have gained here will be a privilege for my future career. A special word of appreciation goes to all the staffs of Renewable Energy & Research Department of DPDC for their generous cooperation and assistance during my entire period of internship.

I would like to thank my family members for their constant support and love in my life that always pushes me forward.

Lastly, I am really thankful to them who have shared their views about my work, provided me with necessary information, criticized my work and congratulated me. This page is not enough to tell them how important their opinions are on this report, how indebted I am to them.

TABLE OF CONTENTS

TABLE OF CONTENTS

List Of Abbreviations

MTOE	Million Tonnes of Oil Equivalent
KGOE	Kilogram Oil Equivalent
LPG	Liquefied Petroleum Gas
BCF	Billion Cubic Feet
PSMP	Power System Master Plan
JICA	Japan International Cooperation Agency
MoPEMR	Ministry of Power, Energy and Mineral Resources
ADB	Asian Development Bank
SREDA	Sustainable & Renewable Energy Development Authority
SHS	Solar Home System
BCS	Battery Charge Station
IEA	International Energy Agency
HVD	High Voltage Disconnect
LVD	Low Voltage Disconnect
MPPT	Maximum Power Point Tracking
PV	Photo Voltaic
IDCOL	Infrastructure Development Company Limited
KW	Kilowatt
MW	Megawatt
DPDC	Dhaka Power Distribution Company Limited
BOO	Build Own Operate
NOCS	Network Operation & Customer Service

List Of Tables

List of Figures

ORIGIN OF THE REPORT

Internship Program of East West University is a Graduation requirement for the B.Sc. students. This report is a partial requirement of the Internship program of B.Sc. curriculum at the East West University. The main purpose of internship is to get the student exposed to the job world. Being an intern the main challenge was to translate the theoretical concepts into real life experience.

The internship program and the study have following purposes:

- To get and organize detail knowledge on solar system.
- To experience the real job field.
- To compare the real scenario with the lessons learned in East West University
- To fulfill the requirement of B.Sc. Program.

This report is the result of three months long internship program conducted in Dhaka Power Distribution Company Limited (DPDC) and is prepared as a requirement for the completion of the B.Sc. program of East West University. As a result I need to submit this report based on the "PROSPECTS & CHALLENGES OF PHOTO VOLTAIC (PV) POWER GENERATION IN BANGLADESH". This report also includes information on the services & activities of DPDC, overview of the organization and also services offered to their customers.

OBJECTIVE OF THE REPORT

The objective of the report can be viewed in two forms:

- General Objective
- Specific Objective

General Objective:

This internship report is prepared primarily to fulfill the Bachelor of Science (B.Sc.) degree requirement under the Electronic & Communication Engineering Department of East West University.

Specific Objective:

More specifically, this study entails the following aspects:

- To give an overview of energy situation of Bangladesh.
- To discuss the photovoltaic power generation in Dhaka city.
- To focus on the Renewable Energy in order to meet energy need.
- To identify prospects & challenges of PV power generation in Bangladesh.

Scope of the Report

The main intention of the report is to identify prospects & challenges of PV power generation in Bangladesh and to get a clear picture of the opportunities we have in order to meet our energy crisis through solar power.

This report covers details about the generation, installation & maintenance of PV power system whether grid-connected or not. Main focus was on the analysis of the current energy need, declining level of domestic resources, availability of solar energy, prospects of installing solar home system even in a densely populated city like Dhaka. However the study is mostly related to the Renewable Energy & Research as I was provided an opportunity to work under this office of DPDC.

The report's scopes are followed below:

Information for the analysis was collected from the company's internal sources, websites, database, newspapers, research papers & study materials.

Geographic scope of this report is limited to DPDC held area in Dhaka city.

METHODOLOGY

The study is conducted in a systematic procedure starting from selection of the topic to final report preparation. The integral part was to identify and collect data. After that they were classified, analyzed, interpreted and presented in a systematic manner to find the vital points. The overall process of methodology followed in the study is explained further.

Selection of the topic:

My supervisor assigned the topic of the study. Before the topic was assigned it was thoroughly discussed so that, a well-organized internship report can be prepared.

Sources of Data:

Primary Sources:

Primary Data was derived from the practical deskwork. Moreover, my supervisor at DPDC also helped me to get information directly from the company.

Secondary Sources:

Internal sources: Different documents provided by concerned officers and different circulars, manuals and files of the organization.

External source: Different websites related to renewable energy and online resources.

Classification, analysis, interpretations and presentation of data:

Some diagrams and tables were used in this report for analyzing the collected data and to explain certain concepts and findings more clearly. Moreover, collected data were analyzed more precisely.

Findings of the study:

The collected data were analyzed well and were pointed out and shown as findings at the end.

Final report preparation:

The final report is prepared after valuable suggestions and advice of my honorable advisor.

LIMITATIONS

My working area was mostly the office of Renewable Energy & Research. Being unfamiliar to work environment it was difficult in the beginning to understand about the procedure and the extent to which DPDC is working in the field of renewable energy. Another problem was time constraint. It was hard enough to analyze large data due to time constraint. The duration of my work was only three months. But this period of time is not enough for a complete and clear study. So there may be some personal mistakes in the report. Although there were many limitations I tried my level best to furnish the report.

EXECUTIVE SUMMARY

Energy is one of the major inputs for the economic development of any country. The consumption of energy is increasing at fast pace while available resources limited. Global need for energy is increasing on an average by about 1.5% every year. Out of total amount of primary energy, around 80% comes from fossil fuels. The current consumption of fossils fuels, particularly oil, is not sustainable in long term.

In Bangladesh, about 70 percent of energy demand is met from natural gas. Among other fuels- oil, coal, biomass etc. are vital. There is a huge reserve of coal in our country, but coal is less produced as well as less used here. On the other hand, natural gas reserve is not that substantial, but its production and consumption are the highest among the available resources. Besides those, energy demand is being met through imported oil and LPG. Moreover, the government has already started importing LNG to meet increasing gas demand. Biomass is being used as a lion's share of energy. The energy demand is also being met by importing electricity from India.

The amount of power generation using solar system is currently about 325 MW. The contribution of renewable energy is at a very low level (0.01% of total energy generated). Major part is solar energy which are mostly in off-grid. A guideline has been prepared by SREDA for on-grid solar energy through net metering system. There is little possibility to generate 10% of total electricity through renewables by 2020 as per PSMP 2016 (2,000MW of solar power by 2021).

Total generation from RE including hydropower (230MW) was 569.80MW, which was 3% of total electricity generation capacity (18,753 MW) of the country including off grid, RE and Captive.

Bangladesh is one of the world's most vulnerable countries to the effects of climate change. Solar photovoltaics (PV) can help manage climate vulnerabilities and also ensure energy access for all. Bangladesh is among the largest users of off grid solar home systems globally. The markets for on-grid systems such as utility scale solar parks and distributed generation on rooftops, other off-grid markets such as irrigation, public lighting, water pumping, telecom towers etc. also hold substantial promise for adoption. Stronger policy and innovation is crucial to overcome market barriers and accelerate further adoption.

DPDC has started buying solar-generated electricity, from consumers' rooftop plants, under the newly-introduced Net Metering system. It has signed contracts with consumers to procure solar power from their respective rooftop solar panels. Currently these consumers are supplying 3.066 MW of electricity to the national grid & DPDC purchased 13.3 kW from three consumers till December 2018.

CHAPTER 1 – INTRODUCTION

1.1 INTODUCTION

Energy is one of the major inputs for the economic development of any country. The consumption of energy is increasing at fast pace while available resources limited. Global need for energy is increasing on an average by about 1.5% every year. Out of total amount of primary energy, around 80% comes from fossil fuels. The current consumption of fossils fuels, particularly oil, is not sustainable in long term.

Energy consumption has a significant impact on our natural environment. This is clear evidence that climate change is caused by human activity, mostly related to the use of energy developing renewable energy is its inevitable choice for sustainable economic growth. Renewable energy has been categorized as traditional and new. The former includes large hydropower, biomass burnt directly etc; the latter includes small hydropower, solar energy, wind energy, biomass energy, and geothermal energy etc.

1.2 CLASSIFICATION OF ENERGY

1.2.1 PRIMARY ENERGY:

Primary energy refers to all type of energy extracted or captured directly from natural resources. It is further sub divided into two groups.

1.2.1.1 RENEWABLE (SOLAR, WIND, GEOTHERMAL, TIDAL, BIOMASS)

Obtained from natural sources, which are in exhaustible, e.g: Solar, wind power, geothermal, tidal power & hydro electric power – No pollutant in this case.

1.2.1.2 NON- RENEWABLE (FOSSIL FUELS, CRUDE OIL, COAL, NATURAL GAS, NUCLEAR ETC.)

Natural resources such as coal, oil & natural gas are example of non –renewable energy.

1. 2.2 SECONDARY ENERGY:

Primary Energy sources are mostly converted in industrial utilities into secondary energy sources e.g. Coal, oil or gas converts to steam & electricity.

1.2.3 COMMERCIAL:

Energy available in market e.g., electricity, lignite, coal, oil, natural gas etc.

1.2.4 NON COMMERCIAL:

Fuels such as firewood, cattle dung, and agricultural waste;

1.3 Bangladesh Energy Scenario

At present Bangladesh is a mid-income country. Her GDP growth rate is one of the world's largest. Development is the precondition for continued growth of GDP. And energy is the main driving force of the country's development. To meet the country's growing energy demands proper use of energy is essential as well as to lift up from a mid-income country to a developed one. Energy is playing a vital role in implementing Vision-2021, Vision-2041 and achieving Sustainable Development Goals.

In Bangladesh, about 70 percent of energy demand is met from natural gas. Among other fuels- oil, coal, biomass etc. are vital. There is a huge reserve of coal in our country, but coal is less produced as well as less used here. On the other hand, natural gas reserve is not that substantial, but its production and consumption are the highest among the available resources. Besides those, energy demand is being met through imported oil and LPG. Moreover, the government has already started importing LNG to meet increasing gas demand. Biomass is being used as a lion's share of energy. The energy demand is also being met by importing electricity from India.

The use of renewable energy instead of gas, coal and oil has been started in the whole world and is essential for sustainable development and keeping up with the environment by preventing carbon emissions. Many countries in the world like Sweden, Germany, China and USA are currently using renewable energy as a significant part of their energy demand. Bangladesh is also using renewable energy, but it's very less than necessity. The government has taken various steps to increase the use of renewable energy in the future, including solar home system, solar irrigation system, Rooppur nuclear project, etc.

Development of energy sector is the key factor for continued development of the country. Bangladesh needs to emphasize on the new exploration activities using latest techniques to explore new mines. Apart from reducing dependence on natural gas, it needs to be coordinated with the imported LNG and enhance the percentage of usage oil and LPG; thereby Bangladesh will succeed in reaching its desired goal of development [1].

1.4 Current Position of Energy Resources in Bangladesh

Known commercial energy resources in Bangladesh include indigenous natural gas, coal, imported oil, LPG, imported LNG, imported electricity and hydro-electricity. Biomass accounts for about 29% of the primary energy and the rest 71% is being met by commercial energy. Natural gas accounts for about 68% of the commercial energy.

Imported oil accounts for the lion's share of the rest. Every year Bangladesh imports about 6.6 million metric ton of crude and refined Petroleum Products. Apart from natural gas and crude oil, coal is mainly used as fuel in the brick-fields and Thermal Power Plant.

Moreover, power is also being generated by using Solar Home System (SHS) in on-grid and off grid areas. The amount of power generation using solar system is currently about 325 MW. In addition there are some poultry and dairy farms in which bio-gas plants are being set up and this bio-gas is used for cooking and power generation. The amount of power generation from such plants is currently about 1 MW. Steps have been taken to generate electricity by Bio Mass Gasification Method in the country.

Estimated final consumption of total energy is around 47 Million Tonnes of Oil Equivalent (MTOE). Average increase of energy consumption is about 6% per annum. Per capita consumption of energy in Bangladesh is on an average 293 kgoe (Kilogram Oil Equivalent) and per capita generation of electricity is 464 kWh with an access to electricity 90%, which is lower than those of South Asian neighboring countries.

Table 1.1: Energy calculation for 2017-18 (Million Tonnes of Oil Equivalent)

Name of Fuel	Unit	MTOE
Oil (Crude + Refined + LPG) in K ton	6948	6.9
LPG	554	0.5
Natural Gas in Bcf	961	22.3
Coal (Imported) in K ton	3395	2.1
Coal (Local) in K ton	923	0.6
RE (Hydro) in MW	230	0.2
RE (Solar) in MW	350	0.3
Electricity (Imported) in MW	625	0.5
Sub- total	--	33.4
Biomass	--	13.6
TOTAL		**47.0**

Source: Power Division, MoPEMR.

Bangladesh also has a bright potential to produce electricity from wind and mini-hydro. Recently, solar power based irrigation pump has been used in a number of areas of the country. Its wide use will lessen the pressure on diesel and electricity.

1.5 POWER SYSTEM MASTER PLAN 2016

The energy source of Bangladesh mainly depends on Domestic Natural Gas. The Government of Bangladesh formulated the Power System Master Plan 2010 (PSMP2010) targeting, among others, for a long term energy diversification due to the foreseen decrease in the production volume of Natural Gas.

However, energy development is not on track compared with the PSMP2010 plan, because various assumptions about expected sources for base load energy have subsequently changed. In particular, a review is needed reflecting namely exponential increasing of oil based rental power plants and development constraints of domestic primary energy.

Currently, many of power plants in Bangladesh cannot generate electricity as specified in terms of power, thermal efficiency etc. for each unit. Daily shortage of power does not allow to stop facilities and to undertake periodical maintenance in a planned way. Legal framework does not stipulate preventive maintenance works as an obligation for plant owner. Low financial soundness of public generating companies due to low electricity tariff does not permit to purchase in advance necessary spare parts. In order to secure a stable electricity supply, we need to find out solutions to all of these issues and to establish a comprehensive institutional framework. Moreover, hydro power generation studies (on small scale hydropower plants of 30 kW ～ 5MW and a pumped storage power plant as a regulator between demand and supply) have become an urgent issue through the government's renewable energy promotion policy.

Based on the aid policy of the Government of Japan for Bangladesh, the Japan International Cooperation Agency (JICA) is considering the power sector as one of priority areas assisting Bangladesh not only by Yen Loans to the construction of power plants (gas combined cycle, super-critical using import coal and hydropower), transmission and distribution lines and development of renewable energy but also by Technical Assistance such as the master plan for energy efficiency. JICA is thus supporting the entire power and energy sector. It was under such circumstances that JICA decided to undertake the Power System Master Plan 2016 (PSMP2016) in order to grasp middle to long term development issues and risks and to formulate a comprehensive and result-oriented aid strategy for the energy sector by examining effective approaches for each issue.

After the start of this survey, however, the Government of Bangladesh announced, in its new policy "Vision 2041", an important target of becoming one of the developed nations by 2041. Consequently, for the power and energy sector which receives quite dominant development budget, it has become newly necessary to secure the consistency between the economic development strategy of the country toward joining the developed countries and the master plan of the power and energy sector (PSMP). With such consistency only, JICA will be able to make the best use of the result of this survey as basic information for the future cooperation.

To study consistency between an economic growth strategy and PSMP, an additional survey on estimated changes of the industrial structure that will be brought by the coming strategy and a precise forecast of future demand of primary energy and corresponding supply policy must be added to this survey, since the power sector is one of the largest sectors which consume primary energy. It was therefore decided to estimate in this survey the most rational and probable demand and supply scenarios of primary energy for other sectors than power sector such as fertilizer, industry, commerce, and transportation.

Moreover, the power sector will be required to cope with the changes of industrial structure in line with the economic growth as expected in order for Bangladesh to join the developed nations. Specifically, improvement of the quality of electricity is indispensable given the view of the government that sophistication of industries is generally essential for the nation to become one of the developed countries.

After the commencement of this survey, Bangladesh started considering also a specific plan to expand power import from neighbouring countries such as India, Bhutan and Nepal. Usually, international cooperation in power system is oriented toward direct cooperation by means of alternate current and, to do so, quality of electricity is required to be equivalent or better than that of counterpart countries.

It is therefore necessary for the promotion of international cooperation to improve the quality of electricity. Since this issue will be a concern to the entire power sector in revising PSMP, it was also decided to add to this survey collection of additional basic information and examination of feasible measures responding to the specific needs of quality improvement.

Therefore, the collection and analysis of the information on the plan for the supply and demand for primary energy sources and the needs for the improvement of the quality of power supply were included in this survey that had consisted of the revision of power development plan and the studies on the institutional reform for the improvement of O&M and the introduction of hydropower generation.

This inclusion of the new survey subject enabled the formulation of a new master plan that covers not only the power sector but also the energy sector comprehensively and describes the interface between the two sectors.

The new master plan is the output of the first joint survey of the two divisions in the Ministry of Power, Energy and Mineral Resources (MoPEMR), Power Division and Energy Division, and this survey is expected to serve as a good precedent of the cooperation between them in the implementation of policies in the power and energy sectors [9].

1.6 RENEWABLE ENERGY

Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services.

In the 1970s environmentalists promoted the development of renewable energy both as a replacement for the eventual depletion of oil, as well as for an escape from dependence on oil, and the first electricity-generating wind turbines appeared. Solar had long been used for heating and cooling, but solar panels were too costly to build solar farms until 1980.

Figure 1.1: Image of DPDC’s Rooftop Solar Power Project at Bangladesh Secretariat

CHAPTER 2 – RENEWABLE ENERGY

2.1 Introduction: Renewable Energy in Bangladesh

Contribution of renewable energy is at a very low level (0.01% of total energy generated). Major part is solar energy which are mostly in off-grid. The incremental contribution of hydropower, as per plan is rather discouraging. A guideline has been prepared by SREDA for on-grid solar energy through net metering system. There is little possibility to generate 10% of total electricity through renewables by 2020 as per PSMP 2016 (2,000MW of solar power by 2021).

A private firm set up solar plant for producing 28 megawatts (MW) and will feed 20MW to the local substation during sunlight hours. The government signed a deal to buy power from a joint venture company (a Japanese and a local firm) to purchase 5 MW power from a grid-tied PV solar power plant project to be set up in Gwainghat, Sylhet. The Power Division is now waiting for a positive note from the Asian Development Bank (ADB) about its financing to implement a 50MW floating solar project in the Kaptai Lake [5] [10].

Table 2.1: Electricity generation plan from Renewable energy source (MW)

Technology	**Achievement up to 2016**	**2018**	**2019**	**2020**	**2021**	**Total**
Solar	200	350	250	300	250	1470
Wind	2.9	150	350	300	300	1153
Biomas	0	6	6	6	6	30
Biogas	5	0.5	0.5	0.5	0.5	7
Hydro	230	1	1	2	2	236
Total	**437.9**	**507.5**	**607.5**	**608.5**	**558.5**	**2896**

Source: SREDA (Retrieved on 9 March 2019)

Table 2.2: Renewable Energy Generation Capacity (MW)

Technology	**Off-Grid**	**On-Grid**	**Total**
Solar	291.12	47.53	338.65
Wind	2	0.9	2.9
Hydro	-	230	230
Biogas to Electricity	0.68	-	0.68
Biomass to Electricity	0.4	-	0.4
Total	**294.2**	**278.43**	**572.63**

Source: SREDA (Retrieved on 9 March 2019)

2.2 Renewable Energy Resources in Bangladesh

It was mentioned in the Renewable Energy Policy 2008 that 5% and 10% of total electricity would be generated using renewable energy by 2015 and 2020 respectively (GOB 2008). SREDA Act 2012 was enacted for the establishment of Sustainable & Renewable Energy Development Authority (SREDA) for promotion of efficient energy and renewable energy technology. The authority (SREDA) is in the process of institutionalization. Total generation of electricity from new-renewable energy sources (e.g. solar PV, biomass, biogas etc.) up to June 2018 was 339.80 MW. Total generation from RE including hydropower (230MW) was 569.80MW, which was 3% of total electricity generation capacity (18,753 MW) of the country including off grid, RE and Captive.

In line with the policy, government has already taken different initiatives in renewable energy development, in which some projects/programs have been completed and some are under implementation.

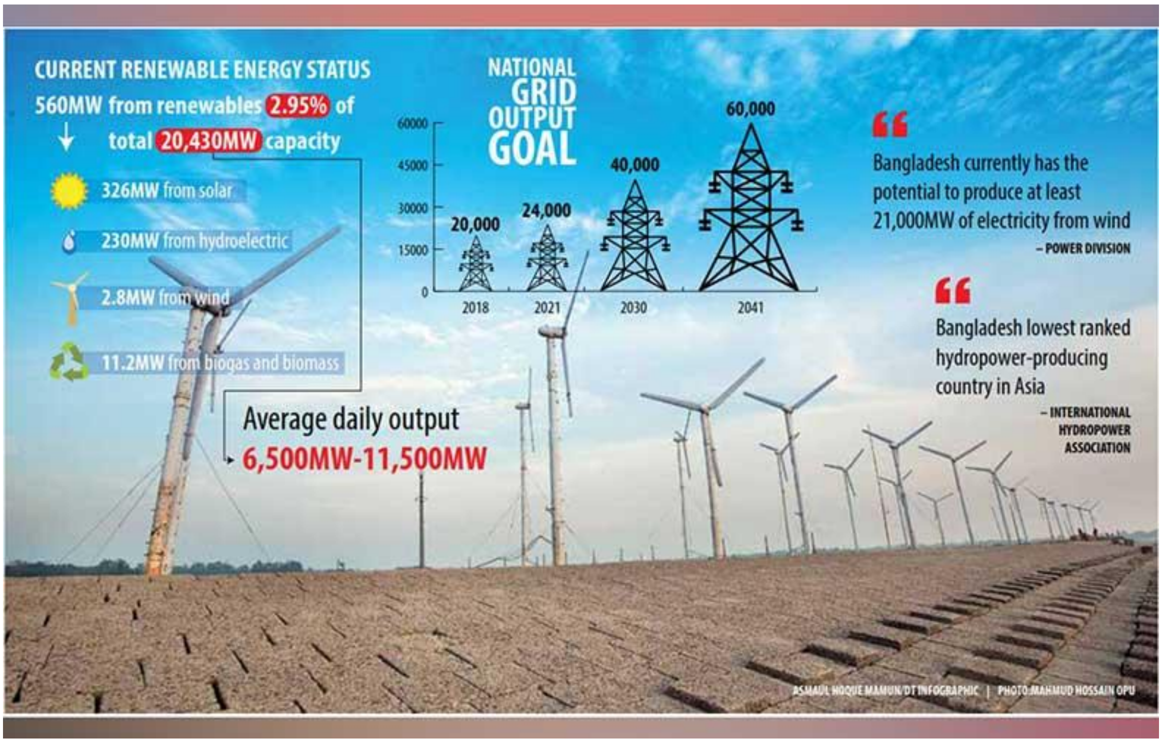

Figure 2.1: Renewable Energy in Bangladesh

2.2.1 Solar Energy

Bangladesh is geographically located in a favorable position for harnessing sunlight, available abundantly for most of the year except for the three months June-August when it rains excessively. The amount of Solar Energy available in Bangladesh is high about 4 to 7 $kWh/m^2/day$, enough to meet the demand of the country. There is a fast-growing acceptance of rural people to solar photovoltaic (PV) systems to provide electricity to households and small businesses in rural off grid areas. The Rural Electrification Board (REB), a government agency has been engaged in commercializing solar power electrification of domestic, commercial, irrigation in rural area. IDCOL, a government-owned entity has disseminated some SHS through its partners NGOs. Due to higher cost of its production it has to go a long way to become commercially competitive. However, in remote areas of Bangladesh it is gradually becoming popular and government has undertaken a lot of scheme to subsidize on it. Government has planned to setup solar panel with capacity of 5~10 MW.

SOLAR HOME SYSTEM (SHS)

Solar Home System (SHS) provides reliable power for lighting and operating low powered appliances such as radio, television, small electric fans. The electricity provided by a SHS can also be used to run Direct Current (DC) driven equipment such as DC shouldering irons, drilling machines etc. and to charge the battery of mobile phones. Larger systems can run computers, refrigerators, pumps etc. IDCOL and BREB are distributing Solar Home System (SHS) to the people living in the off-grid areas. IDCOL through different partner organization has already distributed about 55 lakh (installed capacity 250 MW) SHS and BREB distributed about 30 thousand SHS throughout the country.

Figure 2.2: Solar Home System

Figure 2.3: Solar Home System

Solar Irrigation System

Solar powered irrigation is the breakthrough technology for energy stricken agro-based economy. Solar powered irrigation is the innovative and environment friendly solution for the irrigation system, which currently depends on hugely inefficient electric and diesel pumps. Gradually replacing the electric and diesel pumps for irrigation with solar water pumps could save significant capacity of electricity and huge investment cost. Up to June'18, a 1158 nos solar irrigation pump has been installed by IDCOL.

2.2.2 Bio Fuel

Bio fuels can be produced from a variety of plants like rapeseed, mustard, corn, sunflower, canola algae, soybean, pulses, sugarcane, wheat, maize, and palm. The most popular option for producing bio-fuels is from non-edible oilseed bearing trees. The two most suitable species are:

Jamal gota (Jatropha curcas) and Verenda (RicinusCommunis). Both of these trees can grow virtually anywhere in any soil and geo- climatic condition.

Bio-fuel use is not new in Bangladesh. In the early 20th century, bio-fuel was used for lighting lamps or lanterns. In an agriculturally based country like Bangladesh, bio-fuel can be a better alternative because a 30 percent blend of bio-fuel can be used along with our diesel or petrol. This can also be an excellent fuel to kindle lamps in rural Bangladesh.

The use of bio-fuel is increasing in most European countries. Germany has thousands of filling stations supplying bio-fuel and it is cheaper than petrol or diesel. The German government declared that 5 percent of every liter of fuel must be bio-fuel by 2010.

2.2.3 Wind Energy

Bangladesh is exploring the potential of wind power. In the coastal area of Bangladesh, windmills with a capacity of 2.9 MW are in operation. Bangladesh has had to wait for a breakthrough in wind power technology to be competitive against other conventional commercial energy sources. A pilot project to install windmills along the seashore with a capacity of 20 MW has been planned by the government. Based on the results of the pilot project, another 200 MW of power could be harnessed from wind power.

Rising fossil fuel and CO_2 prices, technological advances and economies of scale with wider deployment are expected to make renewable-based systems increasingly cost competitive in coming decades (IEA 2011).

2.2.4 Tidal Energy

The tides at Chittagong, south east of Bangladesh are predominantly semidiurnal with a large variation in range corresponding to the seasons, the maximum occurring during the south-west monsoon. A strong diurnal influence on the tides results in the day time tides being smaller than the night time.

In the year 1984, an attempt was made from the EEE department of BUET, Dhaka to access the possibility of tidal energy in the coastal region of Bangladesh, especially at Cox's Bazar and at the islands of Maheshkhali and Kutubdia. The average tidal range was found to be within 4-5 meter and the amplitude of the spring tide exceeds even 6 meter.

From different calculation it is anticipated that there are a number of suitable sites at Cox's Bazar, Maheshkhali, Kutubdia and other places, where a permanent basin with pumping arrangements might be constructed which would be a double operation scheme. Tidal energy might be a good alternative source for Kutubdia Island where about 500 kw power could be obtained. At present there are only 2x73kVA diesel generator sets to supply electricity for 5-6 hours/day for 72,000 people and there is practically no possibility of main grid supply in the future.

2.2.5 Wave Energy

Until to now no attempt has been made by Government of Bangladesh to assess the prospects for harnessing energy from sea waves in the Bay of Bengal. Wave power could be a significant alternative source of energy in Bangladesh with favorable wave conditions especially during the period beginning from late March to early October.

Waves are generally prominent and show a distinct relation with the wind. Waves generated in the Bay of Bengal and a result of the south-western wind is significant. Wave heights have been recorded by a wave rider buoy and correlated with wind data. Maximum wave heights of over 2 m, with an absolute maximum of 2.4 m, on the 29 July were recorded. The wave period varies between 3 to 4 sec for waves of about 0.5 m, and about 6 sec for waves of 2 m.

In Bangladesh wind speeds of up to 650 kmph (400mph), 221 kmph (138 mph) and 416 kmph (260 mph) have been recorded in the years 1969, 1970 and 1989 respectively. Severe cyclonic storms and storm surge of up to 15 m have been reported. Plant must also be able to survive the exceptional occurrence of very high waves in storm conditions.

2.2.6 River Current

A network of rivers, canals, streams etc. numbering about 230 with a total length of 24140 km covers the whole of Bangladesh flowing down to the Bay of Bengal. Different sizes of boats are the main carriers of people and goods for one place to another. Boatmen usually use the water-sails to run their boasts against the wind direction. But until now no research has been reported to utilize the energy of river current properly.

2.2.7 Waste to Electrical Energy

Dhaka City has been suffering for a long time from a tremendous environmental pollution caused by municipal solid waste, medical waste and various industrial wastes. In order to save the city from environmental pollution the waste management as well as electricity generation from the solid wastes program is being taken by the Government.

CHAPTER 3 – PHOTOVOLTAIC POWER GENERATION SYSTEM

3.1 Solar Energy – The Basic Physics

3.1.1 A Brief Introduction to Electricity

What is Electricity?
The term electricity is used generically in reference to four related physical states as follows:

Electric charge: the build up of electrical energy measured in coulombs. Naturally it occurs as static electricity. Batteries store electric charge.

Electric current: the rate of flow of electric charge measured in amperes

Electric potential: the potential difference in electrical energy between two points e.g. between the positive and negative terminals of a battery. It is measured in volts.

Electromagnetism: the relationship between electricity and magnetism, which enables electrical energy to be generated from mechanical energy (as in a generator) and vice versa (as in a motor).

3.2 The Solar Resource

The term “Solar Energy” refers to radiant heat and light from the sun. This energy travels over 93 million miles from the sun to the earth. As solar energy travels through the atmosphere to the earth’s surface, not all of the energy reaches the earth’s crust. The following diagram shows how solar energy travels through the atmosphere to the earth where it can be utilized [12].

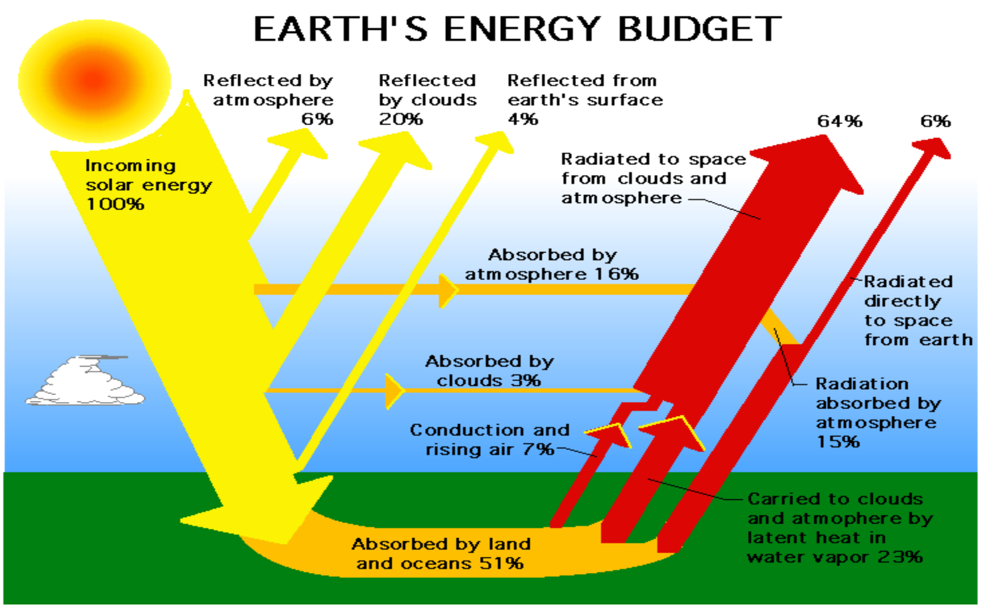

Figure 3.1: Solar Energy

In addition to the factors shown in the illustration above, the amount of solar energy (insolation) available at a particular location on the earth's surface is affected by:

- Latitude (the location's distance north or south of the equator),
- The earth's tilt, and
- Time of year

The average insolation for a particular location is known as irradiance and is measured in Watts per square meter.

3.3 Solar Energy Conversion

Solar Energy is harnessed and converted to heat or electricity using various technologies. Below is a description of the basic technologies.

3.3.1 Solar Energy to Electricity

The term photovoltaic means electricity from the sun. Photovoltaic technology is used to convert light energy into electrical energy. This technology has been developed on the basis that some semiconductor materials such as silicon generate voltage and current when exposed to light.

A thin wafer consisting of an ultra-thin layer of N-type silicon on top of a thicker layer of P-type silicon (where N – Negative and P – Positive) will have an electrical field where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of the wafer, it causes the electrical field to provide momentum and direction to light-stimulated electrons, resulting in a flow of electrical current to any electrical load connected. Figure X below illustrates this principle.

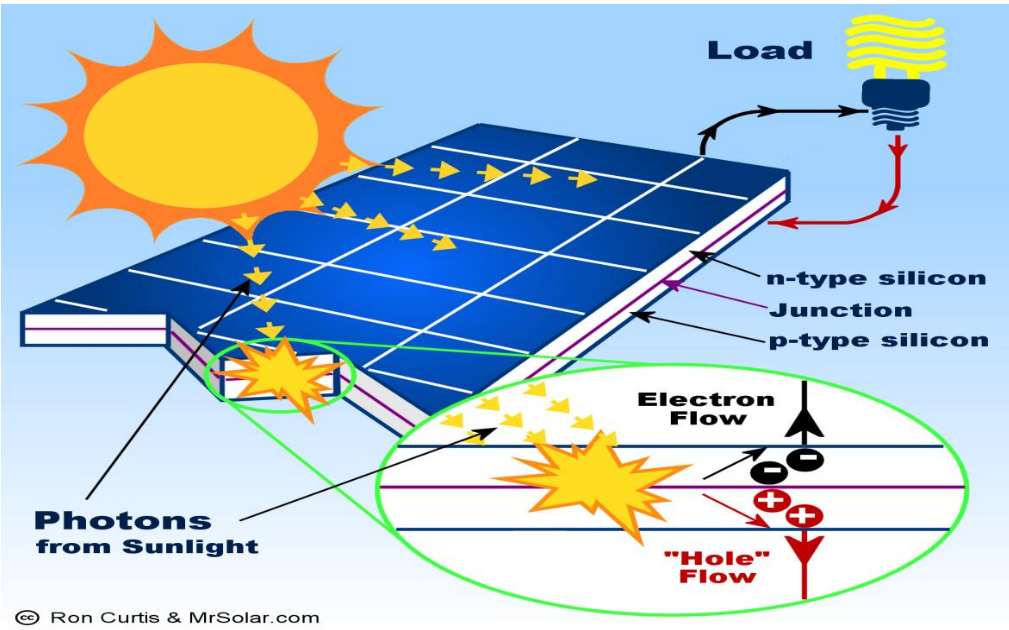

Figure 3.2: Solar Energy to Electricity

3.3.2 Solar Energy to Thermal Energy

Solar thermal systems operate when radiation/heat from the sun is directed to a device which captures and concentrates the heat to a carrying media (air or water). The fluid gains heat from the pipes/fins installed within the system and delivers it through an outlet either as warm or hot. Figure 3.3 below illustrates the concept using water as the medium.

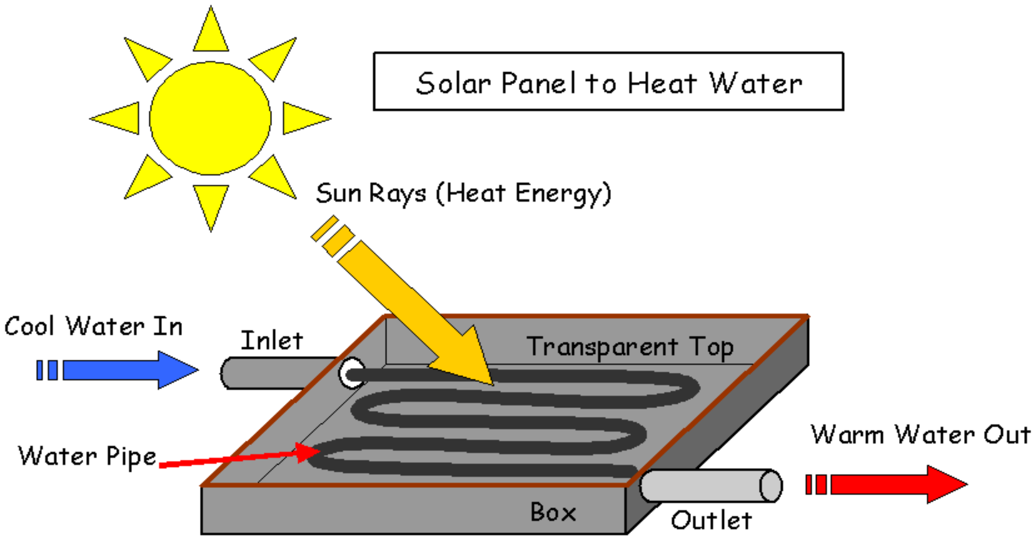

Figure 3.3: Solar Energy to Thermal Energy

3.4 Solar Power

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using concentrated solar power, or a combination.

At a high level, there are three types of solar power system [4]:

1. On-grid solar,
2. Off-grid solar, and
3. Hybrid solar.

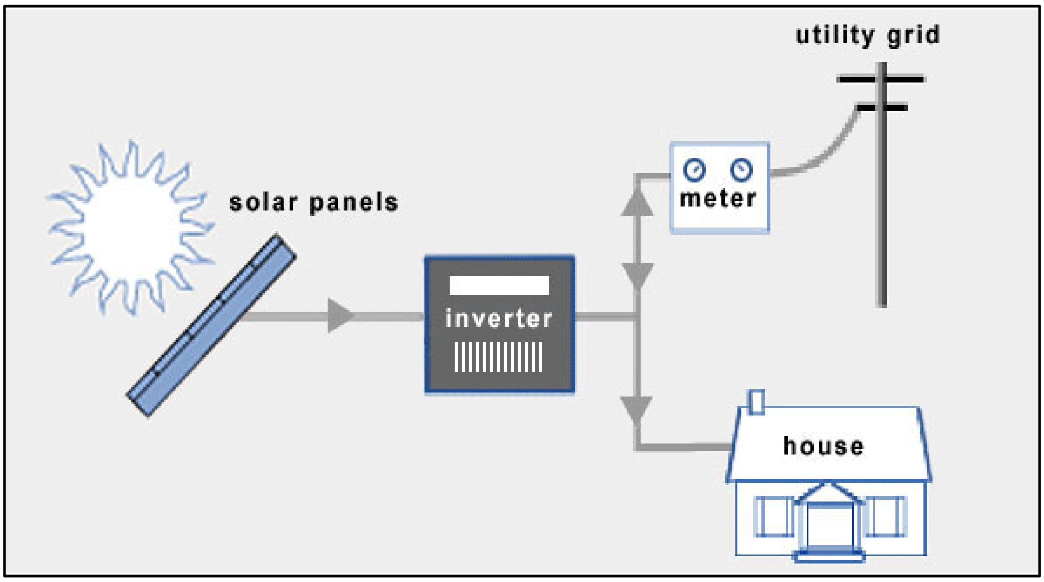

Figure 3.4: On-grid solar system

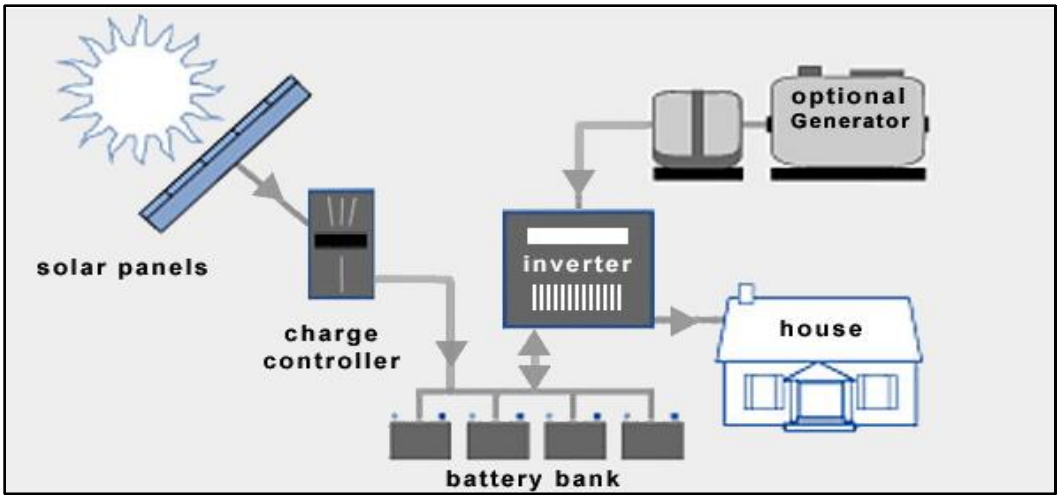

Figure 3.5: Off-grid solar system

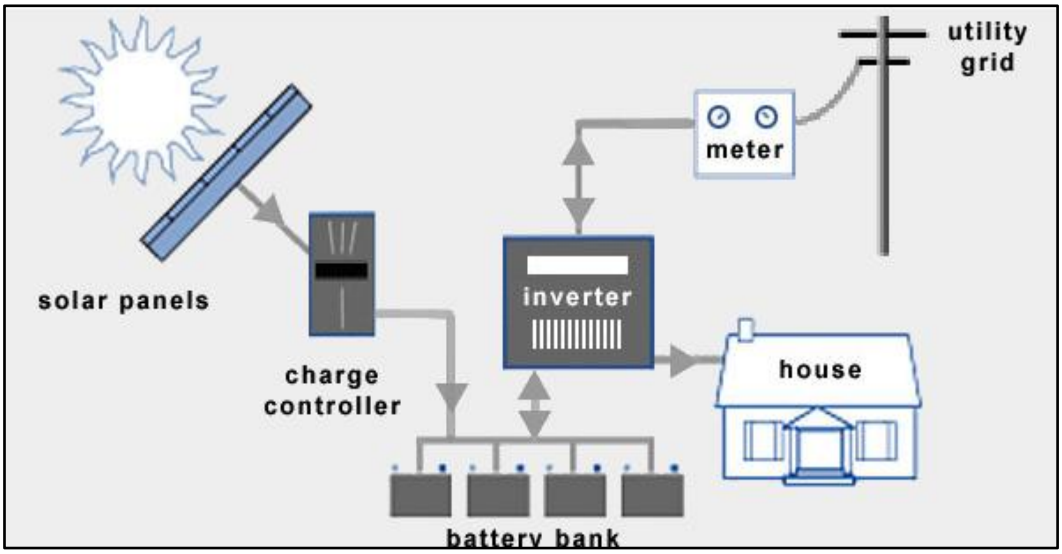

Figure 3.6: Hybrid solar system

3.5 Fundamental Performance of PV system

-No energy supply (fuel) is required after system installation.
- The user can design the required size of the PV system. (Suitable system size should be discussed from various points of view.)
- PV system can be installed any place that receives a suitable amount of sunlight.
- The installed PV system cannot control the energy supply. The energy source of the system depends on the weather.

3.6 Features of the PV System

Merit	Demerit (Weak point)
-Free energy source	-Power supply depends on the weather
-Short work period	-High initial cost (at present)
-Any size of system is applicable and can be set-up anyplace where there is ample sunlight.	-Limitation of supply power
-Use of conventional electric appliances.	-Limitation of useable electric appliances
-Easy maintenance	

3.7 Type of PV Systems

Several kinds of PV systems, such as BCS and SHS, centralized PV systems, are used for village electrification.

Table 3.1: Types of PV System

<table>
<tr><th colspan="5">PV System</th></tr>
<tr><th colspan="2">DC load</th><th colspan="3">AC load</th></tr>
<tr><td>BCS
(Battery Charge Station)</td><td>SHS (Solar Home System)</td><td>SHS (Solar Home System)</td><td>Stand-alone PV system</td><td>Grid-connected PV system</td></tr>
<tr><td>For group</td><td>For private use</td><td>For private use</td><td>Centralized PV system</td><td>Individual system
Centralized system</td></tr>
<tr><td colspan="3">Small system</td><td colspan="2">Large system</td></tr>
</table>

The general description of each system is outlined as follows [6]:

3.7.1 Battery Charge Station (BCS)

BCS are composed of a PV array and a controller. The DC power generated by the PV array is used for charging the user’s battery. One BCS is used in rotation by five to ten users.

3.7.2 Solar Home System (SHS)

The PV array is installed individually on a house or public facility to supply electric power. The SHS is composed of a PV array, a storage battery, a controller, and DC electrical appliances, such as a FL lamp and indoor-wiring. The DC power generated by the PV array is stored in the storage battery. The controller controls the charge and discharge of the storage battery. DC power is supplied to the indoor-wiring connected to all DC electric appliances.

3.7.3 Centralized PV Systems

PV arrays are centrally installed in one place in the village. A centralized PV system is composed of a PV array, a storage battery, an inverter, a controller, and a mini-grid for power distribution. The DC power generated by the PV array is stored in the storage battery and converted into AC power by the inverter when needed. AC power is distributed to all connected households by the mini-grid.

3.7.4 Grid-connected PV Systems

PV arrays are installed in one place. Grid-connected PV systems are composed of a PV array and an inverter. The DC power generated by the PV array is converted into AC power, and then the AC power is supplied to grid.

Standard Components of a PV Systems are shown below in a table:

Table 3.2: Standard Components

Type of System	BCS	SHS	Centralized	Grid connection
1) PV Module	150 – 300Wp	50-500Wp	More than 1kW	M ore than 1kW
2) Junction Box	-	-	Necessary	Necessary
3) Support Structure	Pole type	Pole type	Frame type	Frame type
4) Storage Battery	Necessary	Necessary	Necessary	-
5) Battery Charge Controller	Only HVD	Small	Large	-
6) Inverter	-	Necessary (In case of AC system)	Self operation	Grid connection
7) Transmission Panel	-	-	Necessary	Necessary
8) Distribution Line	-	-	Necessary	-
9) Current Limiter / WH meter	LVD	-	Necessary	-

HVD: High Voltage Disconnect, LVD: Low Voltage Disconnect

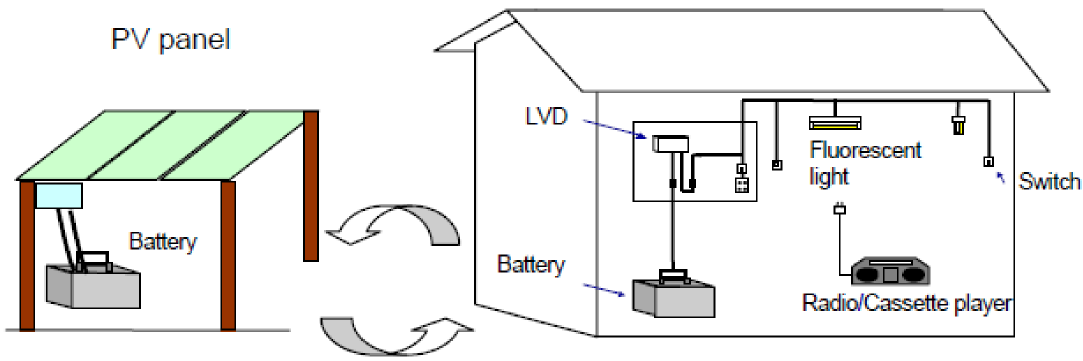

Figure 3.7: Image of a Battery Charging Station

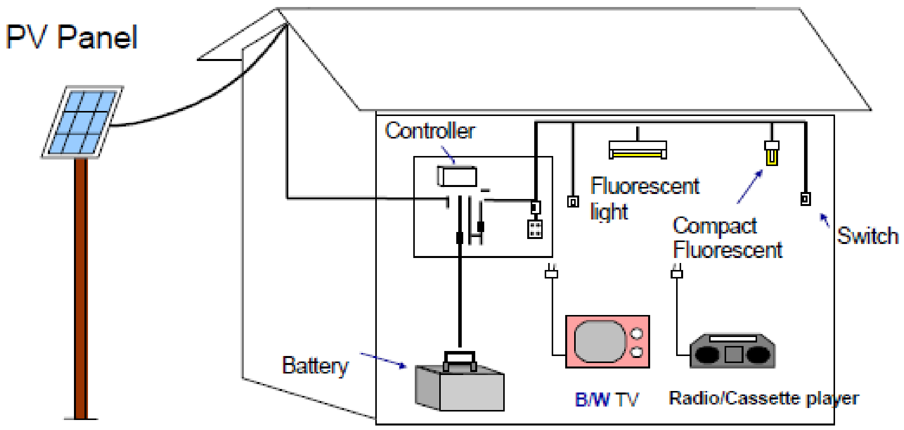

Figure 3.8: Image of a Solar Home System

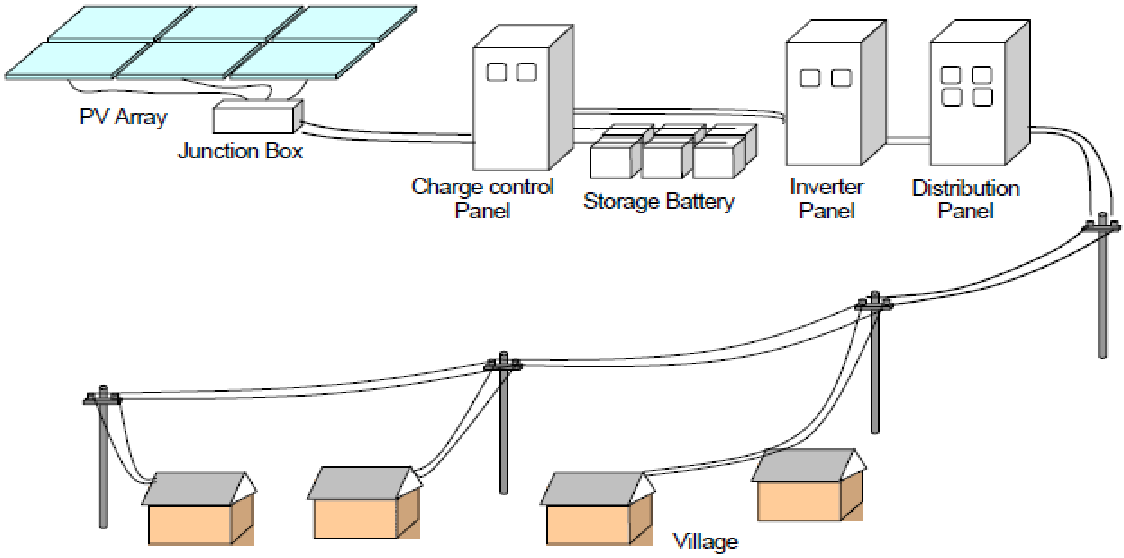

Figure 3.9: Image of a Centralized PV System

3.8 Favorable Conditions for a Photovoltaic Power Generation System

3.8.1 Battery Charge Station (BCS)

A densely populated district has the advantage to apply a BCS. A well- organized village may be favorable for sustainable system operation.

Common uses of electricity are for lighting and radio. For the promotion of sustainable operation, users should understand that BCS has limitations regarding useable energy and appliances due to limitations of the battery capacity.

3.8.2 Solar Home System (SHS)

For districts with a dispersed population, solar home systems is favorable compared with BCS. Small and well organized villages are deemed necessary for sustainable system operation.

Common uses of electricity are for lighting and small appliance loads. For the promotion of sustainable operation, users should understand that SHS system has limitations regarding useable energy and appliances due to limitations of the battery capacity.

3.8.3 Centralized PV System (Stand-Alone System)

A centralized PV system is most applicable in densely populated areas. A well- organized community usually results to the sustainable operation of the system.

Common uses of electricity are for lighting and TV. For the promotion of sustainable operation, additional applications may be useful. If the system is designed to supply enough power, a centralized PV system can supply power to various appliances. For example, ice-making by a chest freezer is possible. Storage of fresh food such as a fish and meat is also possible with a cool box, chest freezer, etc. A small size well pump without a storage tank can also be used. The new application of electricity may create small business opportunities in the village.

3.8.4 Grid-connected PV systems

A grid-connected PV system can be applied to districts with grid electrification. Special technicians are requested for sustainable system operation. A grid- connected PV system can supply surplus power to the grid and receive power from the grid in case of power shortages.

3.9 Solar Electric System Installation

Basic components of grid-connected PV systems with and without batteries are [11]:

- Solar photovoltaic modules
- Array mounting racks
- Grounding equipment
- Combiner box
- Surge protection (often part of the combiner box)
- Inverter
- Meters – system meter and kilowatt-hour meter
- Disconnects:
    - ✓ Array DC disconnect
    - ✓ Inverter DC disconnect
    - ✓ Inverter AC disconnect
    - ✓ Exterior AC disconnect

If the system includes batteries, it will also require [11]:

- ✓ Battery bank with cabling and housing structure
- ✓ Charge controller
- ✓ Battery disconnect

3.9.1 Solar Modules

The heart of a photovoltaic system is the solar module. Many photovoltaic *cells* are wired together by the manufacturer to produce a solar *module.* When installed at a site, solar modules are wired together in series to form *strings*. Strings of modules are connected in parallel to form an *array*.

3.9.2 Grounding Equipment

Grounding equipment provides a well-defined, low-resistance path from the system to the ground to protect the system from current surges from lightning strikes or equipment malfunctions. Grounding also stabilizes voltages and provides a common reference point. The grounding harness is usually located on the roof.

3.9.3 Combiner Box

Wires from individual PV modules or strings are run to the combiner box, typically located on the roof. These wires may be single conductor pigtails with connectors that are pre-wired onto the PV modules. The output of the combiner box is one larger twowire conductor in conduit. A combiner box typically includes a safety fuse or breaker for each string and may include a surge protector.

3.9.4 Surge Protection

Surge protectors help to protect the system from power surges that may occur if the PV system or nearby power lines are struck by lightning. A power surge is an increase in voltage significantly above the design voltage.

3.9.5 Inverter

Inverters take care of four basic tasks of power conditioning:

- Converting the DC power coming from the PV modules or battery bank to AC power
- Ensuring that the frequency of the AC cycles is 60 cycles per second
- Reducing voltage fluctuations
- Ensuring that the shape of the AC wave is appropriate for the application, i.e. a pure sine wave for grid-connected systems

3.9.5.1 Criteria for Selecting a Grid-Connected Inverter – The following factors should be considered for a grid-connected inverter:

- The voltage of the incoming DC current from the solar array or battery bank.
- The DC power window of the PV array
- Characteristics indicating the quality of the inverter, such as high efficiency and good frequency and voltage regulation
- Additional inverter features such as meters, indicator lights, and integral safety disconnects
- Manufacturer warranty, which is typically 5-10 years
- Maximum Power Point Tracking (MPPT) capability, which maximizes power output

Most grid-connected inverters can be installed outdoors, while most off-grid inverters are not weatherproof. There are essentially two types of grid-interactive inverters: those designed for use with batteries and those designed for a system without batteries.

3.9.6 Disconnects

Automatic and manual safety disconnects protect the wiring and components from power surges and other equipment malfunctions. They also ensure the system can be safely shut down and system components can be removed for maintenance and repair. For grid- connected systems, safety disconnects ensure that the generating equipment is isolated from the grid, which is important for the safety of utility personnel. In general, a disconnect is needed for each source of power or energy storage device in the system.

For each of the functions listed below, it is not always necessary to provide a separate disconnect. For example, if an inverter is located outdoors, a single DC disconnect can serve the function of both the array DC disconnect and the inverter DC disconnect. Before omitting a separate disconnect, however, consider if this will ever result in an unsafe condition when performing maintenance on any component. Also consider the convenience of the disconnect's location. An inconveniently located disconnect may lead to the tendency to leave the power on during maintenance, resulting in a safety hazard.

3.9.6.1 ARRAY DC DISCONNECT – The array DC disconnect, also called the PV disconnect, is used to safely interrupt the flow of electricity from the PV array for maintenance or troubleshooting. The array DC disconnect may also have integrated circuit breakers or fuses to protect against power surges.

3.9.6.2 INVERTER DC DISCONNECT – Along with the inverter AC disconnect, the inverter DC disconnect is used to safely disconnect the inverter from the rest of the system. In many cases, the inverter DC disconnect will also serve as the array DC disconnect.

3.9.6.3 INVERTER AC DISCONNECT – The inverter AC disconnect disconnects the PV system from both the building's electrical wiring and the grid. Frequently, the AC disconnect is installed inside the building's main electrical panel. However, if the inverter is not located near the electrical panel, an additional AC disconnect should be installed near the inverter.

3.9.6.4 EXTERIOR AC DISCONNECT – Utilities commonly require an exterior AC disconnect that is lockable, has visible blades and is mounted next to the utility meter so that it is accessible to utility personnel. An AC disconnect located inside the electrical panel or integral to the inverter would not satisfy these requirements. One alternative that is as acceptable to some utilities as an accessible AC disconnect is the removal of the meter itself, but this is not the norm. Prior to purchasing equipment, consult the electric utility to determine their requirements for interconnection.

3.9.6.5 BATTERY DC DISCONNECT – In a battery-based system, the battery DC disconnect is used to safely disconnect the battery bank from the rest of the system.

3.9.7 Battery Bank

Batteries store direct current electrical energy for later use. This energy storage comes at a cost, however, since batteries reduce the efficiency and output of the PV system, typically by about 10 percent for lead-acid batteries. Batteries also increase the complexity and cost of the system.

Types of batteries commonly used in PV systems are:

- Lead-acid batteries
  - Flooded (a.k.a. Liquid vented)
  - Sealed (a.k.a. Valve-Regulated Lead Acid)
    - ✓ Absorbent glass mat
    - ✓ Gel cell
- Alkaline batteries

  Nickel-cadmium - Nickel-iron

3.9.7.1 Lead-Acid Batteries – Lead-acid batteries are most common in PV systems in general and sealed lead acid batteries are most commonly used in grid-connected systems. Sealed batteries are spill-proof and do not require periodic maintenance. Flooded lead- acid batteries are usually the least expensive but require adding distilled water at least monthly to replenish water lost during the normal charging process.

3.9.7.2 Alkaline Batteries – Because of their relatively high cost, alkaline batteries are only recommended where extremely cold temperatures (-50oF or less) are anticipated or for certain commercial or industrial applications requiring their advantages over lead-acid batteries. These advantages include tolerance of freezing or high temperatures, low maintenance requirements, and the ability to be fully discharged or over-charged without harm.

3.9.7.3 Sizing Battery Banks – For grid-connected systems, batteries are usually sized for relatively short time periods with 8 hours being typical. Size may vary, however, depending on the particular needs of a facility and the length of power outages expected. For comparison, battery banks for off-grid systems are usually sized for one to three cloudy days.

3.9.7.4 Interaction with Solar Modules – The solar array must have a higher voltage than the battery bank in order to fully charge the batteries. For systems with battery back-up, pay particular attention to the rated voltage of the module, also called the *maximum power point* (Vmpp), in the electrical specifications. It is important that the voltage is high enough relative to the voltage of a fully charged battery. For example, rated voltages between 16.5V and 17.5V are typical for a 12V system using liquid lead-acid batteries. Higher voltages may be required for long wiring distances between the modules and the charge controller and battery bank.

3.9.8 Charge Controller

A charge controller, sometimes referred to as a *photovoltaic controller* or *battery charger*, is only necessary in systems with battery back-up. The primary function of a charge controller is to prevent overcharging of the batteries. Most also include a low-voltage disconnect that prevents over-discharging batteries. In addition, charge controllers prevent charge from draining back to solar modules at night. Some modern charge controllers incorporate maximum power point tracking, which optimizes the PV array's output, increasing the energy it produces.

3.9.8.1 Types of Charge Controllers – There are essentially two types of controllers: shunt and series. A shunt controller bypasses current around fully charged batteries and through a power transistor or resistance heater where excess power is converted into heat. Shunt controllers are simple and inexpensive, but are only designed for very small systems. Series controllers stop the flow of current by opening the circuit between the battery and the PV array. Series controllers may be single-stage or pulse type. Single-stage controllers are small and inexpensive and have a greater load-handling capacity than shunt-type controllers. Pulse controllers and a type of shunt controller referred to as a multi-stage controller (e.g., three-stage controller) have routines that optimize battery charging rates to extend battery life.

Most charge controllers are now three-stage controllers. These chargers have dramatically improved battery life.

Figure 3.10: Solar Mini Grid

Figure 3.11: Solar Mini Grid

Definition of Renewable Energy based Mini-grid, Micro-grid, Nano-grid and Pico-Grid			
SL.	**System Type**	**System's Capacity**	**Other conditions**
1.	Mini Grid	5 MW > System size ≥ 100 kW	▪ Each RE generation system must have at least 10 consumers. ▪ Commercial operation with consumer or Contributory participation among prosumer. ▪ Isolated from National Grid network.
2.	Micro Grid	100 kW > System size ≥ 10 kW	
3.	Nano Grid	10 kW > System size ≥ 3 kW	
4.	Pico Grid	3 kW > System size ≥ 500 W	

Figure 3.12: Solar MiniGrid, MicroGrid, Nanogrid and Picogrid

3.10 Operations and Maintenance

Operations & Maintenance of PV systems can be illustrated as follows [7]:

S/N	Components/ Equipments	Description	Remedy/Action
1	PV modules	Check for dust/debris on surface of PV module	Wipe clean. Do not use any solvents other than water
		Check for physical damage to any PV module	Recommend replacement if found damaged
		Check for loose cable terminations between PV modules, PV arrays, etc.	Retighten connection
		Check for cable conditions	Replace cable if necessary
2	PV inverter	Check functionality, e.g. automatic disconnection upon loss of grid power supply	Recommend replacement if functionality fails
		Check ventilation condition	Clear dust and dirt in ventilation system
		Check for loose cable terminations	Tighten connection
		Check for abnormal operating temperature	Recommend replacement
3	Cabling	Check for cable conditions i.e. wear and tear	Replace cable if necessary
		Check cable terminals for burnt marks, hot spots or loose connections	Tighten connections or recommend replacement
4	Junction boxes	Check cable terminals e.g. wear and tear or loose connections	Tighten or recommend replacement
		Check for warning notices	Replace warning notice if necessary
		Check for physical damage	Recommend replacement

S/N	Components/ Equipments	Description	Remedy/Action
5	Means of isolation	Check functionality replacement	Recommend
6	Earthing of solar PV system	Check earthing cable conditions	Recommend replacement
		Check the physical earthing connection	Retighten connection
		Check continuity of the cable to electrical earth	Troubleshoot or recommend replacement
7	Bonding of the exposed metallic structure of solar PV system to lightning earth	Check bonding cable conditions	Recommend replacement
		Check physical bonding connection	Tighten connection
		Check continuity of the bonding to lightning earth	Troubleshoot or recommend replacement

CHAPTER 4 – PHOTOVOLTAIC POWER GENERATION IN BANGLADESH

4.1 Solar Power Development in Bangladesh

4.1.1 Prospects & Challenges

The pace at which renewable energy including solar and wind is being developed worldwide suggests that these will overtake the fossil fuels (oil, gas, coal) as dominant sources in power generation in a shorter time frame than previously forecasted. In mid-1990s renowned energy experts predicted that oil, gas and coal will remain the predominant fuel for power generation until 2030. This will give way to natural gas becoming the universal fuel in 2050; the battle between fossil fuels and renewable (solar and wind) for dominance over world energy market will begin in earnest by 2060 and the battle will clearly swing in favour of renewables by 2070.

Bangladesh has a success story in developing off-grid rooftop solar power known as solar home system (SHS) which has given electricity to a large number of people living in rather remote off-grid areas and who would not have electricity otherwise. More than four million SHS installed domestically have uplifted the lifestyle of these impoverished people by providing small-scale power at their homes. But in the context of national power demand and generation, the contribution of SMS is tiny, a mere 250 megawatt, which is only two percent of the total power generation capacity in the country. In fact, in the solar industry worldwide, large-scale solar power generation essentially means on-grid solar (grid-connected).

According to the government plan, renewable sources should provide about 10 percent of the total power generation capacity by 2021, meaning 2400MW power generation from renewable sources. The prospect of wind power (presently total installed capacity is 2MW), bio-energy (present installed capacity 1MW) or new hydro-power have been limited in Bangladesh and therefore, growth of renewable energy in Bangladesh will rely mainly on the development of on-grid solar power. At present the on-grid solar power generation capacity amounts to 15MW (SREDA 2018) including one well-publicised solar park with 3MW capacity built on 8 acres of land in Sarishabari in Jamalpur district.

With such low level of development it would be impractical to believe that the growth of solar power would reach anything near the projected target by 2021. To date, the government has approved proposals for establishing 19 on-grid solar power parks submitted by different private companies. Individually the proposed solar parks have generation capacity ranging from 5MW to 200MW and the cumulative power generation of all these installations would amount to 1070MW. Among these, only six companies have so far reached the final stage of negotiations by signing power purchase agreement (PPA) and implementation agreement with the government. According to the prevailing regulation, a company has to complete the construction and start power generation within one and a half years from signing the PPA and IA. Unfortunately, none of the companies could complete construction and start power generation till date although the deadlines have passed. From the above, it appears that the development of the on-grid solar has so far failed to provide a realistic hope of achieving projected government target.

4.2 WHAT HOLDS BANGLADESH BACK IN DEVELOPING SOLAR POWER?

Realistically, there are a number of reasons that are restricting expected growth of on-grid solar. One of the major challenges is the difficulty of acquiring land. As per the government rule, no agricultural land can be used for solar power project. Bangladesh is a densely populated fertile agricultural land and non-agricultural unused land is not easily available. A 100MW solar park for example would require about 300 acres of land. It is expected that the efficiency of the solar panel will increase in future through new technological advances thus requiring lesser area for generating per unit of power. But until that happens, acquiring land will be a major problem for rapid expansion of on-grid solar in Bangladesh.

Another drawback in developing on grid solar in Bangladesh is lack of governmental incentive. The companies which are engaged in negotiations and implementation of solar park opine that solar industry in Bangladesh is still in an immature and infant stage and requires incentives from the local authorities. A major point in this is fixing the tariff of the produced power. Over the last few years the cost of solar power generation and therefore the tariff offered has moved progressively downward as seen in India and China for example. In India, solar power was offered a tariff of 19 cents (Tk 15.80) per unit in 2010 and this has come down to 5 cents (Tk 4) in 2017. Nevertheless, how logical will it be to take the Indian experience directly to fix the tariff in Bangladesh at this moment may be questionable for a number of reasons.

Firstly there are abundant areas left barren in India which are comparatively easy to procure (both in cost and logistic considerations) for solar park developments, including large span of desserts. This is not so in Bangladesh. Also the facts that the average sun shine time is 5.5 to 6.5 hour per day in India compared to 4 to 4.5 hours per day in Bangladesh. Furthermore India has by now achieved a solar generation capacity of 20,000MW and thus boasts a well trained and qualified work force of its own. On the contrary, Bangladesh has to depend essentially on foreign experts for development of solar parks. All the above factors let India generate solar power at lesser cost than that of Bangladesh.

The organizations engaged in building solar power plants in Bangladesh opine that unless incentive in solar power tariff is given, their effort to develop solar industry would not be economically feasible. It appears that the companies consider 9 cent per unit tariff offered by the government too low a price to build a solar plant and make a profit. Ideally, the government negotiators should be good at offering tariff which is biased towards the people and not towards the companies. But solar power industry in Bangladesh is yet to stand on its feet and at this initial stage it needs incentive to grow to a reasonable strength. Tariff incentive is perhaps a vital area which makes a company decide its future in Bangladesh.

From the above discussion it appears that the rapid growth of renewable energy in power generation will change the world for better in not so distant future. The use of traditional fuels oil gas and coal will gradually decrease to be replaced by renewable solar winds etc till a time when the formers will find their place in history book. Bangladesh does not have an option to remain isolated when rest of the world embraces a future with smarter and cleaner renewable energy for their power. The challenges in developing renewables may be high, but it is the government which should extend its hand to help it grow in the initial stage.

4.3 Solar Photovoltaic (PV) in Dhaka

Bangladesh is one of the world's most vulnerable countries to the effects of climate change. Solar photovoltaics (PV) can help manage climate vulnerabilities and also ensure energy access for all. Bangladesh is among the largest users of off grid solar home systems globally. The markets for on-grid systems such as utility scale solar parks and distributed generation on rooftops, other off-grid markets such as irrigation, public lighting, water pumping, telecom towers etc. also hold substantial promise for adoption. Stronger policy and innovation is crucial to overcome market barriers and accelerate further adoption.

DPDC has started buying solar-generated electricity, from consumers' rooftop plants, under the newly-introduced Net Metering system. It has signed contracts with consumers to procure solar power from their respective rooftop solar panels. Currently these consumers are supplying 3.066 MW of electricity to the national grid & DPDC purchased 13.3 kW from three consumers till December 2018 [8].

4.3.1 How does the idea work?

Under the system, any consumer can set up a rooftop solar panel system—covering up to 70% capacity of the sanctioned load—and sell the additional or unconsumed solar power through a special meter; under an exchange arrangement. Consumers will use their own solar power alongside that of the grid. However, on holidays, when solar power is not used, they can sell power to the national grid.

On working days, they can preserve their solar power at the grid, and sell it to their power supply company, or take it back for consumption. At the end of the month, bills will be adjusted based on consumption and sales of solar power to the utilities. Consumers will be paid by the distribution company at a bulk rate if sales exceed consumption.

Figure 4.1: Solar Photovoltaic (PV) in DPDC Held Area

4.4 Major Constraints

Solar PV accounts for only 0.1% of the total installed (on-grid) electricity generation capacity of Bangladesh. The slow growth of large-scale solar power generation capacity can be attributed to the following [2]:

4.4.1 Financing Challenges:

In Bangladesh, majority of financing for solar power projects is provided by government bodies (for eg, IDCOL) which have access to credit lines from multilateral and development banks. Private players lack interest in project financing due to less experience and high amount of risk involved. Hence, there is a need for diversified sources of funding.

However, the project financing market in the country is still immature to provide long term financing to projects. Financiers do not possess enough experience and knowledge of utility scale renewable energy projects and have low risk appetite. Moreover, small institutional investor base and undeveloped capital markets are not equipped enough to support infrastructure financing.

4.4.2 Land Availability:

A solar power plant requires 3 to 4 acres of land to generate each megawatt of electricity. Bangladesh is a densely populated agricultural country where non-agricultural unused land is not easily available. According to World Bank, agricultural land accounted for 70% of total land area in Bangladesh in 2015. The Government of Bangladesh does not allow the use of agricultural land for renewable energy projects. Therefore, it is a major challenge to find land for installing ground level solar projects.

4.4.3 Project Development:

There is limited information available for project developers due to lack of technical studies, insufficient data on resource availability and gaps in project due diligence, resulting in project development challenges.

The Government has implemented several policies and measures to facilitate both public and private sector investment in solar energy projects to scale up the contribution of renewable energy-based electricity production. The Government adopted the Renewable Energy Policy in 2008 which aims to source 10% of electricity from renewable sources by 2020. However, the contribution of renewable sources to electricity generation currently stands at merely 3%, much below the target outlined. This indicates that a stronger policy support from the Government is needed to boost this sector.

4.5 Guidelines for Grid-connected Small Scale (Rooftop) Solar PV Systems

4.5.1 Scope and Purpose

These Guidelines are for grid-connected small scale (rooftop) solar PV systems. This document is a guideline document only and the Government Departments and Organizations may make suitable modifications to these documents to meet their specific (process) requirements.

4.5.2 Grid-Connected Solar PV Systems

There are basically two solar PV systems: stand-alone and grid-connected. Stand-alone solar PV systems work with batteries. The solar energy is stored in the battery and used to feed building loads after conversion from DC to AC power with a stand-alone inverter. These systems are generally used in remote areas without grid supply or with unreliable grid supply. The disadvantage of these systems is that the batteries require replacement once in every 3 – 5 years.

Grid-connected solar PV systems feed solar energy directly into the building loads without battery storage. Surplus energy, if any, is exported to grid and shortfall, if any, is imported from the grid. These guidelines apply to grid-connected small scale (rooftop) solar PV systems.

4.5.3 Solar Net-Metering

In net- metering the solar energy exported to the grid is deducted from the energy imported from the grid subject to certain conditions. The consumer pays for the net-energy imported from the grid.

4.5.4 Rooftop and Installation Requirements

The shadow-free area required for installation of a rooftop solar PV system is about 12 m2 per kW (kilowatt). This number includes provision for clearances between solar PV array rows. The solar panels may be installed on the roof of the building with a south facing tilt angle that varies in Tamil Nadu from 11 – 13 degrees depending on the latitude of the location. Sufficient area shall be available for servicing the system. The minimum clearance required for cleaning and servicing of the panels is 0.6m from the parapet wall and in between rows of panels. In between the rows of solar panels sufficient gap needs to be provided to avoid the shading of a row by an adjacent row. The solar grid inverter shall be placed indoor in a safe and easily accessible place.

4.5.5 System Components

A grid-connected solar PV system consists of the following main components:

- Solar PV (photo-voltaic) array
- Solar PV array support structure
- Solar grid inverter
- Protection devices
- Cables

4.5.6 Solar PV System Capacity Sizing

The size of a solar PV system depends on the 90% energy consumption of the building and the shade-free rooftop (or other) area available.

CHAPTER 5 – MY EXPERIENCE AT DPDC AS AN INTERN

5.1 About DPDC

5.1.1 The Company

Dhaka Power Distribution Company Limited (DPDC) is one of the largest power distribution companies in Bangladesh. Dhaka Power Distribution Company Limited (DPDC) had been incorporated on 25th October, 2005 under the Companies Act 1994 with an authorized share capital of Tk. 10,000 (ten thousand) crore divided into 100 (one hundred) crore ordinary share of Tk. 100 each.

The company was granted permission to commence business from 25th October, 2005 and started its function from 14th May 2007. The company started its commercial operation on 1st July of 2008 by taking over all assets and liabilities from the then DESA. When the company started its operation, the number of customers were 6,62,553 now customers have reached at 11,95,829. The Board of Directors is the ultimate authority for the overall management of the company within the framework of the prevailing law. The Board comprises 12 (twelve) directors nominated by the Government.

Under the guidance of the Board of Directors, DPDC's strategic functions are run by a management team headed by the Managing Director and 5 (five) executive directors, i.e. Executive Director (Tech.), Operation; Executive Director (Tech.), Engineering; Executive Director (Tech./ICT), ICT & Procurement; Executive Director (Finance) and Executive Director (Admin. & HR) [3].

5.1.2 Corporate Motto

Dependable Power - Delighted Customer

5.1.3 Vision

Provide quality and reliable electricity to the people of Dhaka city and Narayangonj area for desired economic, social and human development of the country.

5.1.4 Mission

- To deliver quality electricity with service excellence.
- To make electricity available on demand within the geographical area of DPDC.
- To ensure customer satisfaction.
- To develop new mindset for all of the employees congruent with corporate culture.
- To reach self-sufficiency and profitability by increasing income and reducing expenditure.

5.1.5 Commitment

- Quality power supply to all customers.
- Quickest response to customers' need.
- Initiatives to match the changing needs of the customers.
- Digitalization of Distribution System.

5.1.6 Core Objectives

5.1.6.1 For the customers

Rendering reliable and uninterrupted power supply with customers care.

5.1.6.2 For the Owner and Shareholders

Financial sustainability of the Company.

5.1.6.3 For the Society

Strengthening the social values and undertake corporate social responsibility.

5.1.6.4 For the Nation

Taking all out effort to achieve national growth and economic prosperity.

5.1.7 DPDC at a Glance

Name of the Company:	Dhaka Power Distribution Company Limited (DPDC)
Administrative Ministry:	Power Division, Ministry of Power, Energy & Mineral Resources
Registered Office:	Biddut Bhaban, 1 Abdul Gani Road, Dhaka-1000
Head Office:	Biddut Bhaban, 1 Abdul Gani Road, Dhaka-1000
Incorporation:	25 October, 2005
Commercial Operation:	1 July, 2008
Authorized Capital:	Tk. 10,000 crore
Total area covered:	350 sq. km
Total electricity line:	5,371 Km
Total Number of Substation:	58 Nos
Max. Demand (June 2018):	1479.40 MW
Distribution Transformer:	18,986 Nos
Annual Load Growth:	7.10%
Import of Energy (FY 2017-2018):	Mkwh 8,819
Sale of Energy (FY 2017-2018):	Mkwh 8,165
Sales Revenue (FY 2017-2018):	MTk. 46,218.24
System Loss:	7.41%
Payment to the National Exchequer:	MTk. 7,671
Number of Customers:	11,95,829 Nos (As on 30.06.18)
Human Resources (As per set-up):	5,734.

5.2 Renewable Energy Related Projects Taken By DPDC

5.2.1 Ongoing Projects

1. Net-Meter Installation:

- No: 100
- Total Capacity: More than 900KWp

2. Implementation of 750 KWp Grid Tied Roof top Solar Power project on BOO basis:

- Total Capacity: 750KWp
- Project Location:
  - ✓ LOT_1: 17 Installation at North Zone (285KWp)
  - ✓ LOT_2: 17 Installation at South Zone (275KWp)
  - ✓ LOT_3: 10 Installation at Central Zone (190KWp)
- Implementing Agency: Power Utility Bangladesh Ltd
- Contract Signed: 03 Mar, 2017
- Present Status: Already systems installed

5.2.3 Completed Projects

1. Implementation of a 50KWp Grid Tied Solar Project on the Rooftop of Bangladesh Secretariat Building/s on BOO (Build Own Operate)

   - Total Capacity: 50KWp
   - Project Location: Secretariat Building
   - Implementing Agency: Rahimafrooz Renewable Energy Ltd.
   - COD: 31.12.2014
   - Present Status: In Operation

2. Implementation 200KWp Grid Tied Solar Power Plant on the Rooftop of Sheikh Russel Roller Skating Complex

   - Total Capacity: 200KWp
   - Project Location: Sheikh Russel Roller Skating Complex
   - Implementing Agency: Bangladesh Roller Skating Federation
   - COD: 15.12.2017
   - Present Status: In Operation

3. Installation of 20KWp Solar Charging Station

- Total Capacity: 20KWp
- Project Location: Siddirgonj, Narayangonj
- Implementing Agency: DPDC
- COD: 28.05.2018
- Present Status: In Operation

5.3 NET METERING IN DPDC

Net energy metering (NEM) refers to a policy mechanism that allows prosumers to connect their renewable energy systems to the distribution grid. Thus any excess electricity after self-consumption that is generated from renewable sources is supplied to the distribution grid, and in exchange the prosumer can either import equal amount of electricity from the grid or receive price of net amount of exported electricity at the end of settlement period as per this guideline.

The measured data can be stored in the meter or transferred to a centralized aggregator service. The customer's bill is calculated according to the net energy recorded on the meter; i.e. the aggregated energy drawn from the network minus the energy delivered to the network over the specified billing period. If the amount of electricity consumed from the grid is higher than the amount of electricity supplied to the grid from the rooftop solar PV system, the consumer has to pay the bill for net consumption.

On the other hand, if the amount of electricity generated and exported from solar PV system or the renewable energy system to the grid is higher than the imported electricity, then the distribution utility shall allow all the credit (in terms of kWh) of the consumer to roll over to the next billing period. By the end of the specified rolling cycle or settlement period, the consumer is compensated for all kWh credits as a rate prescribed in this guideline by the distribution utility, and on 1 July of every year credit account is set to zero. Figure 5.1 illustrates the architecture of a typical net metering arrangement using solar PV as an example of distributed renewable energy system.

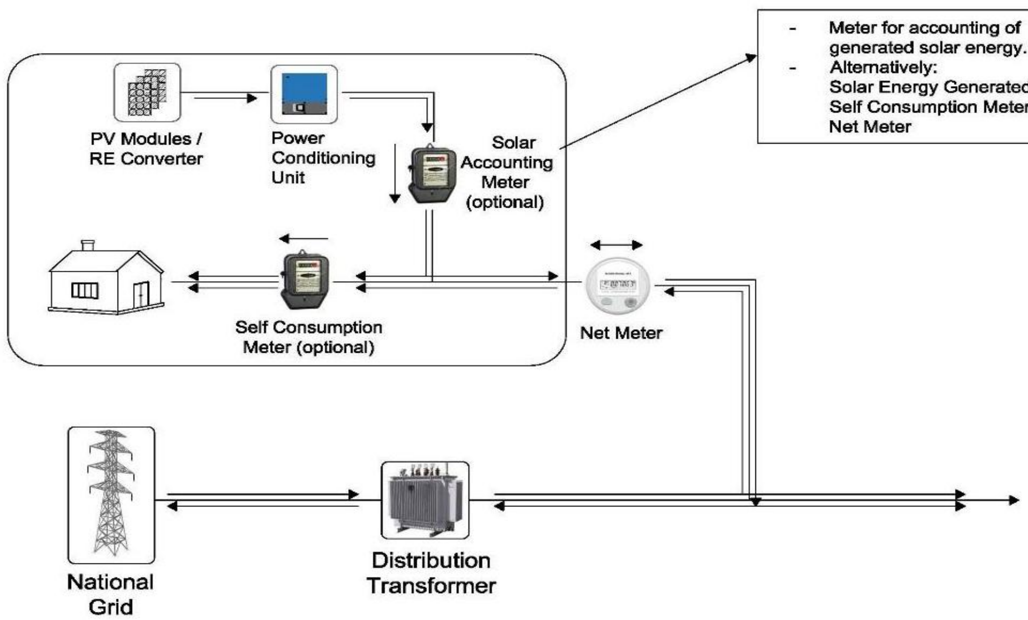

Figure 5.1: Typical net metering architecture

The rate at which the customer is billed is determined considering various factors such as the consumer tariff class, type of renewable energy technology, installed capacity and export limitations. While installing such connections, the prosumer must also abide by the interconnection technical requirements and safety regulations set by the concerned authority.

The interconnection process, the mechanism by which net metered distributed energy systems may be legally and safely connected to the electricity grid, is critical to the success of net metering programs. Interconnection standards are typically outlined separately from net metering policy parameters, but are fundamental to the development of the NEM policy.

5.4 Solar System in DPDC

Dhaka Power Distribution Company Limited (DPDC) has ‘Rooftop on Grid Solar System’ along with ‘smart complaint management system’ that helps to improve the quality of the services greatly of the utility service provider.

In the table below we can see how DPDC is doing in Solar System Installation.

Table 5.1: Solar System Installation in DPDC

Financial Year	**Installation of Net Meter**		**Installation of Solar System**						
			DPDC Own			**Customer Premises**		**Total**	
			Location	**Nos.**	**KWP**	**Nos.**	**KWP**	**Nos.**	**KWP**
Upto 2013	**Nos.**	**KWP**	-	-	-	12409	2379.273	12409	2379.27
FY 2013-2014	-	-	12 Different Sub-stations of DPDC	12	34.500	3791	726.948	3803	761.448
FY 2014-2015	-	-	Secretariat Building	1	50.000	4295	823.714	4296	873.714
FY 2015-2016	-	-	-	-	-	4066	779.646	4066	779.646
FY 2016-2017	-	-	-	-	-	4384	840.513	4384	840.513
FY 2017-2018	-	-	-	1	200.000	2728	2680.440	2729	2880.440
July’18	-	-	-	0	0.000	180	123.897	180	123.897
Aug’18	-	-	-	0	0.000	159	155.513	159	155.513
Sept’18	-	-	-	0	0.000	167	171.236	167	171.236
Oct’18	1	4.50	-	0	0.000	239	201.684	239	201.684
Nov’18	33	346.10	-	0	0.000	214	264.909	214	264.909
Dec’18	6	43.50	-	0	0.000	232	180.200	232	180.200
Jan’19	9	66.90	-	0	0.000	324	203.575	324	203.575
Feb’19	17	165.50	-	0	0.000	226	230.964	226	230.964
Mar’19	6	43.55	Rooftop of DPDC’s own installation	42	750.000	300	209.657	342	959.657
Apr’19	6	61.58	-	0	0.000	349	279.379	349	279.379
May’19	-	-	-	0	0.000	-	-	-	-
Jun’19	-	-	-	0	0.000	-	-	-	-
FY’18-19 (upto Apr’19)	**78**	**732**	**-**	**42**	**750.000**	**2390**	**2021.014**	**2432**	**2771.01**
DPDC Total	**78**	**732**	**-**	**56**	**1034.50**	**34063**	**10251.548**	**34119**	**11286.048**

Source: office of the SE, Renewable Energy & Research, DPDC.

5.5 GRID SYSTEM IN DPDC

5.5.1 Synopsis of Dhanmondi 132/33/11 kV Substation Yearly Maintenance done (2018-2019)

S/L No.	Equipment/Switchgear under testing/maintenance	Testing/Maintenance	Remarks
01	132/33 kV, 50/75 MVA Grid transformer GT-1, GT-2, GT-3, GT-4 & 33 /11kV, 20/28 MVA Power transformer T-1, T-2	Tanδ Test	O. K
		Winding Resistance test	O. K
		Insulation Resistance test	O. K
		Body protection checking	O. K
		Indication Checking	O. K
		Relay testing	O. K (Performed by System Protection, North, DPDC)
		Dissolved Gas Analysis & Breakdown Voltage test	O. K
		General maintenance (i.e Nut bolt tightening, oil leakage prevention, General cleaning)	O. K
02	132 kV GIS Breaker, 33 kV GIS Breaker, 11 kV Bus & Switchgear Maintenance under 33/11 kV Transformer T-1, T-2	Gas pressure checking, Gas leakage, general cleaning	O. K
		Contact Resistance Test	O. K (For 11 kV Circuit Breakers)
		Insulation Resistance Test	O. K
		CT, PT, Cable termination checking	O. K
		Indication Checking	O. K
		Relay testing	O. K (Performed by System Protection, North, DPDC)
		General Maintenance (i.e general cleaning, contact greasing, nut bolt tightening)	O. K
03	Battery & Battery Charger	Specific Gravity & Cell Voltage Measurement	O. K
		Battery Bank Charging & Discharging	O. K
		Charging Voltage, Current (AC/DC), (Float/Boost mode)	O. K
		Indication Checking	O. K
		General Maintenance (General cleaning, contact greasing, intercell connector tightness, corrosion cleaning)	O. K

Additional Test to be done in next year:
Circuit Breaker timing test along with dynamic contact resistance test for all circuit breakers.

5.5.2 Test Report of Dhanmondi 132/33/11 kV GIS Substation Protective Relays

<table>
<tr><th rowspan="2">S/L No.</th><th rowspan="2">Name of Bay</th><th colspan="2">Tested Relays</th><th rowspan="2">Manufac-turer</th><th rowspan="2">Remarks</th></tr>
<tr><th>Type</th><th>Model No.</th></tr>
<tr><td rowspan="2">01</td><td rowspan="2">132 kV Incomer of GT-3</td><td>Transformer Differential (87T)</td><td>7UT61</td><td rowspan="8">SIEMENS, Germany</td><td rowspan="12">Tested by System Protection, North, DPDC</td></tr>
<tr><td>Back up Overcurrent/Earth Fault (50/51 P/N)</td><td>7SJ64</td></tr>
<tr><td rowspan="2">02</td><td rowspan="2">132 kV Incomer of GT-4</td><td>Transformer Differential (87T)</td><td>7UT61</td></tr>
<tr><td>Back up Overcurrent/Earth Fault (50/51 P/N)</td><td>7SJ64</td></tr>
<tr><td rowspan="2">03</td><td rowspan="2">33 kV Incomer of T-1</td><td>Transformer Differential (87T)</td><td>7UT61</td></tr>
<tr><td>Back up Overcurrent/Earth Fault (50/51 P/N)</td><td>7SJ64</td></tr>
<tr><td rowspan="2">04</td><td rowspan="2">33 kV Incomer of T-2</td><td>Transformer Differential (87T)</td><td>7UT61</td></tr>
<tr><td>Back up Overcurrent/Earth Fault (50/51 P/N)</td><td>7SJ64</td></tr>
<tr><td rowspan="2">05</td><td rowspan="2">11 kV Incomer of T-1</td><td>Directional Overcurrent/Earth Fault (67 P/N)</td><td rowspan="2">REX521</td><td rowspan="4">ABB, Finland</td></tr>
<tr><td>Back up Overcurrent/Earth Fault (50/51 P/N)</td></tr>
<tr><td rowspan="2">06</td><td rowspan="2">11 kV Incomer of T-2</td><td>Directional Overcurrent/Earth Fault (67 P/N)</td><td rowspan="2">REX521</td></tr>
<tr><td>Back up Overcurrent/Earth Fault (50/51 P/N)</td></tr>
<tr><td rowspan="2">07</td><td rowspan="2">11 kV Outgoing Feeders</td><td rowspan="2">Overcurrent/Earth Fault</td><td>SPAJ 140 C</td><td>ABB, Finland</td><td rowspan="2">Tested by Grid North-1, DPDC</td></tr>
<tr><td>SEL 551</td><td>SEL, USA</td></tr>
</table>

SL. No.	Particulars	Description
1.	Manufacturer	SIEMENS, Germany
2.	Serial Number	K31263934 (GT-3), K31263927 (GT-4)
3.	Rated Voltage	145 kV
4.	Rated lightning impulse withstand voltage	650 kV
5.	Rated power frequency withstand voltage	275 kV
6.	Rated Current	2000 A
7.	Frequency	50 Hz
8.	Short Circuit Breaking Current	31.5 kA
9.	Short Circuit Duration	3s
10.	Operating sequence	0-0.3s CO-3Min-CO
11.	Type	8DN8
12.	Standard	IEC 62271-203
13.	Year of manufacturing	2013
14.	Weight of SF_6 filling	104 kg (GT-3), 99 kg (GT-4)
15.	Weight including SF_6 filling	3.9 ton (GT-3), 3.6 ton (GT-4)

5.5.3 Name Plate Data of 33 kV Transformer Incoming GIS Bay of GT3, GT4, T1, T2 Transformer

SL. No.	Particulars	Description
1.	Manufacturer	Schneider Electric, Germany
2.	Serial Number	TM-251387-1 (GT-3), TM-251661-1 (GT-4), TM-250829-1 (T-1), TM-251138-1 (T-2)
3.	Rated Voltage	36 kV
4.	Rated lightning impulse withstand voltage	170 kV
5.	Rated power frequency withstand voltage	70 kV
6.	Rated Current	2500 A (GT-3 & GT-4), 2000 A (T-1 & T-2)
7.	Frequency	50 Hz
8.	Short Circuit Breaking Current	31.5 kA
9.	Short Circuit Duration	3s
10.	Operating sequence	0-0.3s CO-3Min-CO
11.	Type	WSA 8/36-2/623
12.	Standard	IEC 62271-200/2003
13.	Year of manufacturing	2016
14.	Weight of SF_6 filling	4.2 kg (T-1 & T-2), 4.7 kg (GT-3 & GT-4)
15.	Sealed pressure SF_6 filling	Max-0.075 MPa, Avg-0.062 MPa, Min-0.057 MPa

5.5.4 Grid Transformer Maintenance Summary

1. Check for oil leakage and seepage.
2. Check for rust, dust and foreign materials.
3. Check for bushings cracks, dust & dirt deposition, salt or chemical deposition, cement or acid fumes depositions should be carefully noted and rectified.
4. Functionality check of buchholz/oil surge relay/pressure relief device.
5. Checking of any loose connections of HV, LV and neutral bushing terminals.
6. Conservator to be cleaned from inside after every three years. Replace conservator breather, dehydration of silica gel if necessary.
7. Check for winding temperature gauge, inspection of winding temperature meter readings
8. Check for Oil level meter along with oil level.
9. Check for radiator, isolation valves, radiator fan, direction of fan rotation, overall cleanliness.
10. Check for color and smell of oil of main tank (top and bottom), conservator tank and OLTC.
11. Check for sludge, dirt and moisture in oil.

5.5.5 Maintenance Works Done at a Glance

S/L No.	Particulars	Condition	Action Taken
01.	General Cleaning	Dusty	Done
02.	Physical Condition	Fine	
03.	Body Protection	Functional	
04.	Magnetic Oil Gauge	Functional	
05.	Connections of HV, LV & neutral bushing terminals	Tight enough	Checked
06.	Tightness check of wirings at Marshalling Box	Tight enough	Checked
07.	Red hot indication/ damaged conductor	Fine	Checked
08.	Radiator Fan/ direction of rotation	Operational	Checked
09.	Indication check	Fine	Checked

5.5.6 Brief Description of Test & Testing Equipment Used For Transformer Testing

S/L No.	Name of the test	Brief description of testing equipment	Testing standard
01	Tanδ/ Dissipation factor	Tettex 2883, Haefely Hipotronics, S/L No.-183464, Country of origin: Switzerland	IEEE 62-1995
02	Insulation Resistance	Megger, MIT 525, Applied voltage: 5,000 Volts DC, Country of Origin: USA.	IEC 60364-6
03	Winding Resistance	DV Power, Model No.-RMO20TW, S/L No.-16R840, Country of Origin: Sweden, Applied Current: 10A	IEEEC 57.152-2013
04	Dissolved Gas Analysis	GE Kelman Transport X, USA (From PGCB)	IEEE C57.104
05	Oil Breakdown Voltage	Megger, Model: OTS80PB, Made in UK	IEC 60156-95
06	Tanδ Test of Transformer Oil	TD1/TC12, Omicron, Austria (From PGCB)	IEEE C57.106

5.5.7 Environmental Condition While Performing Testing of Transformer GT-1, GT-2, GT-3, GT-4

S/L No.	Date	Maintenance/Test Field	Environmental Condition			
			Ambient temp.	Humidity	Oil temp.	Correction factor
01	21/02/19	132/33 kV, 80/120 MVA GT-1 Transformer	29^{o}c	48%	30^{o}c	1.22
02	22/06/18	132/33 kV, 80/120 MVA GT-2 Transformer	32^{o}c	71%	37^{o}c	2.13
03	12/02/19	132/33 kV, 50/75 MVA GT-3 Transformer	24^{o}c	40%	30^{o}c	1.97
04	13/02/19	132/33 kV, 50/75 MVA GT-4 Transformer	27^{o}c	45%	34^{o}c	1.27

5.5.8 Name Plate Data of 132/33 kV GT-1 & GT-2 Transformer of Dhanmondi 132/33 kV SS

S/N	Particulars	Details	
1.	Rated MVA	80/120 MVA	
2.	Rated Voltage	HV	132.0 kV
		LV	33.0 kV
3.	Rated Current	HV	525 A
		LV	2099 A
4.	Rated Frequency & Phases	50 Hz, 03 Phases	
5.	Makers S/N	16028 (GT-1), 16023 (GT-2)	
6.	Year of Manufacture	2017	
7.	Connection Symbol	Dyn1	
8.	Core & Windings	77,500 kg	
9.	Tank & Fittings	41,000	
10.	Total Oil	46,000 Litre	
11.	Total Mass	159,900 kg	
12.	Transportation mass Without Oil	118,500 kg	
13.	Manufacturer’s Name	Fortune Electric Ltd., Taiwan	
14.	Percentage Impedance	80 MVA	8.55 (GT-1), 8.60 (GT-2)
		120 MVA	12.84 (GT-1), 12.89 (GT-2)
15.	OLTC Information		
	Manufacturer	MR Germany	
	Type	VVIII400D-145-12233W	
	Serial no.	1792246 (GT-1), 1792241 (GT-2)	
	Year of Manufacturing	2016	

5.6 ACTIVITIES AT NETWORK OPERATION & CUSTOMER SERVICE (NOCS) OFFICES OF DPDC

Network Operation & Customer Service (NOCS) offices of DPDC are mainly customer service offices. From applying for a new connection to increase connection load or any other related services are provided by these offices. These offices are the main income source of DPDC. DPDC has 36 NOCS offices within its operational periphery.

DPDC since its inception has been striving to establish better and friendlier service to its customer. In this perspective, DPDC has introduced the opportunity for customers to apply for electric connection through internet. This would also enable them to know about the status of application. Applicants are advised to follow the instructions laid down in the citizen charter.

After the confirmation of the On-Line application, the applicant will be able to download or take a print of the application form. Applicants must submit the required documents in hard copy for validating On-line application, along with his/her signed copy of printed application.

CHAPTER 6 – FINDINGS & OBSERVATIONS

6.1 Findings & Observations

CO_2 is the most important greenhouse gas. The use of fossil fuels – oil, gas and coal – makes a substantial contribution to CO_2 emissions. This is why we need energy sources that will not lead to a further increase in the amount of CO_2 in the earth's atmosphere, such as wind, hydropower, geothermal energy and above all: the sun.

Emission of carbon dioxide and other greenhouse gases is causing global warming, which in turn is leading to climate change and a rise in sea level. These developments are adversely affecting biodiversity, precipitation patterns, fresh water supply, agriculture and food supply, and the safety of those living in low-lying coastal areas.

Solar PV accounts for only 0.1% of the total installed (on-grid) electricity generation capacity of Bangladesh. Dhaka is a densely populated area and scope for something like solar park is far from reality. Only rooftop solar system is a practical and feasible choice. DPDC has started buying solar-generated electricity, from consumers' rooftop plants, under the newly-introduced Net Metering system. It has signed contracts with consumers to procure solar power from their respective rooftop solar panels. Currently these consumers are supplying 3.066 MW of electricity to the national grid & DPDC purchased 13.3 kW from three consumers till December 2018.

According to the government plan, renewable sources should provide about 10 percent of the total power generation capacity by 2021, meaning 2400MW power generation from renewable sources. The prospect of wind power (presently total installed capacity is 2MW), bio-energy (present installed capacity 1MW) or new hydro-power have been limited in Bangladesh and therefore, growth of renewable energy in Bangladesh will rely mainly on the development of on-grid solar power. At present the on-grid solar power generation capacity amounts to 15MW (SREDA 2018) including one well-publicised solar park with 3MW capacity built on 8 acres of land in Sarishabari in Jamalpur district.

With such low level of development it would be impractical to believe that the growth of solar power would reach anything near the projected target by 2021. To date, the government has approved proposals for establishing 19 on-grid solar power parks submitted by different private companies. Individually the proposed solar parks have generation capacity ranging from 5MW to 200MW and the cumulative power generation of all these installations would amount to 1070MW. Among these, only six companies have so far reached the final stage of negotiations by signing power purchase agreement (PPA) and implementation agreement with the government. From the above, it appears that the development of the on-grid solar has so far failed to provide a realistic hope of achieving projected government target.

If the duration of my internship was more than three months then I could have gained more much more knowledge and insight into the activities of DPDC. This in turn would have helped to enrich my report.

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