SOLAR IRRADIATION PATTERN ANALYSIS OF BANGLADESH FOR ELECTRICITY GENERATION

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

By
Md. Sabeto Ibnekar
ID: 142-33-1898
Abdullah Al Mamun
ID: 142-33-1878

Supervised by
Prof. Dr. M. Shamsul Alam
Professor & Dean
Department of Electrical & Electronic Engineering
Faculty of Engineering

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
FACULTY OF ENGINEERING
DAFFODIL INTERNATIONAL UNIVERSITY
December 2018

Certification

This is to certify that this project entitled "**SOLAR IRRADIATION PATTERN ANALYSIS OF BANGLADESH FOR ELECTRICITY GENERATION**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on November 2018.

Signature of the candidates

Name: Md. Sabeto Ibnekar
ID: 142-33-1898

Abdullah Al Mamun

Name: Abdullah Al Mamun
ID: 142-33-1878

Countersigned

Fori

Professor Dr. M. Shamsul Alam

Professor and Dean

Department of Electrical and Electronic Engineering

Faculty of Engineering

Daffodil International University

The thesis entitled **"SOLAR IRRADIATION PATTERN ANALYSIS OF BANGLADESH FOR ELECTRICITY GENERATION"** submitted by **Md. Sabeto Ibnekar**, ID No: 142-33-1898 and **Abdullah Al Mamun**, ID No: 142-33-1878,Session: Spring 2018 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on December, 2018.

BOARD OF EXAMINERS

____

Dr. Engr. … Chairman
Professor
Department of EEE, DIU

____

Dr. Engr. --- Internal Member
Professor
Department of EEE, DIU

____

Dr. Engr. --- Internal Member
Professor
Department of EEE, DIU

Dedicated to

Our Parents

CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Abbreviations

AC	Alternating Current
CHT	Chittagong Hill Tracts
CPV	Concentration photovoltaic
DC	Direct Current
GEF	Global Environment Facility
IDCOL	Infrastructure Development Company Limited
JICA	Japan International Cooperation Agency
KW	Kilo Watt
LGED	Local Government Engineering Department
MW	Megawatt
NGO	Non-governmental Organizations
OPV	Organic Photovoltaic
PV	Photovoltaic
RE	Renewable Energy
RET	Renewable Energy Technology
REB	Rural Electrification Board
SHS	Solar Home System
USAID	United States Agency for International Development
USA	United States of America

ACKNOWLEDGEMENT

First of all, we are paying thanks to the Almighty Allah because of whom we are being able to prepare this Thesis Report. We carefully pay our regard to the Almighty to put us into this success.

We would like to take this opportunity to express our heartiest gratitude to our honorable Thesis supervisor **Prof. Dr. M. Shamsul Alam, Dean, Department of EEE, Daffodil International University** for being dedicated in supporting, motivating and guiding us through this thesis. This thesis can't be done without his useful advice and helps.

We are very thankful to our honorable Vice Chancellor **Prof. Dr. Yousuf Mahbubul Islam, Daffodil International University** for providing opportunity for achieving our degree of B.Sc. in EEE.

We would like to further thank to all teachers of EEE Department & all of our friends for their support and inspiration.

Finally, we would like to give big thanks to our parents how they have given us remarkable inspiration & supports. Without their mental and financial supports, we would not able to complete our thesis.

ABSTRACT

Photovoltaic power generation system (PV system) is an instrument that uses solar cells to convert solar energy into electricity and the principle of the solar cells is the use of semiconductor materials electronics characteristics of P-V conversion. The PV system and its application is a deep research project, which combines the use of green renewable energy, improves the ecological environment, improves the living conditions of an integral whole and combines it with the economy, politics and society in the 21st Century. The following research paper is based on the prospects of solar energy from perspective of Bangladesh. The main aim of our research is to find out the irradiation of sun in Dhaka city in the month of July and August so that the power production by the solar panel can be estimated and we collect the solar irradiation and the maximum power data in Dhaka for (July & August) two months and analyze the data to get average irradiation and find the relationship between solar irradiation and power and by using this data we can easily understand the electricity production by solar home system and create a standard form of power production of solar home system in 2018.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Energy crisis and Global Warming is the burning issue all over the world at present situation. Bangladesh will face global warming mostly as well as adequate and affordable energy crisis. There is no other way to think any kind of development without the Power or electricity. The living standard and prosperity of a nation vary directly with increase in use of power. As technology is advancing the consumption of power is steadily rising. Sufficient and reliable source of electricity is a major prerequisite for a sustained and successful economic development effort and poverty reduction. The production of total electricity cannot fulfil the demand of the consumers adequately and many people do not getting sufficient electricity. Only about 60% of total populations in Bangladesh have access to electricity and it would take around 15 years to provide electricity to all [1]. So that renewable energy is becoming more popular day by day. Renewable energy comes from different types of natural resources mainly from sunlight, wind, rain, tides, and geo-thermal heat, biodiesel, biofuel etc. [2]

1.2 Renewable Energy

Renewable energy is the energy which is generated from natural resources such as sunlight, wind, rain, tides, geothermal heat which are naturally replenished. The majority of renewable technologies are powered by the sun. The hydrosphere (water) absorbs a major function of the incoming radiation. Most radiation is absorbed at low latitude around equator, but the energy is dissipated around the globe in the form of winds and ocean currents. Renewable energy is derived from the natural processes that are replenished constantly. In its various forms, it derives directly from sun or from heat generated deep within the earth. Electricity and heat is generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and bio-fuels and hydrogen derived from renewable resources. Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation, and economic benefits. In international public opinion surveys there is strong support for promoting renewable sources such as solar power and wind power. At the national level, at least 30 nations around the world already have renewable energy contributing more than 20 percent of energy supply [3]. Renewable energy systems are rapidly becoming more efficient and cheaper day by day.

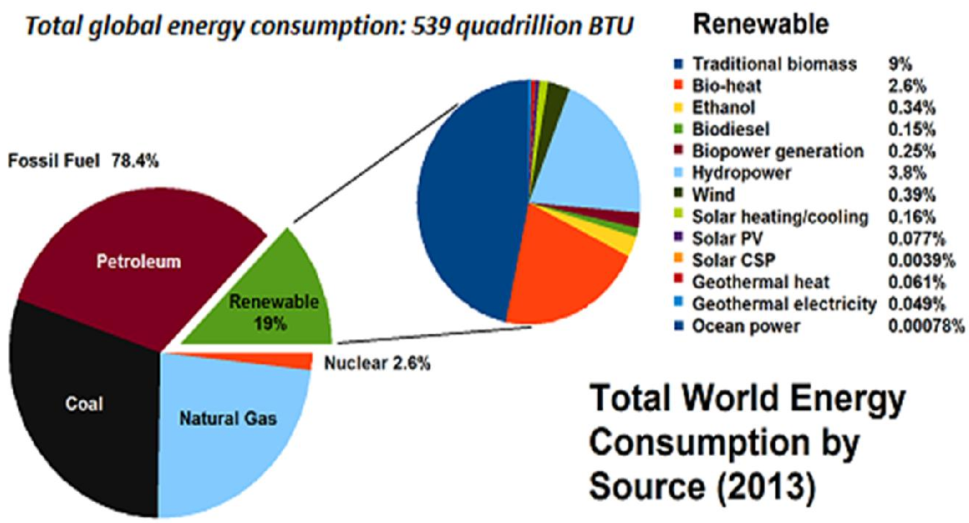

Figure 1.1: Total world energy consumption

1.2.1 Main Sources of Renewable Energy

- Wind Energy.
- Biomass.
- Geothermal Energy.
- Hydropower.
- Photo voltaic (PV) Cells.

1.2.2 Types of Renewable Energy

There are many types of renewable energy. Most of these renewable energies depend in one path or another on sunlight. Wind and hydroelectric power are the direct result of differential heating of the Earth's surface which leads to air moving about and precipitation forming as the air is lifted. Solar energy is the straight conversion of sunlight using panels or collectors. Biomass energy is gathered sunlight contained in plants. Other renewable energies that do not rely on sunlight are geothermal energy, which is a result of radioactive decay in the crust combined with the original heat of accreting the Earth, and tidal energy, which is a conversion of gravitational energy. Renewable energy produces no green-house gases during operation. Types of renewable energy shown in the figure-1.2

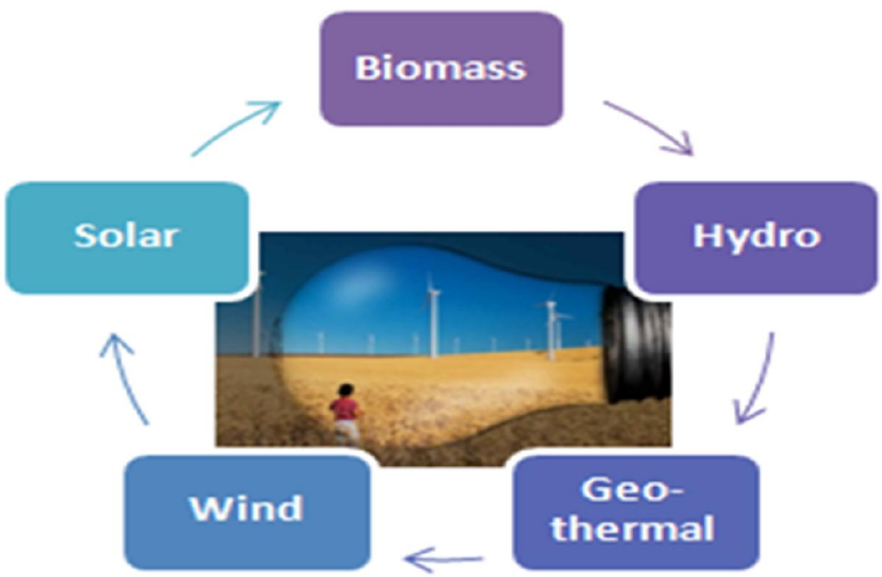

Figure 1.2: Types of renewable energy

1.2.2.1 Hydro Energy

This form uses the gravitational potential of elevated water that was lifted from the oceans by sunlight. It is not strictly speaking renewable since all reservoirs eventually fill up and require very expensive excavation to become useful again. At this time, most of the available locations for hydroelectric dams are already used in the developed world. Being a flat country, Bangladesh is not in a favorable position for large-scale hydropower. There are small potential of mini and micro-hydropower in CHT region and greater Sylhet region. The total hydropower potential of the country in three locations (Kaptai, Sangu and Matamuhuri) is 1500 GWh/year (755 MW) of which about 1000 GWh/year (230 MW) has been harnessed at Kaptai through 5 units of hydropower plants [4]. Future development of hydropower at Sangu and Matamuhuri should be considered with due attention to their negative impacts on environment and on local population.

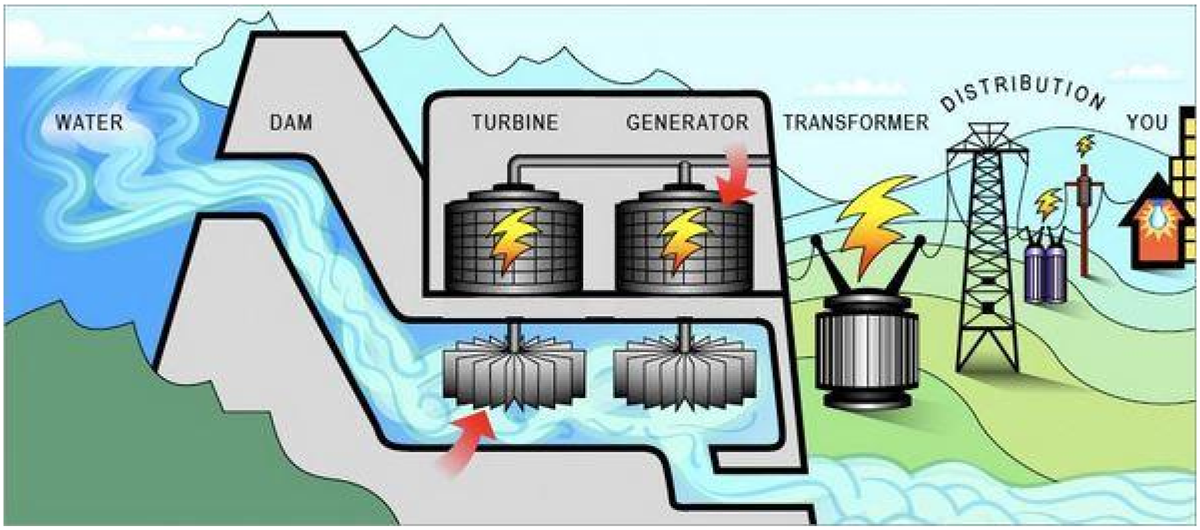

Figure 1.3: Hydroelectric Dam

1.2.2.2 Biomass Energy

Biomass is the term for energy from plants. Energy in this form is very commonly used throughout the world. Unfortunately the most popular is the burning of trees for cooking and warmth. This process releases copious amounts of carbon dioxide gases into the atmosphere and is a major contributor to unhealthy air in many areas. Some of the more modern forms of biomass energy are methane generation and production of alcohol for automobile fuel and fueling electric power plants. Agriculture based country Bangladesh has huge potential for utilizing biogas technology. Biogas is a fuel gas obtained in the absence of oxygen of cattle dung, poultry droppings, human excreta, and agricultural residues. Bangladesh is in a favorable position in respect of availability of raw materials and the climatic conditions for biogas production. Cost is the most dominant factor limiting the wide application of biogas.

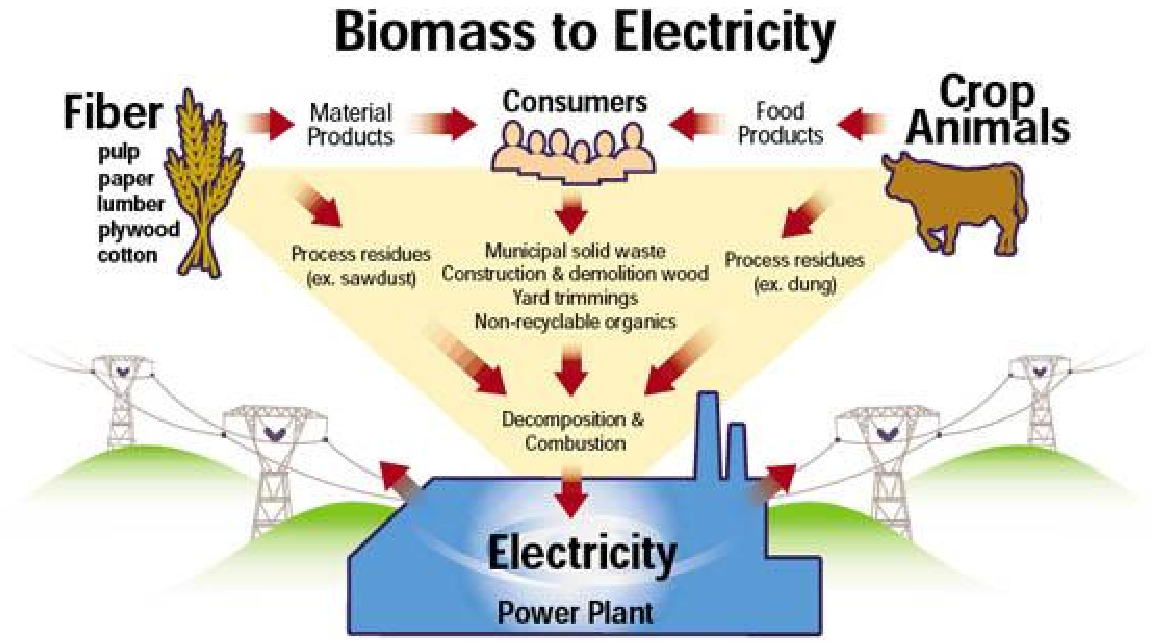

Figure 1.4: Biomass energy

1.2.2.3 Tidal Energy

Tidal power or tidal energy is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity. Although not yet widely used, tidal energy has potential for future electricity generation. A mean head of at least five meters is usually considered to be the minimum for viable tidal power generation. Therefore, there is very less potential prospect of tidal resource in Bangladesh. There may be scope of integrated tidal power plants in the coastal regions.

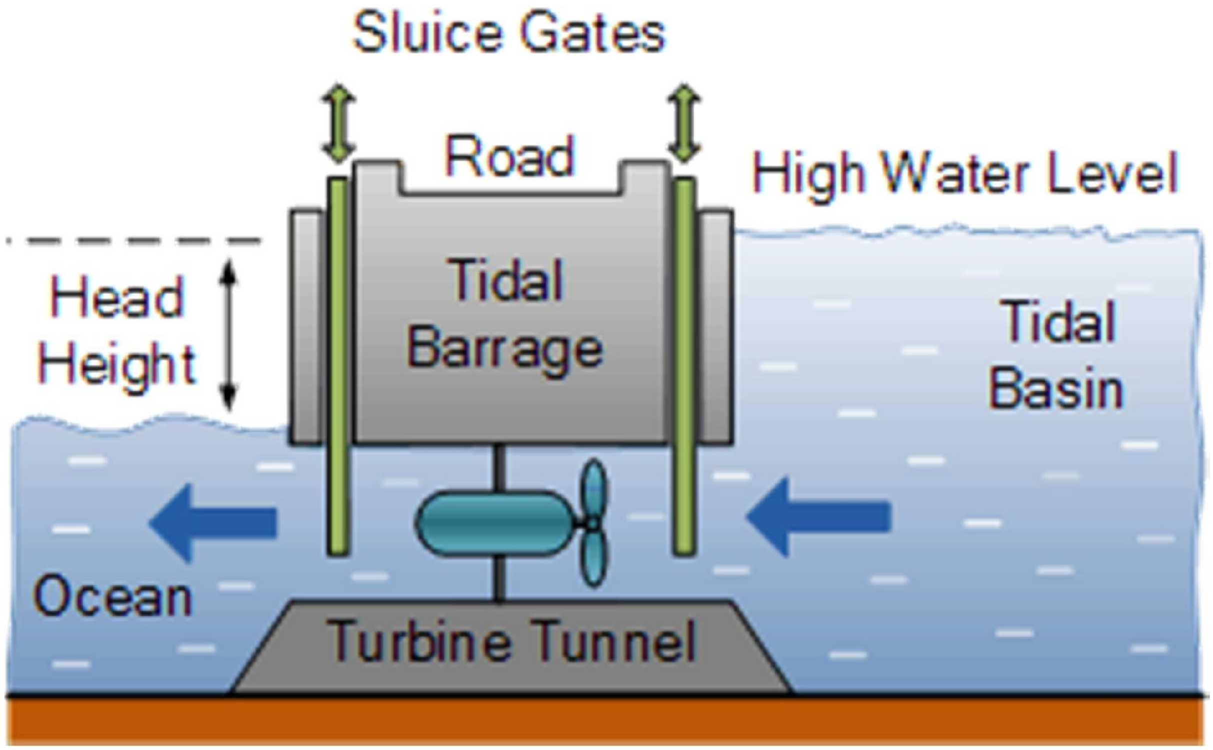

Figure 1.5: Tidal barrage power generation

1.2.2.4 Wind Energy

The movement of the atmosphere is driven by differences of temperature at the Earth's surface due to varying temperatures of the Earth's surface when lit by sunlight. Wind energy can be used to pump water or generate electricity, but requires extensive areal coverage to produce significant amounts of energy. Wind energy has been utilized since ancient times as windmills for milling and water lifting in countries like Denmark, Norway and USA. In Bangladesh wind energy has found very limited applications, simply because of non-availability of reliable wind. Some costal locations of Bangladesh have fair wind speed between 4.0 and 4.5 m/s at 25m above sea level. Between 4.5 and 6 m/s at 50m above ground level which is good for wind turbine.

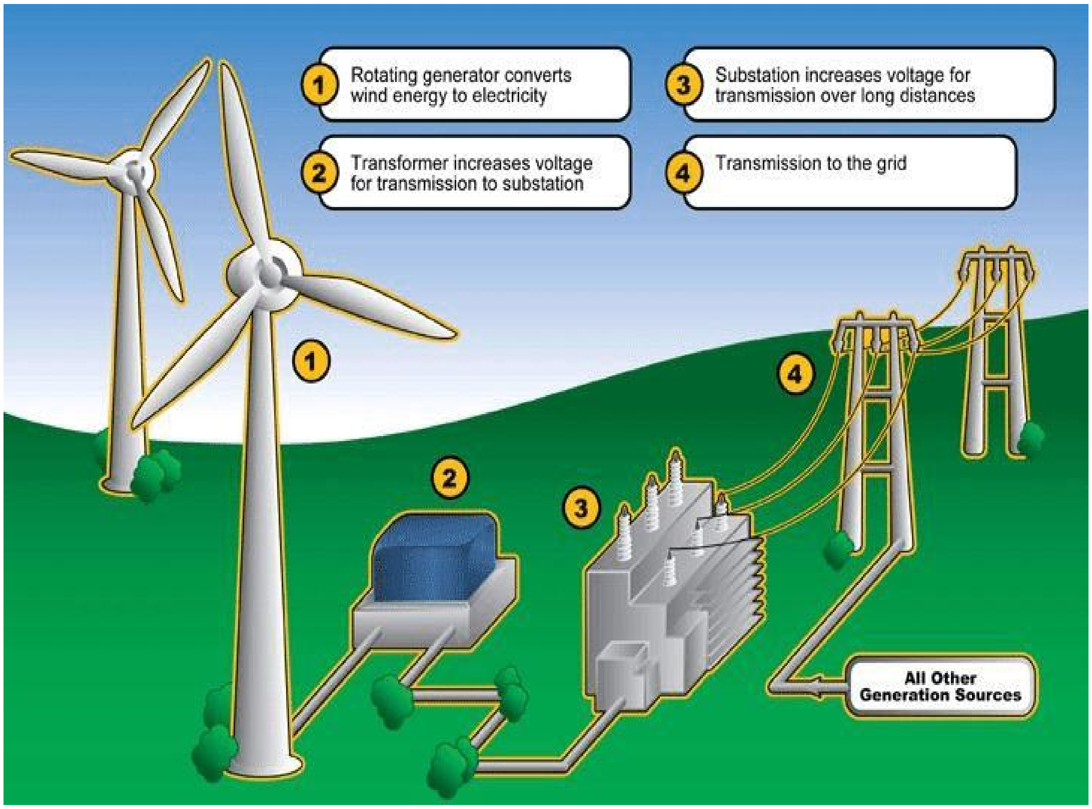

Figure 1.6: Wind turbine

1.2.2.5 Solar Energy

This form of energy relies on the nuclear fusion power from the core of the Sun. This energy can be collected and converted in a few different ways. The range is from solar water heating with solar collectors or attic cooling with solar attic fans for domestic use to the complex technologies of direct conversion of sunlight to electrical energy using mirrors and boilers or photovoltaic cells. Unfortunately these are currently insufficient to fully power our modern society. Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east, which is an ideal location for solar energy utilization [5]. However, the use of solar energy, as a commercial energy source has not yet received any popular acceptance in the country. The availability of reliable and well-organized data on solar isolation in the region is also limited.

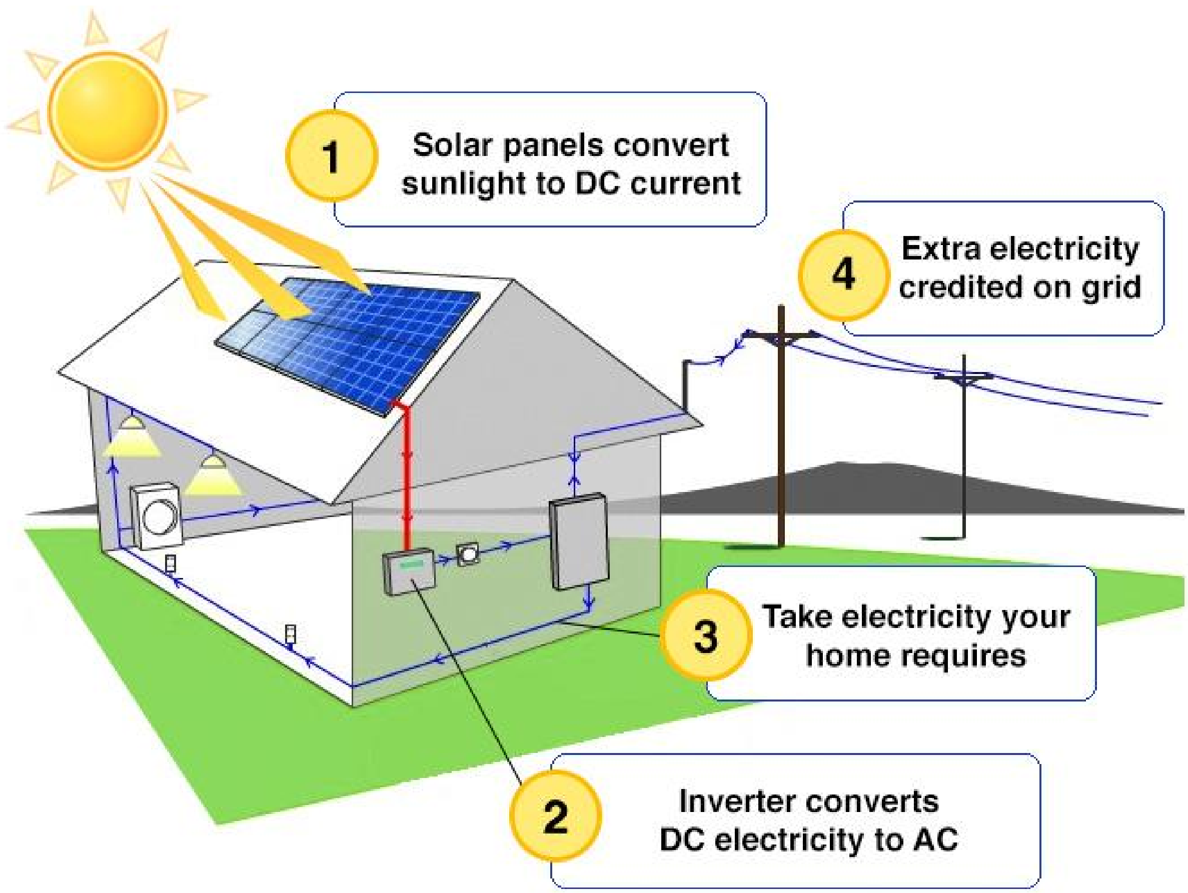

Figure 1.7: Solar electric system

1.3 Problem Statement

Solar energy offers the most abundant, reliable and pollution-free energy in the world. But what is hampering solar power has everything to do with cost of the technology. Solar panels use expensive semiconductor material to generate electricity directly from sunlight. Semiconductor factories need 'clean' manufacturing environments and are expensive to build & maintain. The efficiency of solar cells currently ranges from around 20% up to a top range of around 40%, although this continues to improve. The rest of the sunlight that strikes the panel is wasted as heat. Maintenance costs and time can add-up since every inch of a solar panel must be kept clean and clear of debris for them to operate at their most efficient. Large storage systems need to be developed to provide a constant and reliable source of electricity when the sun isn't shining at night or when a cloud goes overhead. When solar panels are not producing energy, it takes longer to recoup their installation and maintenance cost.

1.4 Objectives

The objectives of the study are given as follows:

1. To study solar PV system of Bangladesh.
2. To analyze data to get average irradiation and find the relationship between solar irradiance and power.
3. To increase the awareness of PV power system potential and value and thereby provide advice to decision makers from government, utilities and international organizations.
4. To make solar PV power system as a reliable power source to the users.
5. To neutralize the growing energy demand by using Renewable energy source as solar.
6. To determine the role of SHS on socio-economic development in Bangladesh.
7. To promote the technology by continuous research and development.

1.5 Scopes

Since majority of the population live in rural areas, there is much scope for solar energy being promoted in these areas. So, rural areas are the primary concern of this research. The concept of solar energy is yet new and most of the people in electrified areas will not be interested in using solar energy in alternate to their main source of power. At present time some discussions are going on to consider solar PV in urban areas also.

1.6 Outlines of the Thesis

This thesis is organized in six chapters as follows:

Chapter 1 shows the introduction of the thesis paper.

Chapter 2 reviews the literature.

Chapter 3 describes about solar PV system.

Chapter 4 presents the methodology.

Chapter 5 presents data analysis and its discussion.

Chapter 6 shows the conclusion.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

Growing energy demand and growing environmental concerns in today's climate, non-renewable and polluted fossil fuel consumption options should be looked at. One such alternative solar power solar power through solar power plants has become popular with various financial institutions due to reduced prices and soft loan system in Bangladesh. Besides, unknown, environmentally friendly and clean electricity can be obtained from sources such as. Bangladesh is one of the major reasons for solar power consumption. Using all these solar components in our country as well as in our country there is a considerable amount of research, thesis, implementation, design consideration and improvement.

2.2 Physical Perspective of Renewable Energy in Bangladesh

Today, our power installed capacity is 10312 MW. Where public sector contribution 5962 MW and private 4291 MW currently uses 62% of the total population in Bangladesh and every capital is 321 KW Which is much less than the other developing countries. Indigenous natural gas is dominated by our electricity production which is 90% of the 2010-11 fiscal year. For natural gas production, the rate of 80.37% in the 2013-2013 fiscal year decreased by 9.63%. It has been estimated that the amount of natural gas for electricity production will decrease between 2016 and 2030, respectively between 52% and 20%. Gas reserves have been forced to shift the option of primary fuel from natural gas to coal and liquid fuel. Through the diversity of primary energy sources, Bangladesh is trying to reduce its dependence on natural gas. Currently, the average cost of production of electricity is $6.3 per KWh and diesel-based generation costs $15.80 per KWh.

Yet renewable costs are less expensive than conventional power but the difference is decreasing day by day.

The government has a vision to provide electricity at a reasonable and affordable cost by 2021. But it is true that in the next 20 years grid power will not be available in some remote and isolated areas. In that area, we must rely on solar energy. To meet the demand of electricity by 5% by 2015 and 10% by 2020, renewable energy policy sets targets for the development of renewable energy sources [6]. Bangladesh has already achieved some remarkable success in implementing Renewable Energy Technology (RET). Bangladesh is the ideal area for solar energy from 20.30 to 26.38 degrees north and 88.04-92.44 degrees east latitude. [7]

The use of solar power potential is very important in analyzing the impact of the SHS in our country. Daily average solar radiation varies from 4-6.5 KWh per square meter [8]. We get the highest amount of radiation from March-April and lowest December-January. In the dry season, the average bright sunshine of Bangladesh is about 7.6 hours and in the rainy season about 4.7 hours. Maximum sunlight hours are between 2.35 to 9.04 hours, and in Barisal, readings ranging from 25.5 to 8.75 hours are in Khulna. It produces 8 times more power than Spain's 8-hour, which by the end of 2010 produces national demand of 2.7%. In addition, Germany produces 18-degree electricity, which is 2% of their national demand, half the solar Bangladesh.

According to recent research, the average annual absorption availability in Dhaka is 1.73 megawatts per square area and 1.8 m. Watch area per square is 1.86MWh. Again, the annual amount of radiation varies from 1840-1575 KWh/m^2 which is 50-100% higher than in Europe. The average annual solar radiation in the country is 1900 kWh per solar meter, 1010 × 1018 j. Equivalent to The total annual cost of current electricity is approximately 700 * 1018 J. It shows that even 0.07% of the event radiation can be used, the total requirement of our energy can be met [9]. At present energy utilization in Bangladesh is about 0.15 Watt/sq. meter land area, whereas the availability is above 208 Watt/square [10]. Using this huge solar energy, Bangladesh shows the scope of the probability of SHS. Depending on the availability of appropriate technology for local conditions, which part of it can be used for our use.

2.3 Present Status of Solar Energy in Bangladesh

Bangladesh is an important agricultural country with 163 million people in South Asia, where sustainable development, energy crisis and food security are very worrisome. About 75% of the population lives in rural areas [11, 12] and rural households have access to around 30% grid electricity [13]. Alternative Solutions Introduce the Solar Home System in grid area of the grid area and the solar grid hybrid system is introduced in the rural grid area. As a result of the policy, financial enterprises play a major role in the development of Bangladesh.

Solar Home System (SHS) and Micro Utility Users' response to this system is providing very satisfactory services to solar power based power consumers. In order to develop the Private Sector for setting up a Private Public Partnership Model, the government-owned agency IDCOL was elected as the implementing and monitoring agency of solar energy program. Note that IDCOL solar energy program is one of the fastest growing renewable energy programs in the world. Using electricity, positive changes have been made in the rural areas of rural areas of the country.

Speaker of the United States Senate Foreign Relations Committee John Kerry addressed the World Bank's head office on November 19, 2009, as a good example of the World Bank's literal living program, IDCOL mentioned the SAS project [14]. With the financial support of IDCOL World Bank, Global Environment Facilitation (GEF), KFW (German Development Bank), GIZ (German Technical Corporation), the solar home system (SHS) is promoted in remote rural areas through solar energy program), Asian Development Bank, USAID and Islamic Development Bank. IDCOL started this program in January 2003 and its initial goal was to fund 50,000 SHSs by the end of June 2008. The target was achieved in September 2005, 3 million years before the scheduled schedule and 2.0 million US dollars from the estimated project cost. Ideal aims to install 1 million systems by 2012 to ameliorate its mission.

It was also achieved from the scheduled schedule until June 2011. IDCOL celebrates the installation of 2 million solar home systems on May 12, 2013 under its renewable energy program. Now IDCOL targets 4 million SBS financing by 2015. As of November 2013, 2677,896 SHSs have already been established under the program. IDCOL is implementing this program with financial assistance from World Bank, ADB, IDB, GEF, GIZ, CIDA, JICA and

KFW. Using the IDCOL through 47 partner companies and solar PV growth market improves the quality of living, which gives 200,000 electricity usage per month and 50,000 installed systems to add 2.0 megawatt of national power generation, earning additional income Creates activities in rural areas, encourages local entrepreneurs, both skilled and uneducated people Create jobs for the rural areas, by promoting local industries and reducing carbon.

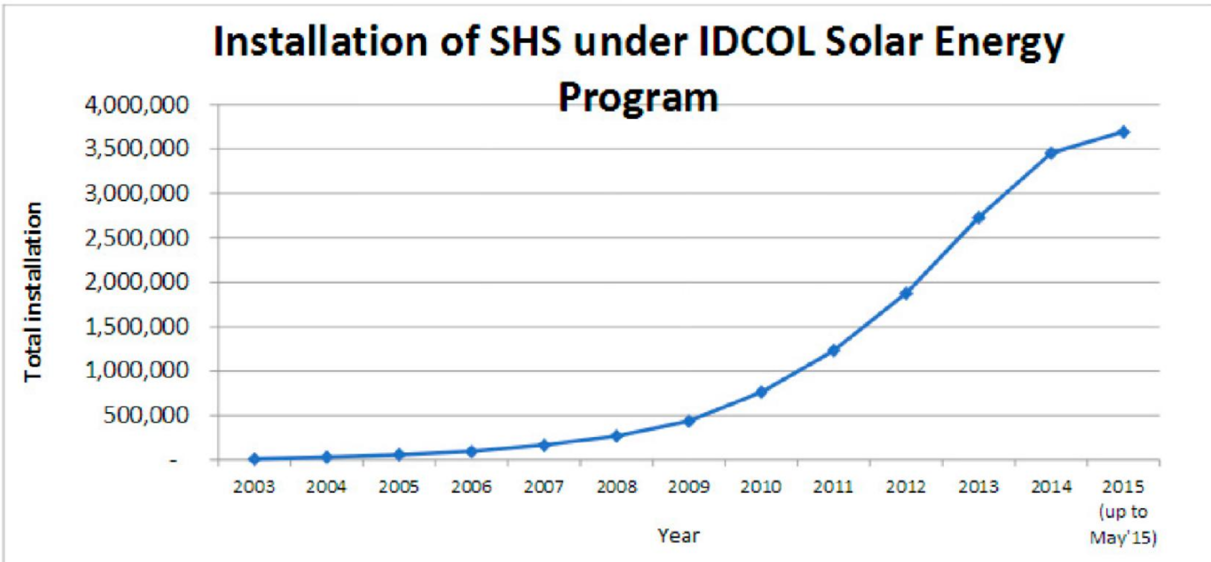

Figure 2.1: Increasing number of total SHS installations financed by IDCOL in recent years.

2.4 Implemented Renewable Energy in Bangladesh

Bangladesh is mainly dependent on solar energy and biomass. Here represents the renewable energy consumption that took place on 2014.

Table 2.1: The implemented Renewable Energy in Bangladesh

S/L No	Category	Achievement
1	Solar Home system(3.3 million)	150MW
2	Solar System at roof top of Govt./non govt. building	03MW
3	Solar System at Commercial building and shopping Mall	01MW
4	Solar PV for new connection at roof top of buildings	11MW
5	Solar Irrigation (193)	01MW
6	Wind based power generation	02MW
7	Bio-mass based power generation	01MW
8	Bio-gas based power generation	05MW
9	Hydro Power	230MW
	Total	404MW

2.5 Solar Energy source of Bangladesh

The first Solar PV was started in 1993 by the Rural Electrification Board (RRB), then the Local Government Engineering Department (LGED), and then Infrastructure Development Company Limited (IDCOL) started their solar power program. Currently, numerous government agencies (Geos) and non-governmental organizations (NGOs) are promoting SHS across the country under various renewable energy programs funded by IDA, GTZ, KFW, GEF, ADB and IDB. IDCOL is a leading provider of support for 47 associate organizations (PAs) for promotion of the SHS. So far in November 2013 a total of 2677,896 SHS programs have already been installed under the program [15].

2.6 Government planning

Government has already taken 500 MW PV base solar programme. Government has set a target to generate 10% by 2020 from renewable sources which is in term of capacity of 2000MW [16].

Government has undertaken various activities to promote renewable energy from different sources like solar, wind, biomass, bio-gas, hydro, tidal and wave to achieve the target. Among those government has identified solar power as the most potential source for sustainable energy development. The strategy of the mission was to embrace 500mw solar power by 2016 as part of the policy at affordable price. The mission will be implemented in public and private sector. Major portion of this mission which is equivalent to 340 MW will be implemented in public and private sector. [17]

2.7 Conclusion

There are two big problems for fuel crisis and potential alternative energy sources for Bangladesh. There is a high likelihood of renewable energy contributing to society by providing a security for energy. Therefore, Bangladesh Government has to take adequate measures to make this sector sustainable and prosperous for higher economic growth. Renewable energy is one of the most sustainable solutions to avoid energy crisis. Bangladesh has already started the investment for the development of the renewable energy sector. It is a difficult and time-consuming task to switch from Bangladesh and switch from non-renewable renewable sources. Changes will take place slowly. But there will always be obstacles to bring positive change in the country. Sufficient procedures can only be applicable if we first determine the limitations and accordingly prepare our plans. It is very obvious that there are many possibilities of RETs to contribute to a sustainable energy mix in Bangladesh. Both the use of fuel and fuel production in Bangladesh are inefficient. Although commercial energy has some reserves, but due to the old technology and economic constraints, it will not be available more than these reserves. Fossil fuel consumption can also have negative impact on the environment. To overcome this barrier, renewable energy should be used significantly more than the current level of use.

CHAPTER 3

SOLAR PV SYSTEM

3.1 Introduction

Solar power system is the cleanest and most reliable form of renewable energy available. It can be used in several forms to help power of home or in business. Solar powered photovoltaic (PV) panels convert the sun rays into electricity by exciting electrons in silicon cells using the photons of light from the sun. An individual PV cell is usually small which can produce about 1 or 2 watts of power. To boost the power output of PV cells are connected together in chains to form larger units known as modules or panels. Modules can be used individually or severally connected to form arrays. One or more arrays are then connected to the electrical grid as part of a complete PV system.

To understand the system we can look at the solar energy components that make up a complete solar power system.

3.2 Photovoltaic Solar Cells

PV cells are electricity producing devices made of different semiconductor materials. PV cells come in many sizes and shapes. Solar cells are often less than the thickness of four human hairs. In order to withstand the outdoors for many years, cells are sandwiched between protective materials in a combination of glass or plastics to make a PV module. When sun rays hit a PV cell it absorbs some of the photons and the photons energy is transferred to an electron in the semiconductor material. With the energy from the photon, the electron can escape its usual position in the semiconductor atom to become part of the current in an electrical circuit.

Figure 3.1: Photovoltaic Solar cells

There are different types of semiconductor materials used in solar cells.

3.2.1 Silicon Photovoltaic Cells

Silicon is the most common material used in PV solar cells. Crystalline silicon cells are made of silicon atoms connected to one another to form a crystal lattice. This lattice provides an organized structure which converts light into electricity. Solar cells made which are made of silicon provide a combination of high efficiency, low cost and long lifetime.

3.2.2 Thin Film Photovoltaic Cells

A Thin-film photovoltaic cell is manufactured by depositing one or more thin layers of PV material on a supporting material such as glass, plastic, or metal. A laser-scribing process is used to separate and link-up the electrical connections between individual cells in a module. Thin-film photovoltaic materials offer great promise for reducing the materials requirements and manufacturing costs of PV modules and systems.

3.2.3 Organic Photovoltaic Cells

Organic Photovoltaic (OPV) cells are composed of carbon-rich polymers and it can be tailored to enhance a specific function of cells, such as sensitivity to a certain type of light. This technology has the theoretical potential to provide electricity at a lower cost than silicon or thin-film technologies. OPV cells could be less expensive to manufacture in high volumes but its efficiency is lower than crystalline silicon and have shorter operating lifetime.

3.2.4 Concentration Photovoltaic Cells

Concentration photovoltaic (CPV), focuses a large area of sunlight onto the solar cell by using optical device such as mirror or lens. When it focuses sunlight onto a small area, less PV material is required. PV materials become more efficient at energy conversion as the light becomes more concentrated. For this reason the highest overall efficiencies are obtained with CPV cells and modules. But for the expensive materials, tracking and manufacturing techniques are required. So the cost advantage over today's high-volume silicon modules has become challenging.

3.3 How Photovoltaic Systems Operate

The PV cell is the basic building block of a PV system. Particular cells can vary in size from about 0.5 inches to about 4 inches across. PV modules vary in size and in the amount of electricity they can produce. However, one cell only produces 1 or 2 Watts, which is only enough electricity for small uses. PV module electricity generating capacity increases with the number of cells in the module or in the surface area of the module. PV modules can be connected in groups to form a PV array. A PV array can be composed of two or hundreds of PV modules. The number of PV modules connected in a PV array which can determine the total amount of electricity that the array can generate. Photovoltaic cells can generate direct current (DC) electricity. This DC electricity can be used to charge batteries. Nearly all electricity is supplied as alternating current (AC) in electricity transmission and distribution systems. To convert the DC electricity to AC electricity inverters are used on PV modules or arrays.

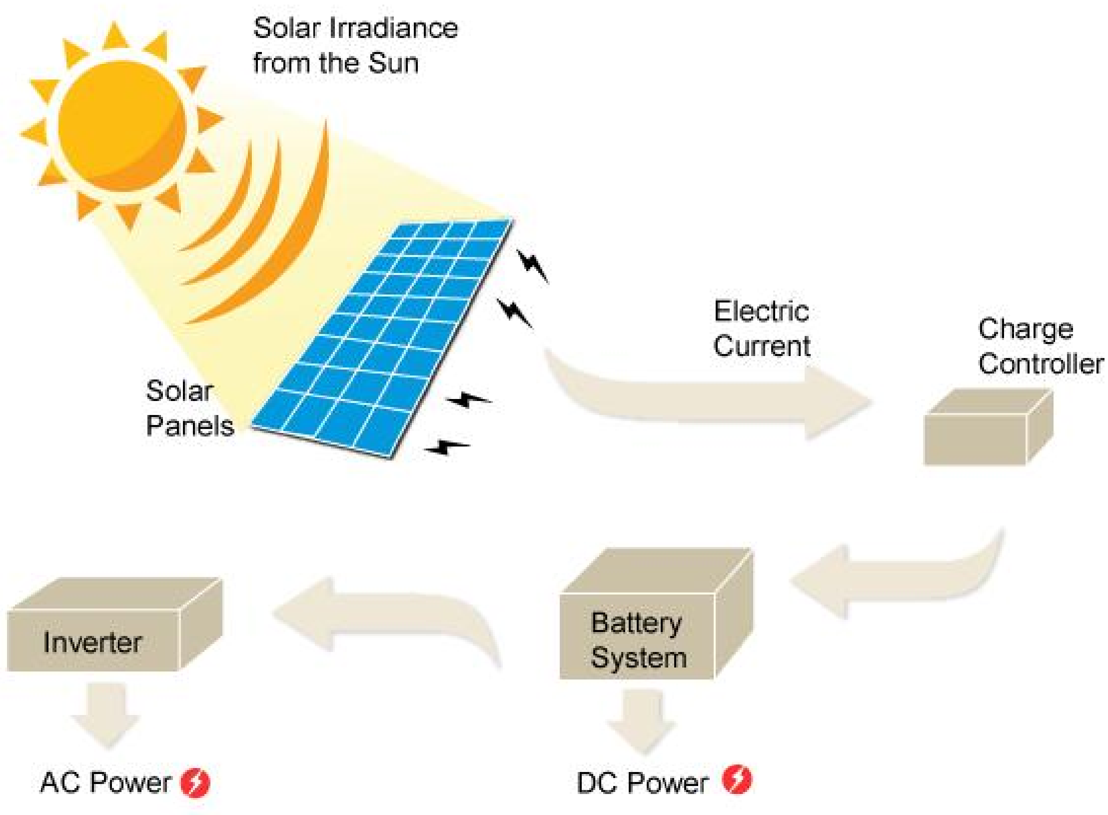

Figure 3.2: Photovoltaic Electric Power Generation System

PV cells can produce the highest amount of electricity when they directly face the sun. PV modules and arrays can use tracking systems that move the modules to constantly face the sun, but these systems are too much expensive. Most of the PV systems have modules in a fixed position.

3.4 Solar Charge Controller

Charge controller is an electronic device which is used in solar system. A solar charge controller is needed in virtually all solar power systems that utilize batteries. The job of the solar charge controller is to regulate the power going from the solar panels to the batteries. Overcharging batteries will at the least significantly reduce battery life and at worst damage the batteries to the point that they are unusable.

Figure 3.3: Solar Charge Controller

The most basic charge controller simply monitors the battery voltage and opens the circuit, stopping the charging, when the battery voltage rises to a certain level. When battery is included in a system, the necessity of charge controller comes forward. A charge controller controls the uncertain voltage build up. In a bright sunny day the solar cells produce more voltage that can lead to battery damage. A charge controller helps to maintain the balance in charging the battery. The main job of the charge controller is to feed electricity from the solar panel to the battery in the most efficient manner. A charge controller will prevent the battery from overcharging by automatically disconnecting the module from the battery bank then it is fully loaded. Most charge controllers also prevent batteries from reaching dangerously low charge levels by stopping the supply of power to the DC load. The inverter LVD needs to be programmed to disconnect the AC loads.

3.5 Solar Energy Storage

Choosing the right photovoltaic panels can be time-consuming and frustrating. For the periods when the sun is not shining batteries are the best method of storing energy from a PV system. Batteries are rechargeable and allow for the storage of solar energy. For this storage system we can use sun's energy even when the sunlight fails to reach upon the solar cells. If the solar photovoltaic system is grid-connected, the extra energy that customers send to the grid can be returned to them at a later point with the help of the solar battery.

Figure 3.4: Battery

The higher a solar battery storage system costs, the more energy they can store and a longer lifetime is guaranteed. An average priced battery is enough for family use.

3.6 Solar Power Inverters

Solar inverter is the third component of the photovoltaic system and its purpose is to convert the direct current (DC) electricity generated by the solar modules into alternating current (AC) electricity. This electricity is used to provide power in homes as well as in the local transmission.

Figure 3.5: Solar Power Inverter

The photovoltaic system usually has two types of inverters:

1. One inverter for all modules or
2. Each module has its own micro inverter.

Usually, one inverter for all modules is more cost-efficient and it is easier to cool down and service if necessary. On the other hand, the micro inverters can be more advantageous if some of the modules are covered by shade since they will operate independently from the modules that are still exposed to sunlight. Without those two types of inverters an advanced ‘smart inverter’ was developed which allows for two-ways communication between the solar inverter and the electrical utility. This way a balance between supply and demand can be achieved which results in cost reduction, ensure grid stability and decrease the likelihood of power blackout.

CHAPTER 4

METHODOLOGY

4.1 Introduction

In this section, we will discuss the process of data collection method and research tools. We also included the primary data that we collected from our study area.

4.2 Site Selection

A study area (Fig 4.1) is a place where we collect data for our necessary work. Our study area has established in Daffodil International University Administrative Building rooftop. It is situated Dhaka 1215, Bangladesh. Different types of solar panel have installed there such as 45W, 60W and 100W. We study the performance analysis the power of 45W off grid solar panel.

Figure 4.1: Study Area

4.3 Satellite View

Figure 4.2: Satellite View

4.4 System Design

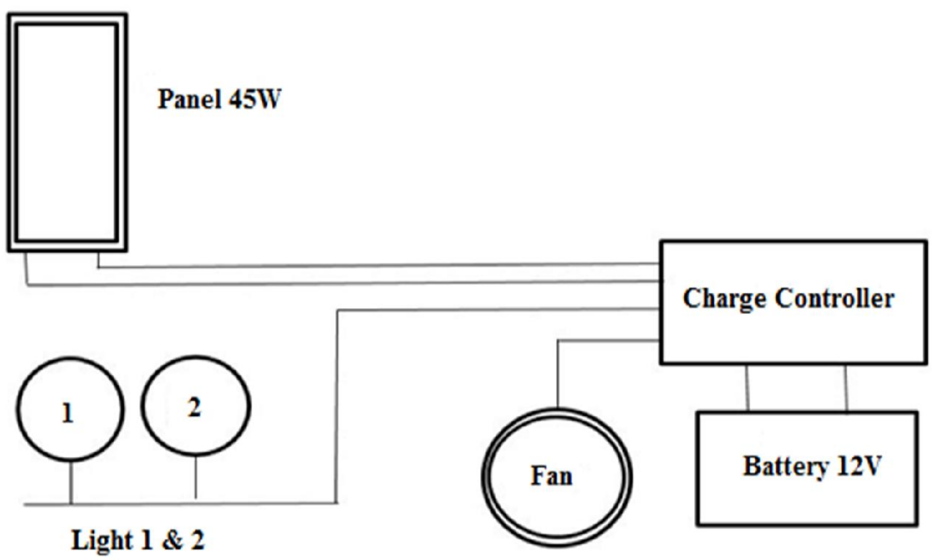

Figure 4.3 System Design (45W)

4.5 Research Machineries & Tools

Some tools have been used to collect data such as I-V 400w, temperature sensor, 45W solar panel, irradiation sensor (HT304N).

4.5.1 45W Solar Panel

The cells of the solar made in Germany. To measure power in Standard Test Condition (STC) cell temperature is 25°C. These solar cells made in Germany and the efficiency of the 45W panel is 14%.

4.5.1.1 Electrical Specifications

Maximum power:	45W
Open circuit voltage:	21.42V
Short circuit current:	2.72A
Voltage at maximum power:	17.10V
Current at maximum power:	2.63A
Module dimension:	580*550*35mm
Module weight:	4.16KGS±3%

Figure 4.4: 45W Solar Panel

4.5.2 I-V 400W

I-V 400w enables to measure of the I-V characteristic of the main characteristic parameters both of a single module and of a whole photovoltaic system up to a maximum of 1000V and 10A. The obtained data are then treated to anticipate the I-V characteristic under standard test conditions (STC) and comparing with rated data. Irradiation and temperature sensor plays a tremendous role for extrapolation of the I-V characteristic under the standard test conditions. Open circuit voltage and short circuit current can measure through the device. With a mobile device, HTANALYSIS™ helps to determine and understand problems may have the in-PV Installations.

Figure 4.5: I-V 400W Photovoltaic Panel Analyzer

4.5.2.1 Electrical Specifications

Table 4.1: Range, resolution and accuracy

Parameter	**Range (V)**	**Resolution (V)**	**Accuracy**
VDC Voltage @ OPC	5.0 ÷ 999.9	0.1	± (1.0%rdg+2dgt)
IDC Current @ OPC	0.10 ÷ 10.00	0.01	± (1.0%rdg+2dgt)
Max Power @ OPC (Vmpp >30V, Impp>2A)	50 ÷ 9999	1	± (1.0%rdg+6dgt)
VDC Voltage (@ STC and OPC), IVCK	5.0 ÷ 999.9	0.1	± (4.0%rdg+2dgt)
IDC Current (@ STC and OPC), IVCK	0.10 ÷ 10.00	0.01	± (4.0%rdg+2dgt)
Max Power @ STC (Vmpp>30V, Impp>2A)	50 ÷ 9999	1	± (5.0%rdg+1dgt)
Irradiance (with reference cell)	1.0 ÷ 100.0	0.1	± (1.0%rdg+5dgt)
Temperature of module (with auxiliary PT1000 probe)	-20.0 ÷ 100.0	0.1	± (1.0%rdg+1°C)

4.5.2.2 General Specifications

Display and Memory:

Features: 128x128pxl custom LCD with backlight

Memory capacity: 256kbytes

Saved data: 249 curves (I-V curve test), 999 IVCK

Power Supply:

SOLAR I-V internal power supply: 6x1.5V alkaline batteries type LR6, AA, AM3, and MN 1500

Autonomy of SOLAR I-V: > 249 curve (I-V curve test), 999 IVCK test

Approx. 120 hours (yield test)

SOLAR-02 power supply: 4x1.5V alkaline batteries type AAA LR03

SOLAR-02 max recording time (@ IP=5s): approx. 1.5h

Output Interference:

PC communication port: optical/USB

Interface with SOLAR-02: wireless RF communication (max distance 1m)

Mechanical Features:

Dimensions (L x W x H): 235 x 165 x 75mm

Weight (batteries included): 1.2kg

Environmental Conditions:

Reference temperature: 23°C ± 5°C

Working temperature: 0° ± 40°C

Working humidity: <80%HR

Storage temperature (batt. not included): -10 ± 60°C

Storage humidity: <80%HR

General Reference Standards:

Safety: IEC/EN61010-1

Safety of measurement accessories: IEC/EN61010-031

I-V curve measurement: IEC/EN60891 (I-V curve test)

IEC/EN60904-5 (Temperature measurement)

Insulation: double insulation

Pollution degree: 2

Overvoltage category: CAT II 1000V DC, CAT III 300V AC to ground

Max 1000V among inputs P1, P2, C1, c2

Max altitude of use: 2000m

4.5.2.3 Temperature Sensor

It senses temperature from the solar cell and sends data to the I-V 400w.

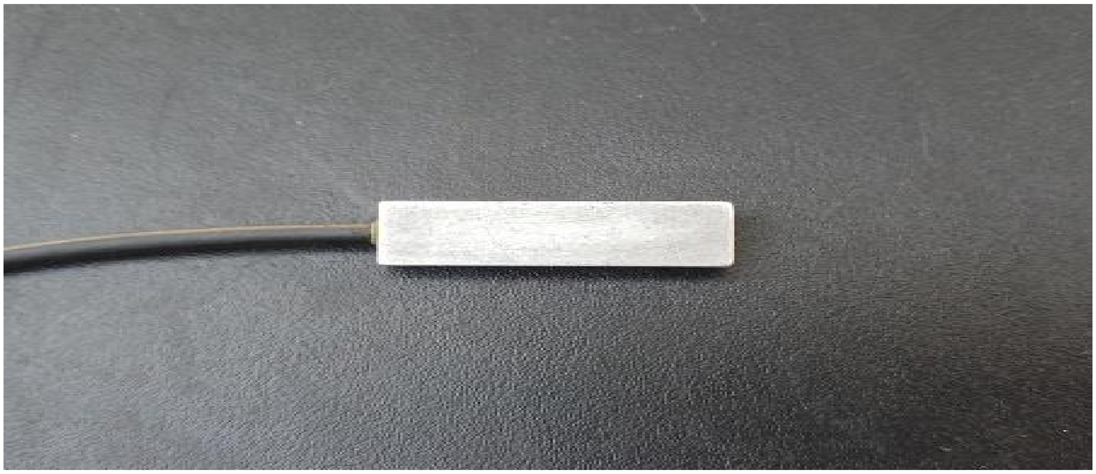

Figure 4.6: Temperature Sensor

4.5.2.4 Irradiation Sensor (HT304N)

This device (Fig.4.7) can able to measure as MONO PANELS or MULTI PANELS. It is a passive sensor and does not necessary any power supply.

Figure 4.7: Irradiation Sensor

Technical Specifications

Table 4.2: Range & accuracy

Parameter	Range [W/m^2]	Accuracy
Irradiation	50 ÷ 1400	±3.0% of readings

General Specifications

Available reference cells: MONO Crystalline and MULTI Crystalline Silicon

Guidelines

Safety: IEC/EN 61010-1

Technical literature: IEC/EN 61187

Calibration: IEC/EN 60904-2

Mechanical protection: IP65 in compliance with IEC/EN 60529

Pollution degree: 2

Mechanical characteristics

Dimensions (L x W x H): 120 x 85 x 40 mm

Weight: 260g

Environmental conditions

Working temperature: -20°C ÷ 50°C

Storage temperature: -20°C ÷ 60°C

4.6 Flow Chart

A flowchart is a type of diagram that represents a workflow or process. The flowchart displays the steps as boxes of numerous kinds and their order by connecting the boxes with arrows. We used flowcharts in analyzing, documenting or managing a process or program in various fields.

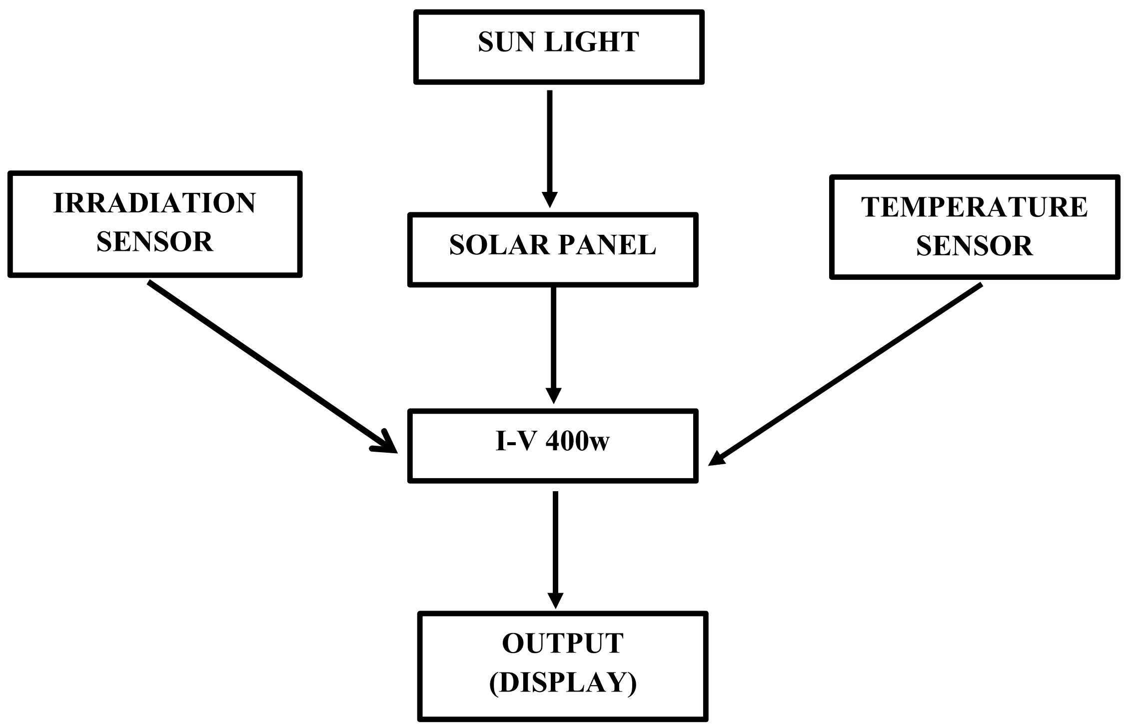

Figure 4.8: Flow Chart

4.7 I-V 400 W Calibration

Before starting the measurement, we must have to calibrate I-V 400 W. For I-V 400 W calibration parameters has given below Table 4.3

Table 4.3: I-V 400 W Calibration

Pmax	50 W
Voc	21.42 V
Vmpp	17.10 V
Isc	3.20 A
Impp	2.92 A
Toll-	1.0 W
Toll+	1.0W
Alpha	0.033 %/°C
Beta	-0.34 %/°C
Gamma	-0.42 %/°C
Noct	45 °C
Tech.	STD
Rs	1 Ω
Degr	0.0 %/yr

4.8 Data Measurement Technique

In July, we collected data from sunrise to sunset and used I-V 400w photovoltaic panel analyzer to measure data. Firstly, setting up irradiation and temperature sensor connect with I-V 400 W photovoltaic panel analyzer. Secondly, 45 W solar panel output cables connected with I-V 400W. The measured data was in Standard Test Condition (STD) form then which we converted these data into Operational Condition (OPC) form.

Table 4.4: Data Sample of a single day (July 14, 2018)

SL	Time (Sunrise to sunset)	Irradiance (W/m^2)	Voltage (V)	Current (I)	Vmpp (V)	Impp (I)	Fill Factor	Pmax (W)
1	5.19	0	0	0	0	0	0	0
2	6:19	229	20.1	0.51	16.4	0.46	0.74	7.54
3	7:19	117	19.4	0.32	16.9	0.21	0.57	3.55
4	8:19	439	20.5	1.12	18.5	0.77	0.62	14.15
5	9:19	296	19.7	0.74	16.1	0.66	0.73	10.63
6	10:19	307	20	0.79	16.8	0.68	0.72	11.42
7	11:19	898	20.4	2.17	17.4	2.07	0.81	36.02
8	12:19	730	20.1	1.62	17.2	1.56	0.82	26.83
9	13:19	251	19.2	0.59	17.8	0.35	0.54	6.14
10	14:19	737	20	1.74	17.6	1.40	0.71	24.55
11	15:19	653	29	1.46	18.2	1.04	0.44	18.84
12	16:19	491	20	1.03	17.5	0.97	0.82	16.98
13	17:19	114	19.2	0.29	16.9	0.23	0.68	3.80
14	18:48	0	0	0	0	0	0	0

Table 4.4 represents parameter-wise data of a single day (July 14, 2018) starting from sunrise to sunset.

CHAPTER 5

DATA ANALYSIS AND DISCUSSIONS

5.1 Introduction

From previous discussions, it is seen that energy plays an important role in the development of a country. Bangladesh is a solar power-rich country in the tropical region. The main objective of this study is to evaluate the effects of solar energy for socio-economic development in rural areas of Bangladesh. In this chapter we will explore on data measurement, solar irradiance, power generation from 45W solar panel, sunny days and rainy days power graph and compare with previous data.

5.2 Irradiance observation of July and August (45W solar panel)

Figure 5.1 shows the data of solar irradiation of July 2018. On 14th July 2018, the highest value of solar irradiance was measured that was 483.5 W/m^2 and on 24th July 2018, the lowest value of irradiance was found that was 11.58 W/m^2 and the main reason behind this situation was sunny day and rainy day. During the sunny day we have gotten the highest value and for rainy day we have gotten the lowest value. Moreover, July 2018 monthly average irradiation is 237.90.W/m^2 per day or 5.70 KWh/m^2/day.

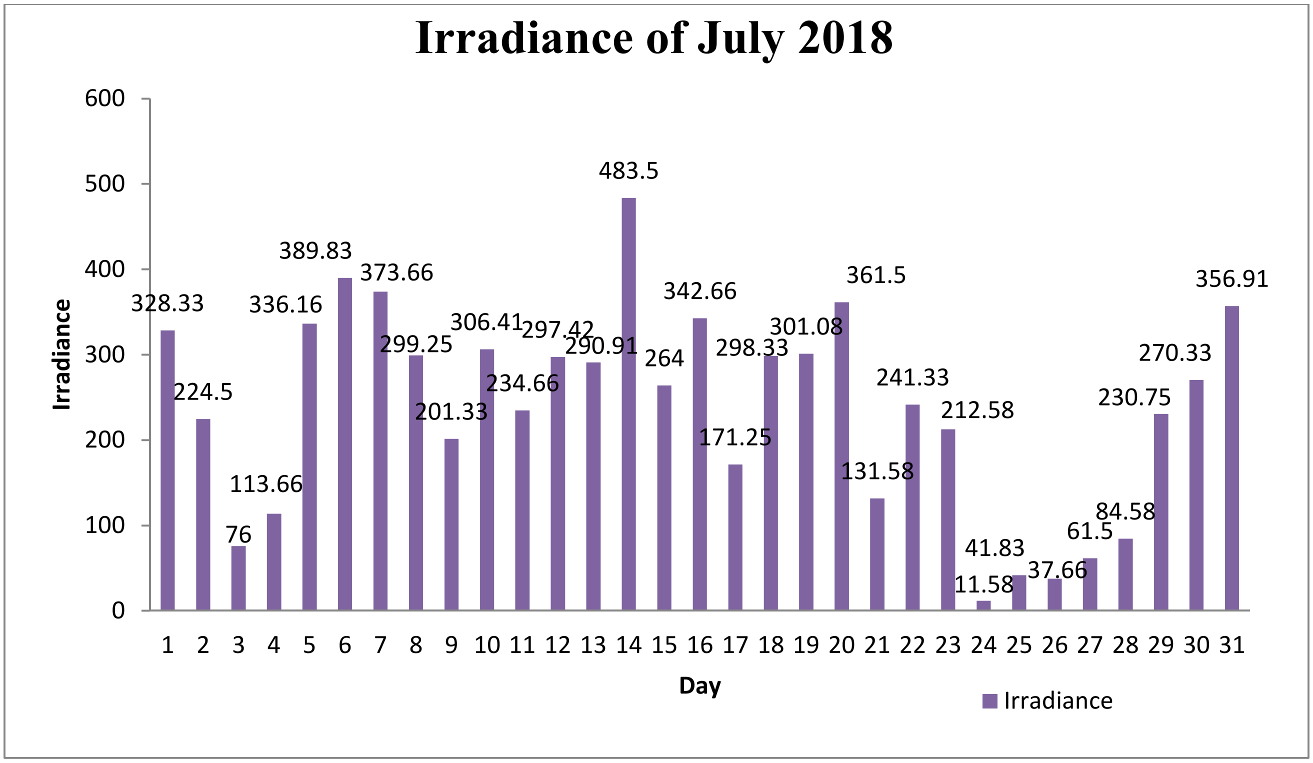

Figure 5.1: Irradiance of July 2018

Figure 5.2 shows the data of solar irradiation of August 2018. On 10th August 2018, the highest value of solar irradiance was measured that was 518.75 W/m^2 and on 4th October 2018, the lowest value of irradiance was found that was 85.25 W/m^2 and the main reason behind this situation was sunny day and rainy day. During the sunny day we have gotten the highest value and for rainy day we have gotten the lowest value. Moreover, August 2018 monthly average irradiation is 288 W/m^2 per day or 6.91 KWh/m^2/day.

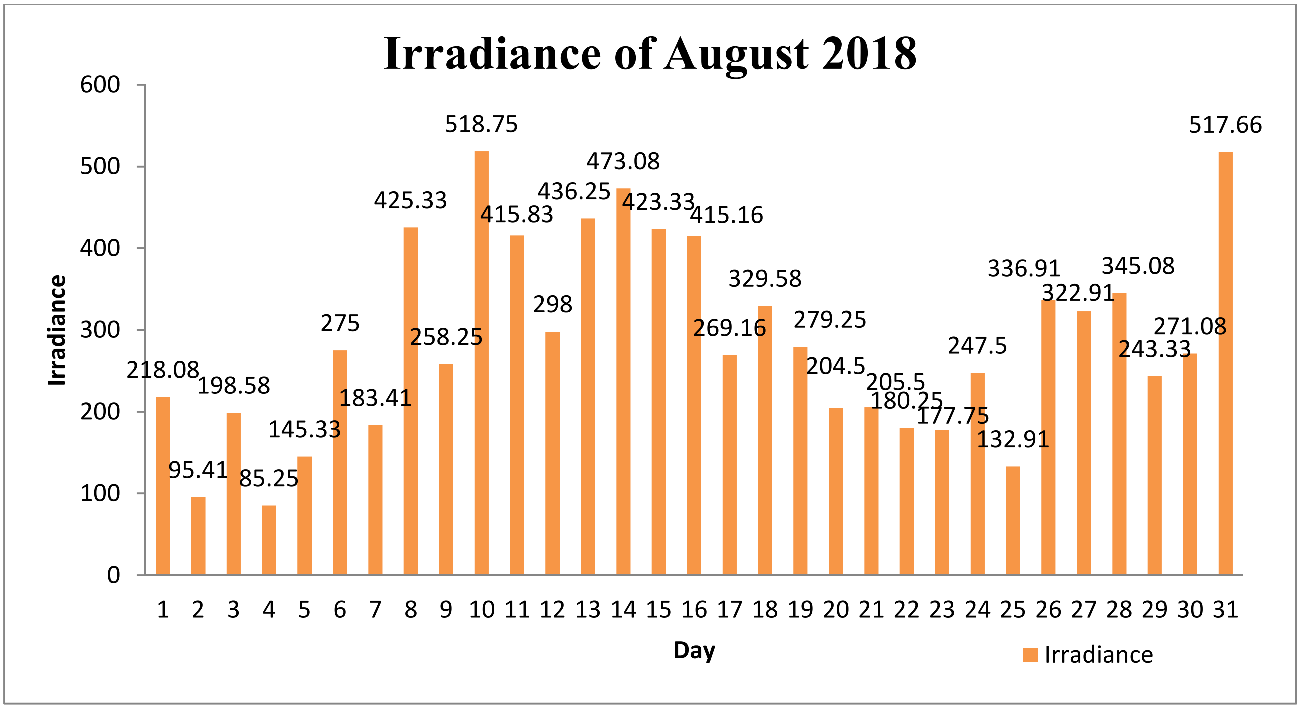

Figure 5.2: Irradiance of August 2018

5.3 Power observation of July and August (45W solar panel)

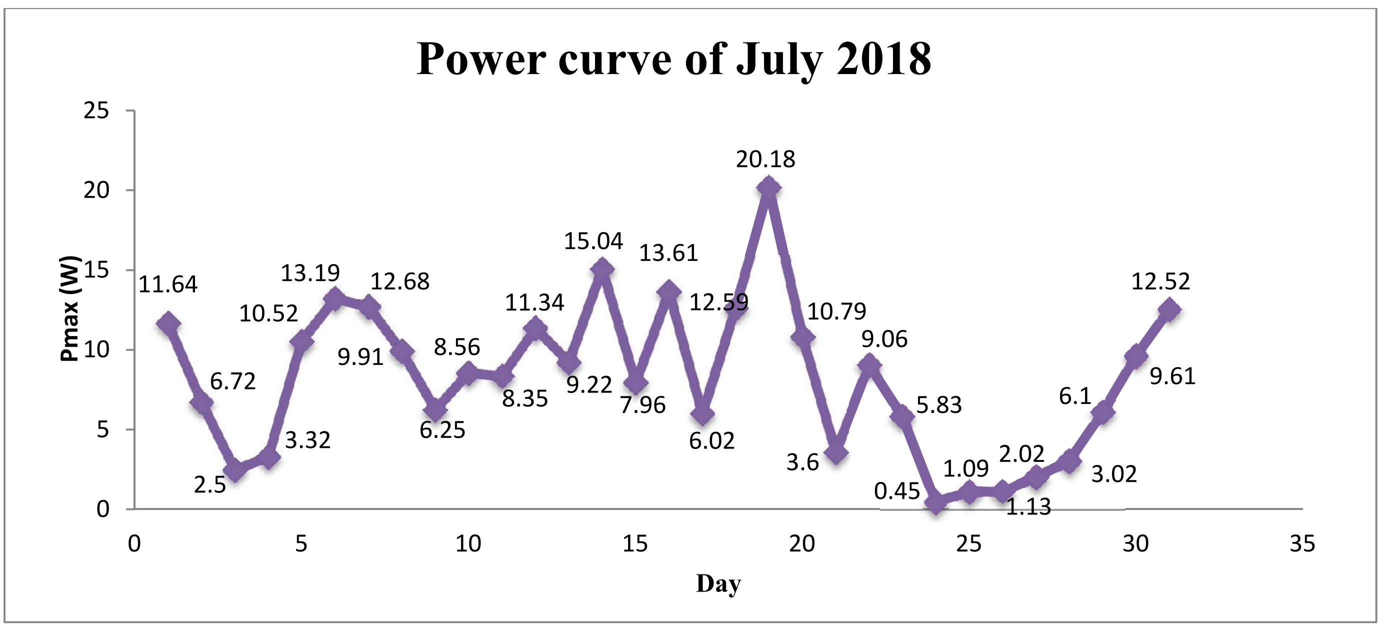

Figure 5.3 Power generation of July 2018

Figure 5.3 represents the maximum power generation curve of 45W solar panel in July 2018. On 19th July 2018, we have found the highest value of maximum power (20.18W) and the lowest value of minimum power (0.45W) in 24th July 2018. Monthly average power is 8.22W

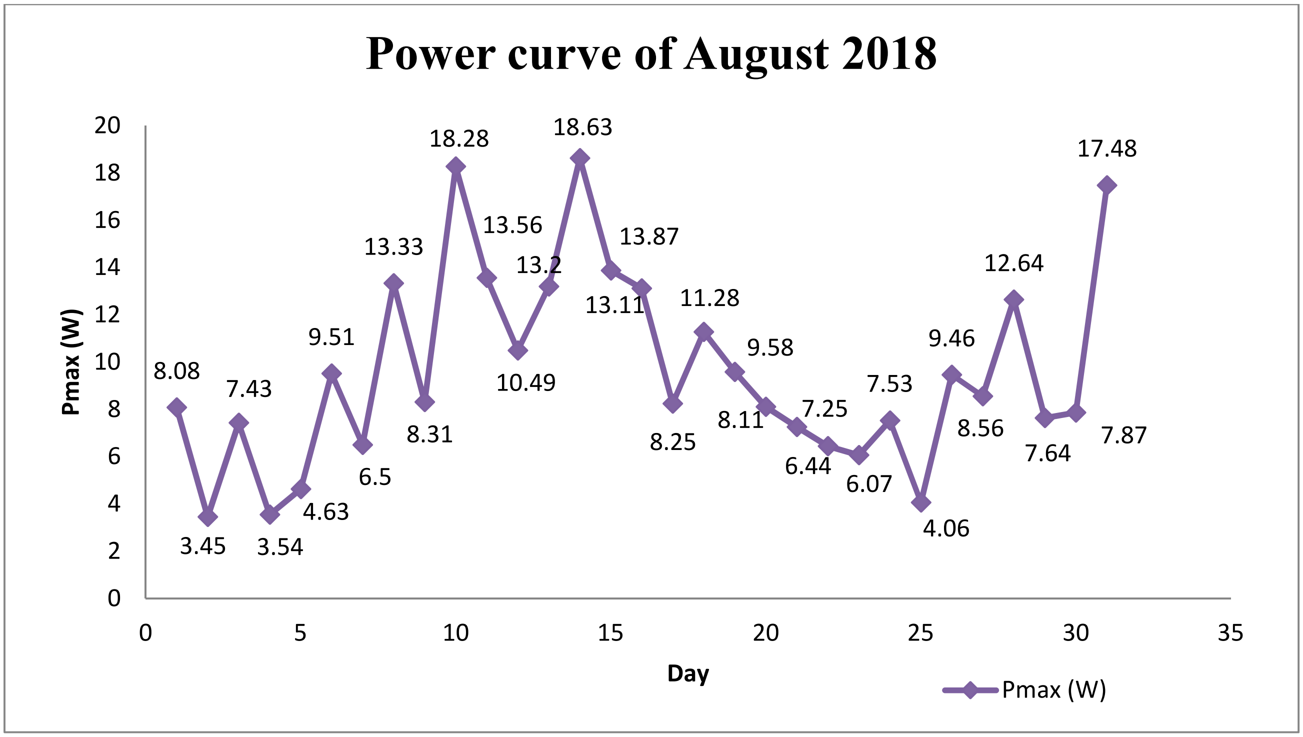

Figure 5.4: Power generation of August 2018

Figure 5.4 represents the maximum power generation curve of 45W solar panel in July 2018. On 14th August 2018, we have found the highest value of maximum power (18.63W) and the lowest value of minimum power (3.45W) in 2ndAugust 2018. Monthly average power is 9.61W

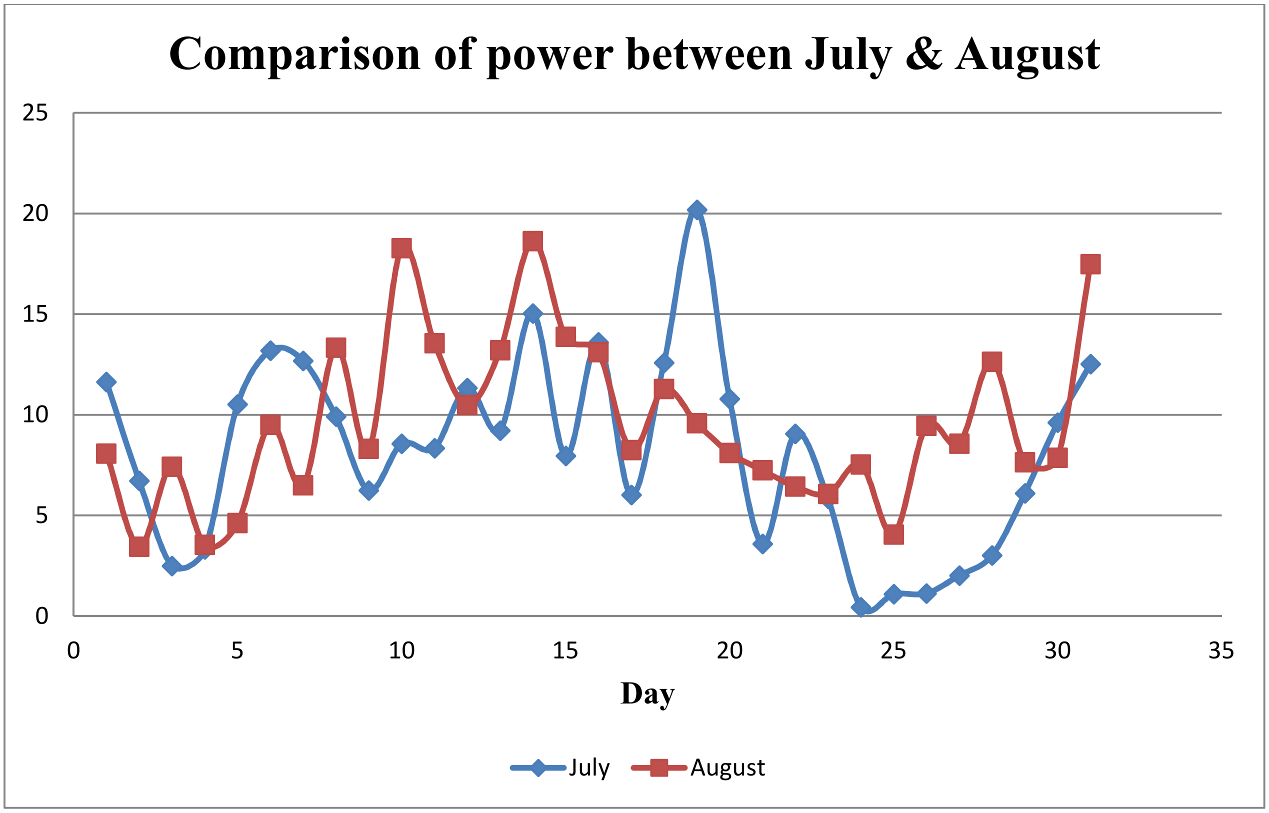

Figure 5.5: comparison of power generation between July and August

From the data observation of July and August we can say that Pmax increases and decreases with the increase and decrease rate of irradiance. We also find that the Irradiance and Pmax remains very low at the time of sunrise and sunset.

5.4 Sunny Days and Rainy Days Power Graph of July and August

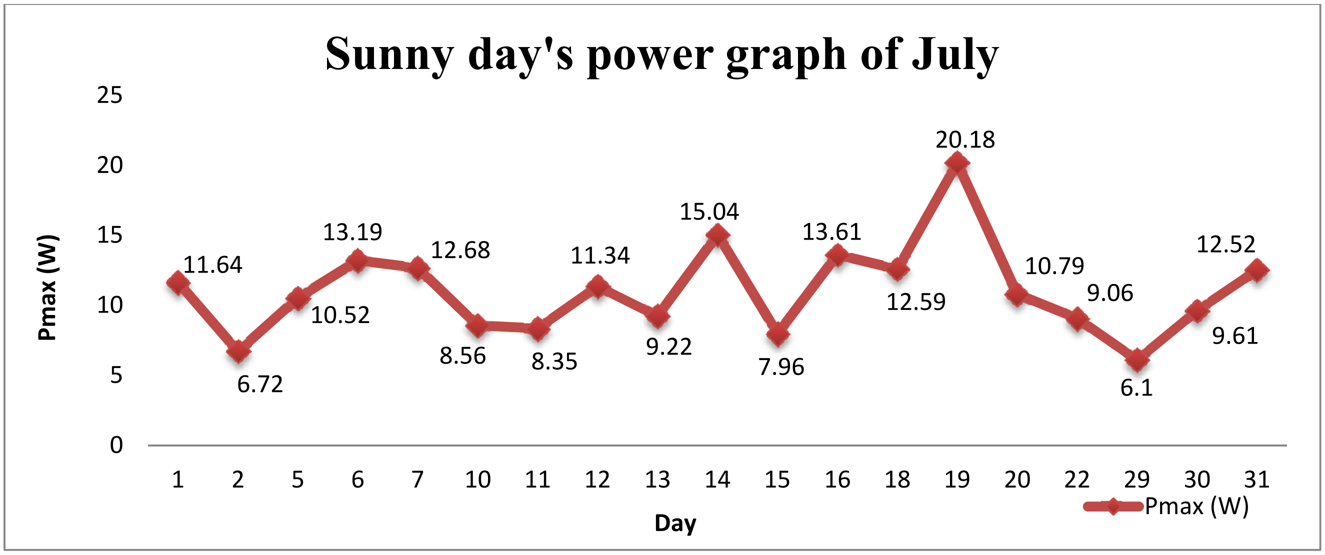

Figure 5.6: Sunny day's power of July

Figure 5.6 shows the data of power regarding the sunny days of July 2018. During sunny day's we get the highest power 20.18W and lowest power 6.10W. In sunny day's we measured our data after every 1hour. The average power of sunny day is 11.03W.

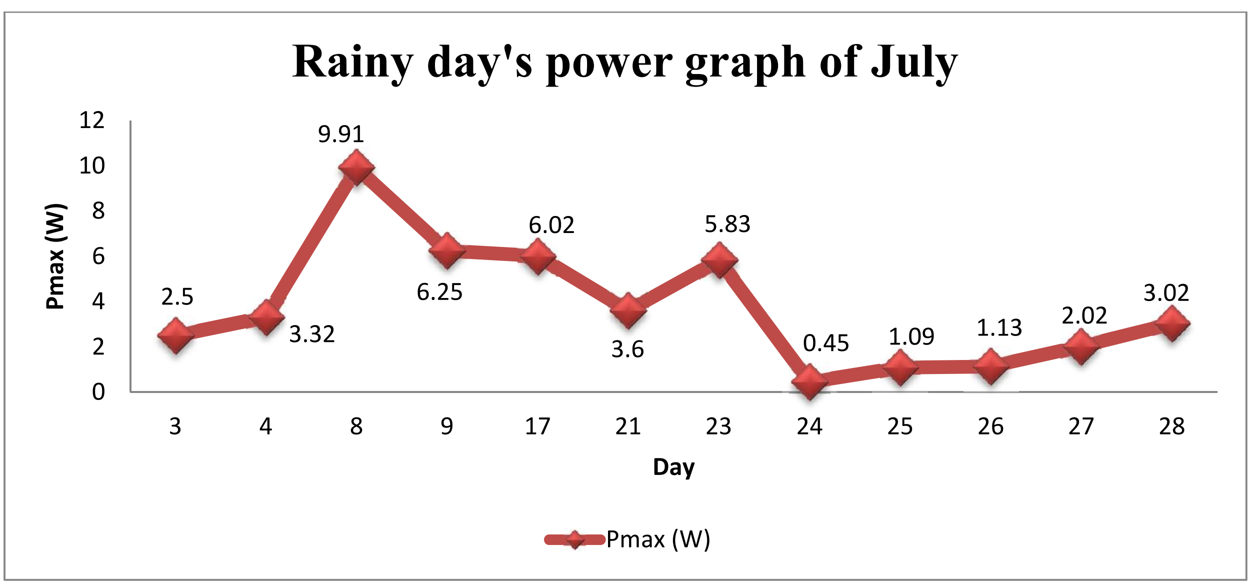

Figure 5.7: Rainy day's power of July

Figure 5.7 shows the data of power regarding of rainy days in July 2018. During rainy day's we got the highest power 9.91W and lowest 0.45W. In rainy day's we measured our data after every 1hour. The average power of rainy day's was 3.76W

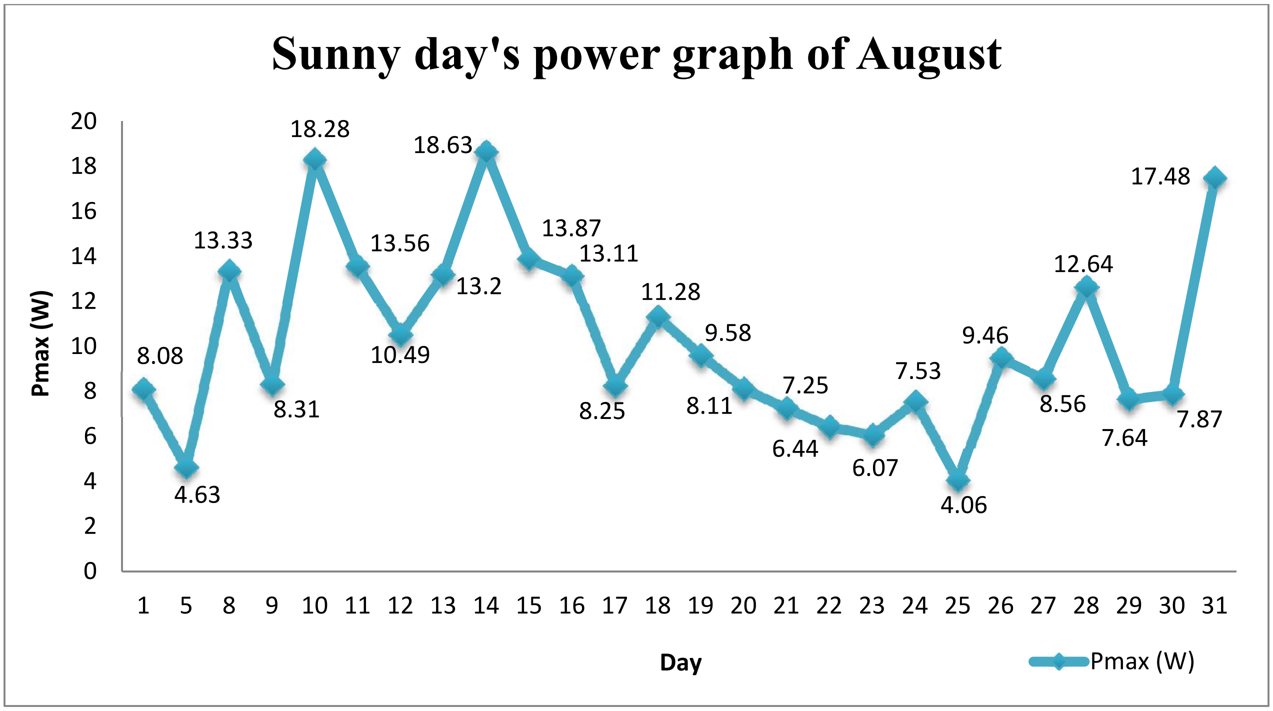

Figure 5.8: Sunny day's power of August

Figure 5.8 shows the data of power regarding the sunny days of August 2018. During sunny day's we get the highest power 18.63W and lowest power 4.06W. In sunny day's we measured our data after every 1hour. The average power of sunny day is 10.30W.

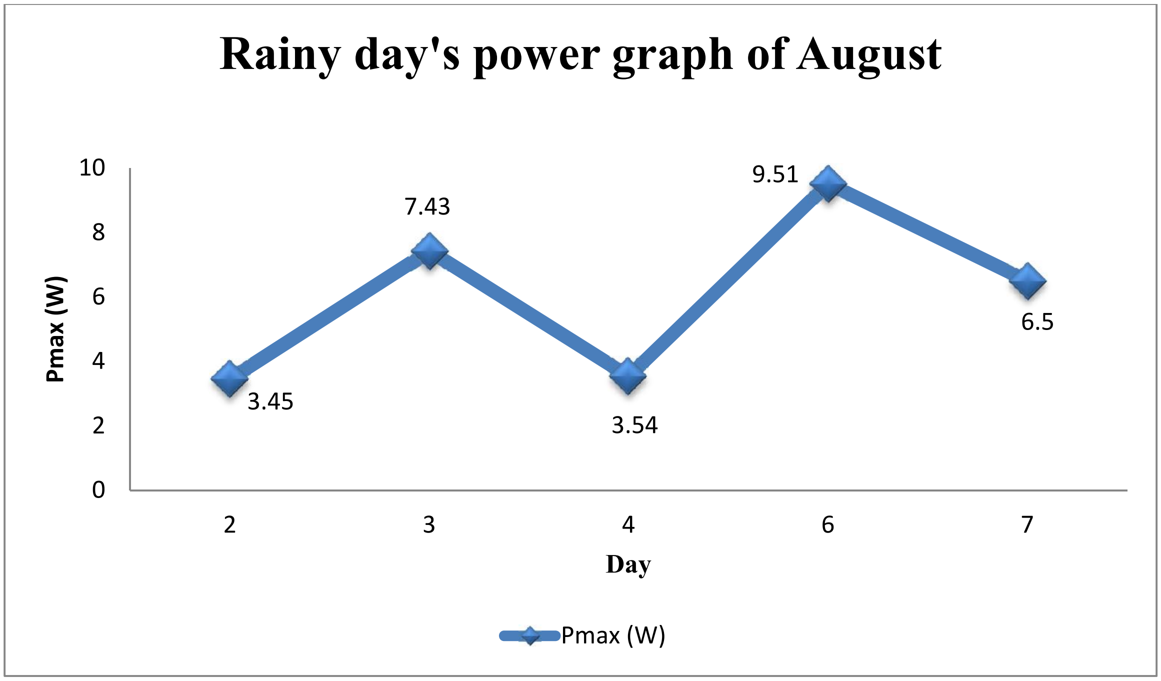

Figure 5.9: Rainy day's power of August

Figure 5.9 shows the data of power regarding of rainy days in August 2018. During rainy day’s we got the highest power 9.51W and lowest 3.45W. In rainy day’s we measured our data after every 1hour. The average power of rainy day’s was 6.09W.

5.5 Calculation of Panel Efficiency

Table 5.1: 45W solar home system efficiency of July 2018

July	Irradiance (W/m^2)	Area of panel (m^2)	Output power, Pmax (W)	Efficiency η%	Average Efficiency
1	328.33	0.32	11.64	10.05%	
2	224.5	0.32	6.72	8.97%	
3	76	0.32	2.5	4.34%	
4	113.66	0.32	3.32	4.28%	
5	336.16	0.32	10.52	7.58%	
6	389.83	0.32	13.19	8.40%	
7	373.66	0.32	12.68	10.25%	
8	299.25	0.32	9.91	7.00%	7.42%
9	201.33	0.32	6.25	6.15%	
10	306.41	0.32	8.56	9.51%	
11	234.66	0.32	8.35	9.68%	
12	297.42	0.32	11.34	10.85%	
13	290.91	0.32	9.22	8.86%	
14	483.5	0.32	15.04	10.42%	
15	264	0.32	7.96	8.00%	
16	342.66	0.32	13.61	9.14%	
17	171.25	0.32	6.02	5.06%	
18	298.33	0.32	12.59	10.99%	
19	301.08	0.32	20.18	13.94%	
20	361.5	0.32	10.79	7.79%	

21	131.58	0.32	3.6	4.98%	
22	241.33	0.32	9.06	7.76%	
23	212.58	0.32	5.83	4.79%	
24	11.58	0.32	0.45	1.01%	
25	41.83	0.32	1.09	1.98%	
26	37.66	0.32	1.13	2.38%	
27	61.5	0.32	2.02	3.05%	
28	84.58	0.32	3.02	5.53%	
29	230.75	0.32	6.1	7.44%	
30	270.33	0.32	9.61	10.14%	
31	356.51	0.32	12.52	9.56%	

5.6 Comparison of Solar Radiation Data among Different Years

Table 5.2: Data of Monthly Average Solar Irradiance in 2008, 2009 & 2010.

Month	Solar Irradiance(W/m^2) (2008)	Solar Irradiance(W/m^2) (2009)	Solar Irradiance(W/m^2) (2010)
January	164.9	165.6	151.5
February	209.8	219.1	186.7
March	225.7	228.3	238.2
April	283.3	273.1	236.7
May	261.1	235.1	225.8
June	212.4	210.3	176
July	176.2	197	201.6
August	174.1	177.5	166.3
September	189.6	166.8	165.5
October	179.7	189.1	175.2
November	208.1	164	168
December	123.7	142.5	159.2
Annual average Irradiance(W/m^2)	209.05	197.36	187.55
Annual Average (kWh/m^2/day)	5.01	4.73	4.50

In the year 2008, annual average solar irradiation was 5.01KWh/m^2/day and the value of irradiation in 2009 was decreased and that was 4.73KWh/m^2/day. There was also a declining trend in solar irradiation value in between 2009 and 2010 because in 2010, only 4.50 kWh/m^2/day irradiation was measured as shown in Table 5.2.

Solar radiation data were collected from Renewable Energy Research Center (Dhaka University), National Renewable Energy Laboratory and Development and Research is given in Table 5.2 Most of these solar radiation data were collected from DU for Dhaka with different cities in Bangladesh.

Table 5.3: Collected Solar Irradiance Data of Bangladesh from 1985-2006 were presented below

Month	**NREL (1985-91)**	**RERC (1987-89**	**RERC (1992)**	**DLR (2000-2003)**	**RERC (2003-2005)**	**RERC (2006)**
January	4.18	4.29	3.34	4.58	3.16	3.4
February	4.68	4.86	4.05	4.81	4.46	3.79
March	5.55	5.53	5.24	5.31	4.88	5.04
April	5.65	5.23	6.02	5.84	5.28	5.06
May	5.58	5.67	5.76	5.21	5.46	5.09
June	4.48	5.13	5.39	3.85	4.22	4.8
July	3.9	3.87	4.2	3.76	4.48	3.84
August	4.12	3.92	4.87	4.11	4.12	4.73
September	3.96	4.5	5.38	3.76	3.78	5.15
October	4.7	4.61	4.93	4.19	3.57	3.18
November	4.25	4.22	3.72	4.47	3.92	3.35
December	4.06	3.89	3.39	4.34	3.19	2.84
Annual Average (kWh/m^2-day)	4.59	4.64	4.69	4.52	4.21	4.45

In the year 1985-1991, annual average solar radiation was 4.59 KWh/m^2/day and it was increased into 4.64 KWh/m^2/day in 1987-89. But in 2000-03, annual average radiation was 4.52 KWh/m^2/day which was decreased into 4.2 kWh/m^2/day in 2003-05. In 2006, radiation was increasing, and the value was 4.45 KWh/m^2/day.

Table 5.4: Collected irradiance from 1985-2005, 2008-2010, 2018 and compare among them were presented below.

Year	Month	Irradiance kWh/m^2/day
1985-1991	July	3.9
	August	4.12
1987-89	July	3.87
	August	3.92
1992	July	4.2
	August	4.87
2000-2003	July	3.76
	August	4.11
2003-2005	July	4.48
	August	4.12
2008	July	4.20
	August	4.18
2009	July	4.72
	August	4.26
2010	July	4.80
	August	3.99
2018	July	5.70
	August	6.91

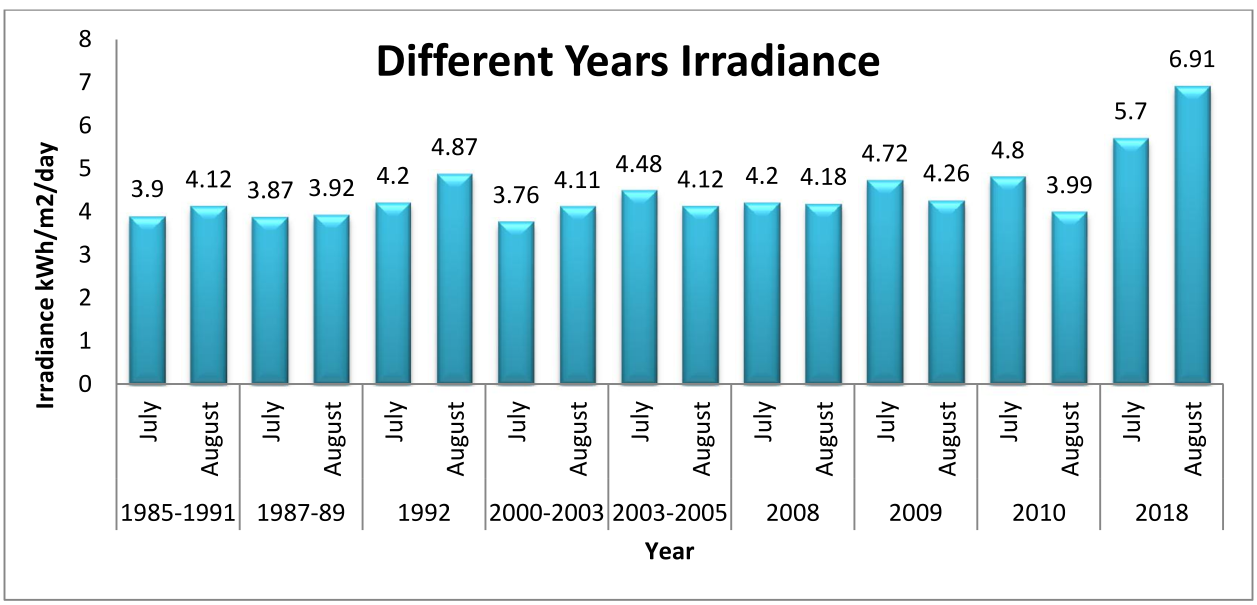

Figure 5.10: Irradiance of different years

After analyzing Figure 5.10 we can say that in the year 1985-1991, July & August average solar irradiation was 3.9 & 4.12 KWh/m^2/day and it was increased into 4.2 & 4.87 KWh/m^2/day in 1992. But in 2000-03, July & August average irradiation was 3.76 & 4.11 KWh/m^2/day which was increased into 4.48 & 4.12 kWh/m^2/ day in 2003-05. In 2009, irradiation was increasing, and the value was 4.72 & 4.26 kWh/m^2/day. Moreover, in 2018, irradiation was increasing, and the value is 5.7 & 6.91 kWh/m^2/day.

Furthermore, in 2018, Irradiance is the highest than previous years. For this reason we can certainly say that global warming is increasing day by day.

5.7 Discussion

By collecting direct sunlight, we can only get more power with PV panel and more efficiency. But it is tough to increase the energy of the fallen sun directly in any particular area. We can increase the sunlight collection area - by mirror or lens - and "power redirect" to this PV panel. The average cell efficiency of a solar panel is between 11-22%. It varies between manufacturers. The higher the efficiency of a solar panel, the more solar power it will produce per square meter. High panel efficiency laboratories have been recorded; Australian scientist is spearheading this issue, which has resulted in a cell that has sunlight increased by 34.5% [18]. At present perspective of Bangladesh, the efficiency of photovoltaic cell we get is not very high. If we can use new technologies for PV system we will be able to get better power and efficiency.

CHAPTER 6

CONCLUSIONS

6.1 Conclusions

The summary of this paper shows that there is a significant opportunity for Bangladesh to meet future power Demand and thus economic growth through renewable resources. For utilizing the solar power more effectively, it is very important to measure the irradiation of that country time to time because the sun radiation is changed over time. In this thesis, our main aim was to find out the irradiation of sun in Dhaka city in the month of July and August so that the power production by the solar panel can be estimated and by using this data we can easily understand the electricity production by SHS and create a standard form of power production of SHS in 2018. Here we find that the average irradiation of July 5.70 kWh/m^2/day and August was 6.91 kWh/m^2/day. And corresponding power produced by 45W solar panel was 8.22 W and 9.61 W respectively. The above mentioned solar energy source can help Bangladesh to reduce load-shedding problems to produce more energy. Time came forward and came to work with this Renewable power fields depend on conventional methods for generating electricity. As an alternative and very convenience, solar panel is very popular with both the consumers and suppliers and the use of solar panel is increasing day-by-day rapidly all over the country [19]. Solar PV Based Power Plant can be a big solution to fill our needs in the power sector. So the government and private sector should focus on this point.

6.2 Future Scopes of the Work

In this research, we try to clarify that how much power can be produced in the month of July & August 2018 from a solar system. We have worked only for two months but in future we can measure power and irradiation throughout the year along with the analysis of panel efficiency.

REFERENCES

[1] R. Rash-Ha Wahi and Nafiz Ul Ahsan, "Feasibility Study of Solar Home System in Rural Areas of Bangladesh: Prospect, Progress and Challenges", Proceedings of the Global Engineering, Science and Technology Conference, Dhaka, Bangladesh, December 2012

[2] K. Anam and H. Al-Bustam, "Power Crisis & Its Solution through Renewable Energy in Bangladesh", Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Renewable and Sustainable Energy (JRSE), September, 2011

[3] https://en.wikipedia.org/wiki/Portal:Renewable_energy, retrieved 22 September, 2018

[4] Keynote Paper ENERGY SCENARIO AND POLICY IN BANGLADESH M. Nurul Islam Institute of Appropriate Technology Bangladesh University of Engineering and Technology Dhaka

[5] Sujoy Barua and M. M. Hasan, "A Study of Socioeconomic Aspects of Motor Assisted Pedal Rickshaw and its PV Solution", IEB Journal of Electrical Engineering, Vol. EE 40, No. I & II, pp.32-36, June & December, 2014

[6] Design and operational recommendations on grid connection of PV hybrid mini grids, IEA PVPS Task 11, Subtask 20, Activity 25, Report IEA-PVPS T11-06: 2011,October 2011

[7] Fahim Hasan, Zakir Hossain, Maria Rahman, Sazzad Ar Rahman, "Design and Development of a Cost Effective Urban Residential Solar PV System", December 2010.

[8] Shahidul I. Khan, Md. Upal Mahfuz, "Prospect of tidal energy in Bangladesh",World Renewable Energy Congress VII, 29 June - 5 July, 2002, Cologne,Germany, pp.875-877.

[9] Shaika Tamanna Eshita;ID:09221111 Alima Hossain;09221198 and Md.Ovik Raihan;Id:09221118 "DESIGN AND SIMULATION OF A SOLAR PV SYSTEM FOR BRAC UNIVERSITY" December, 10.

[10] https://www.academia.edu/37510134/Renewable_Energy_Scenario_in_Bangladesh, retrieved 12 October, 2018

[11] Kibria G, Haroon AKY, Nugegoda D. 2013. Climate change and agriculture, livestock, fisheries, and aquaculture food production. 300p. ISBN: 978-93-81450-512

[12] Kibria, G. 2015. Climate Change Impacts, Actions and Programs for A Most Vulnerable Country- Bangladesh. https://sites.google.com/site/ccbangladesh/, retrieved 28 September, 2018

[13] Shariff, I. 2013. Rural Electrification: the success story of Bangladesh https://cleanenergysolutions.org/sites/default/files/documents/Islam-Sharif-SKJ-Bangladesh-UN.pdf

[14] https://www.scribd.com/document/160298074/Chapter-11-Economic-Analysis-and-Current-Projects retrieved on 28 September,2018

[15] Rifat Abdullah Akhi and Mahzuba Islam study on **Prospects of Solar home system in Bangladesh and a case study for tariff calculation,** International Journal of Innovation and Applied Studies ISSN 2028-9324 Vol. 7 No. 1 July 2014

[16] Foraji, Abdullah Al Masum, study on An economic analysis of Solar PV system in Bangladesh, Daffodil International University, 2014

[17] http://www.powerdivision.gov.bd/user/brec/50/91 , retrieved on October 08, 2018

[18] https://solarcalculator.com.au/solar-panel-efficiency/, retrieved on 14 October, 2018

[19] Rahman, M.A. and Kholilullah, M.I. 2017. Impact of Solar Panel on Livelihoods in a Selected Area of Bangladesh. International Journal of Renewable Energy. Vol.12, No.1, pp. 133-141.