ANALYZING THE SOLAR IRRADIATION PATTERN OF BANGLADESH FOR ELECTRICITY GENERATION

A Thesis paper submitted to the

Department of Electrical and Electronics Engineering

In partial fulfillment of the requirements for the Award of Degree of

Bachelor of Science in Electrical and Electronic Engineering

Submitted By

PRODIP CHANDRA PAL

ID: 153-33-3017

SHANTA ISLAM

ID: 153-33-2842

Supervised by

DR. M. SHAMSUL ALAM

Professor

Department of EEE

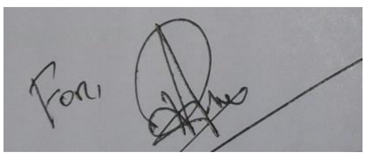
DAFFODIL INTERNATIONAL UNIVERSITY

December 2018

APPROVAL

This thesis titled **"ANALYZING THE SOLAR IRRADIATION PATTERN OF BANGLADESH FOR ELECTRICITY GENERATION",** submitted by Prodip Chandra Pal and Shanta Islam to the Department of Electrical and Electronics Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Electrical and electronics Engineering and approved as to its style and contents. The presentation has been held on.

BOARD OF EXAMINERS



Dr. M. Shamsul Alam

Professor

Department of EEE

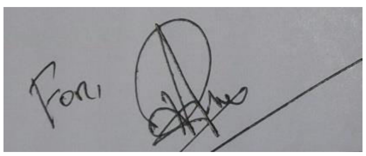
Faculty of Engineering

Daffodil International University

DECLARATION

We hereby declare that, this thesis paper has been done by us under the supervision of **Dr. M. Shamsul Alam,** Professor, Department of EEE, Faculty of Engineering, and Daffodil International University. We also declare that neither this thesis paper nor any part of this thesis paper has been submitted elsewhere for award of any degree or diploma.

Supervised by:



Dr. M. Shamsul Alam,

Professor

Department of EEE

Faculty of Engineering

Daffodil International University

Submitted by:

Name: **Prodip Chandra Pal**

ID: 153-33-3017

Name: **Shanta Islam**

ID: 153-33-2842

CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Abbreviations

PV	Photovoltaic
DC	Direct Current
AC	Alternating Current
KWh	Kilowatt Hour
MW	Megawatt
CO	Carbon Monoxide
IFRD	International Financial Reporting Standards
IDCOL	Infrastructure Development Company Limited
SHS	Solar Home System
NGO	Non-Governmental Organization
BPDB	Bangladesh power development board
TV	Television
RERC	Renewable Energy Research Centre
AGM	Absorbed Glass Mat
GTI	Grid-tie inverter
STC	Standard Test Condition
LCD	Liquid crystal display

USB	Universal Serial Bus
RF	Radio Frequency
OPC	Operational Condition

ACKNOWLEDGEMENT

First, we express our heartiest thanks and gratefulness to the Almighty GOD for his divine blessing to make us possible to complete this project successfully.

It is our great opportunity to convey the deepest and veneration to our honorable thesis supervisor, Dr. M. Shamsul Alam, Professor, Department of EEE, Faculty of Engineering, Daffodil International University (DIU), for engaging me in such an important research. He was always there to share his absolute experience and valuable time. It was his constant supervision, helpful suggestions, constructive criticism and endless patience throughout development of this thesis.

I am also grateful to the respondents of my research questionnaire, without which the thesis would remain incomplete. Apart from that, I would like to thank our entire friends for sharing knowledge; information and helping us in making this thesis a success.

Finally, I beg pardon for our unidirectional errors and omission if any.

ABSTRACT

Now a days, the increasing demand of electric power and shortage of present energy resources lead today's engineers and scientists to think about the alternative sources of energy. The sunlight is a potential source for producing electric power. In recent years, this solar system gains its popularity more and more. In home system applications, the use of solar energy is also attractive. Moreover, solar home systems require very little maintenance and need no fuel. Other advantages of a PV system are reliable power, free source of power, flexibility and quick installation. For socio-economic development a reliable, affordable and secure supply of energy is significant. The following research paper is based on analyzing the solar irradiation pattern of Bangladesh for electricity generation. Irradiation and power are discussed with their optimum capacity. Power is one of the most important factors in developing country and for sustainable economy. Like the rest of the countries of the planet, in Bangladesh the demand for power is increasing day by day. 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

Bangladesh is mostly densely populated countries which have not adequate supply of energy. In Bangladesh, nearly 80% of the people live in the village and only 32% of total population is connected to grid electricity [1]. Considering the present demand for electricity; by 2020 the energy mix will be changed considerably from what it is today. The opportunities of using solar power are already being tested and will mostly increase. But still, most households meet their daily requirements with biomass fuel. With only 60% of Bangladeshis having access to electricity, the per capita energy consumption is only 292 kWh per annum [1]. Solar power systems are contributing a huge amount of energy so that it can mitigate the present energy crisis, especially in rural areas of Bangladesh. Moreover, 30 organizations in Bangladesh are conducting solar energy businesses [2]. Bangladesh is located between 20.30 – 26.38 degrees north latitude and 88.04 – 92.44 degrees east longitude. Daily average solar irradiation rate is 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April (6.5 hour/day) and minimum on December-January (4 hour/day). At present, only 62% (including renewable energy) of the total population in Bangladesh has access to electricity but in rural area, they are deprived from electricity. Approximately 60 million people or 38% of the population in Bangladesh have no access to electricity and they depend on kerosene and natural sources. Bangladesh Rural Advancement Committee (BRAC), a Non-Government Organization (NGO) started Solar Energy Program for sustainable development in 1997 [3,4]. The 3MW solar power plant has been established at Sarishabari in Jamalpur by a local company, Engreen Sharishabari Solar Plant Ltd [5]. Which is the first solar power plant in Bangladesh. Bangladesh Power Development Board (BPDB) is getting 33/11 KV power from this sector. PV systems use sunlight to generate electricity. In addition to the panels, a PV system usually contains an inverter to convert solar power from DC to the AC of the utility grid power transmission and distribution system. Beximco with the Chinese company is setting up a 200MW solar power plant in Gaibandha [6]. Under the Hill Tracts Electrification Project BPDB, total of 173.81 kW, Solar PV Systems has installed in Juraichori, Barkal and Thanchi Upazila of Rangamati District. In Angoorpota and Dohogram Chitmohol BPDB implemented 1.06 kW solar PV systems in 2008-09. Moreover, BPDB implemented 20.16 KW solar PV system at the office of the prime minister on December 2009 [7]. In Chittagong, a 7.4 MW solar power plant was established at Kaptai hydropower station [8]. An 800MW solar power project will set up by Scatec Solar at Chandpur in southern Bangladesh [9]. Solar home system plays a vital role for rural electrification in Bangladesh and for this reason SHS is increasing day by day. According to power and energy ministry data, 2.86% of all power produced in this country comes from renewable energy, including solar power. On the other hand, Renewable energies like wind, solar, bio-mass, geothermal, hydropower energy are environmentally friendly.

Now a day's solar energy is very much popular in our country. Basically, wind energy power is directly proportional to the velocity of the wind. Moreover, wind is an available renewable energy source. Bangladesh Council of Scientific and Industrial Research (BCSIR), Institute of Fuel Research and Development (IFRD) and Centre for Mass Education in Science (CMES) worked together to make a low cost and light weight solar cooker and they have done it successfully. But the manual sun tracking system is the only problem of the cooker. On a bright sunny day, it will take about three hours to cook for 5–6 family members. IFST is working on a sustainable Solar Dryer. They have promoted a cabinet dryer for drying fruits, vegetables etc. IFRD designed it and solar radiation has absorbed by a coated flat plate and converts into heat, after that it transfers the resulting heat to circulating water. This type of heater is suitable for supplying low-grade thermal energy at temperatures below 90 °C [10].

On the other hand, other renewable like wind, biomass can be a great energy source for Bangladesh. Wind energy is directly proportional to the velocity of the wind. Biomass energy can be produced by burning organic material that comes from plants and animals. Wood is biomass energy. Not only biomass is a renewable energy but also sustainable source of energy. Moreover, hydro power is one of the oldest sources of energy to produce mechanical and electrical energy. Moreover, Hydro power used thousands of years ago to turn paddle wheels to help grind grain. Therefore, hydroelectric power is produced by moving water. Here, water is the main source. Kaptai dam is the only hydroelectric power station which is situated in Bangladesh.

The maximum amount of power is generated by the Kaptai hydro-electric power station, which is very close to the coastal area. In 2012, investments in solar technologies were only $3 million. By 2015, that figure had increased to $158 million, growing to $223 million in 2016. The job sector in the solar is rapidly rising. In the context of Bangladesh, the number of jobs in solar PV rose 10% in 2016.The highest number of SHS have installed in Bangladesh and achieved top position among a global list of countries [11].

1.2 Energy Crisis in Bangladesh

Bangladesh has long been suffering from energy starvation of 166 million population, in which 63.5% live in villages [12]. Bangladesh will face in near future a crisis in energy sector. Fire wood, straws and cow dung are still the main source of energy in the villages. Natural gas detection does not make any help to the villagers. Throughout the country trees are being fallen randomly by the thousands to burn brick which may give rise to horrible scene of deforestation and cause ecological imbalance in near future. With a view to solving the problems partially, it is time to think of renewable sources of energy as a supplement to the existing traditional resources. Nature provides us with several renewable sources of energy such as sunshine, wind and tidal power. Unlike fossil fuel energy from these resources can be employed for ages. Science came forward with the idea of trapping the vast energy that the sun floods the earth every day. Several devices have been worked out for trapping and storing solar energy.

Utility and feasibility of the renewable sources of energy should be studied with due consideration. It is compulsory because fear of shortage in conventional energy sources. This is easily understood when we place a statistic on the energy resource availability, consumption and dependence on import of fuel.

1.3 Problem Statement

Bangladesh is a most populated country and land is the biggest problem in Bangladesh. The non-agriculture unused land is not available in Bangladesh. Acquiring land is the biggest problem for rapid expansion of on-grid solar power system. Moreover, panel, charge controller and battery quality are not good enough. In addition, the power factor of the loads does not take into consideration. Fossil fuels massively use in Bangladesh. Most of the people in Bangladesh live in rural area where they badly need of energy. We have a lack of research information in the solar field. Recently some battery company has been established in Bangladesh. High efficiency battery has not import in Bangladesh due to high cost. For low equipment, we can't get sufficient output. Dishonest businessman supplies low-quality equipment which badly impacts. The equipment is costly and for that reason, sometimes it is impossible for the people to replace new equipment.

1.4 Renewable Energy

Renewable energy is energy produced from natural resources—such as sunlight, wind, rain, tides, and geothermal heat—which are renewable (naturally replenished). Hydroelectricity was the next largest renewable source, 16.4 % of global electricity generation and providing 3.5 % of global energy consumption [13]. Wind power is growing at the rate of 30% annually, with a worldwide installed capacity of 121,000 MW in 2008 and is widely used in European countries and the United States. The annual manufacturing output of the photo voltaic industry reached 6,900 MW in 2008, and PV power stations are popular in Germany and Spain. Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 MW Solar Electric Generating System (SEGS) power plant in the Mojave Desert. The world's largest geothermal power installation is The Geysers in California which capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world which is involving production of ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel. Ethanol fuel is also broadly available in the USA. While most renewable energy projects and generation is large-scale, renewable technologies are also suited to small off-grid applications, sometimes in rural and remote areas, where energy is often crucial in human development. Kenya has the world's maximum household solar ownership rate with roughly 30,000 small (20–100 watt) solar power systems sold per year. Some renewable-energy technologies are criticized for being intermittent or unsightly and the renewable-energy market continues to grow. Climate-change anxieties, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable-energy legislation, incentives and commercialization.

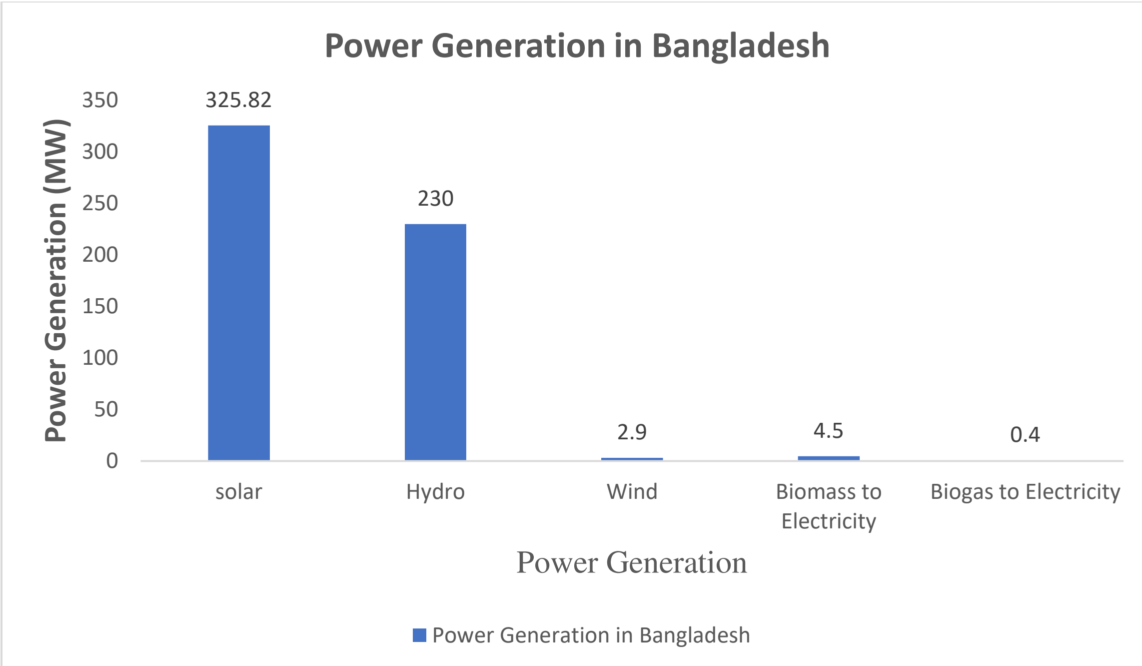


Fig 1.1: power generation in Bangladesh

From the Fig.1, we can analyze how much power generation from renewable energy in 2018. Total generation power from solar energy is 325.82 MW which is the highest power generation among other renewable energy. The lowest power generation is 0.40 MW from the biomass in Bangladesh.

1.5 Renewable Energy Sources

1.5.1 Solar Energy

Solar power comes from thermonuclear reactions in the sun and is the 'ultimate' renewable energy sources. PV systems use sunlight to generate electricity. In addition to the panels, a PV system usually contains an inverter to convert solar power from DC to AC of the utility grid power transmission and delivery system. 3 MW plant has established at Sarishabari in Jamalpur. In our country, solar PV application primarily concentrates on rural home lighting system. Lack of awareness at the ground level and absence of financing facilitators are the major barriers SHS in Bangladesh. Besides, govt. Bureaucracy and damaging price consciousness of some development agencies are also responsible. Rural Electrification Board (REB), Local Government Engineering Department (LGED), Bangladesh Power Development Board (BPDB)

And other agencies implementing solar energy program. There is a powerful potential for alternative energy at intervals the country.

Solar Thermal Power/Concentrating Solar Power (CSP): The technology involves harnessing radiation for generation of electricity through variety of steps finally generating mechanical energy to run a generator. This technology needs to be disseminated within the country to supplement the power supply.

1.5.2 Hydro-power

Hydro-power is one of the oldest sources of energy to produce mechanical and electrical energy. Moreover, Hydro-power used thousands of years ago to turn paddle wheels to help grind grain. Therefore, hydroelectric power is produced by moving water. Here water is the main source. Kaptai dam is the only hydroelectric power with capacity 230 MW which is situated in Bangladesh. The main disadvantage of a hydraulic power station is its high initial value and longer authorization amount. But these disadvantages are offset by the low value of generation as well as the management of floods and increased irrigation facilities.

1.5.3 Wind Energy

Now a day wind is an available renewable energy source. Every day, around the world, wind turbines are converting it to electricity by capturing the wind's power. This source of power generation plays an increasingly significant role. In Bangladesh, Feni having a capacity of 0.9 MW and another one at Kutubia Island with a capacity of 1 MW.

1.5.4 Biomass Energy

The energy which is released by burning and can be converted into biomass energy. We get this energy by burning Organic material that comes from plants and animals. Wood is biomass energy. Biomass is not only a renewable energy but also sustainable source of energy.

1.5.5 Geothermal Energy

The word geothermal comes from the Greek words where geo means earth and thermal means heat. People use geothermal energy to generate electricity. Heat is continuously producing inside the earth, for that reason, geothermal energy is a renewable energy source. In 2018, US installed geothermal electric with capacity 3591 MW.

1.6 Importance of Solar Energy

The fossil fuels like gas, oil, coal and nuclear power plants are the main sources of the element to generate energy in the world. CO_2 is released; when we burn this fossil fuel and greenhouse gases are released and it has a bad impact in our atmosphere.

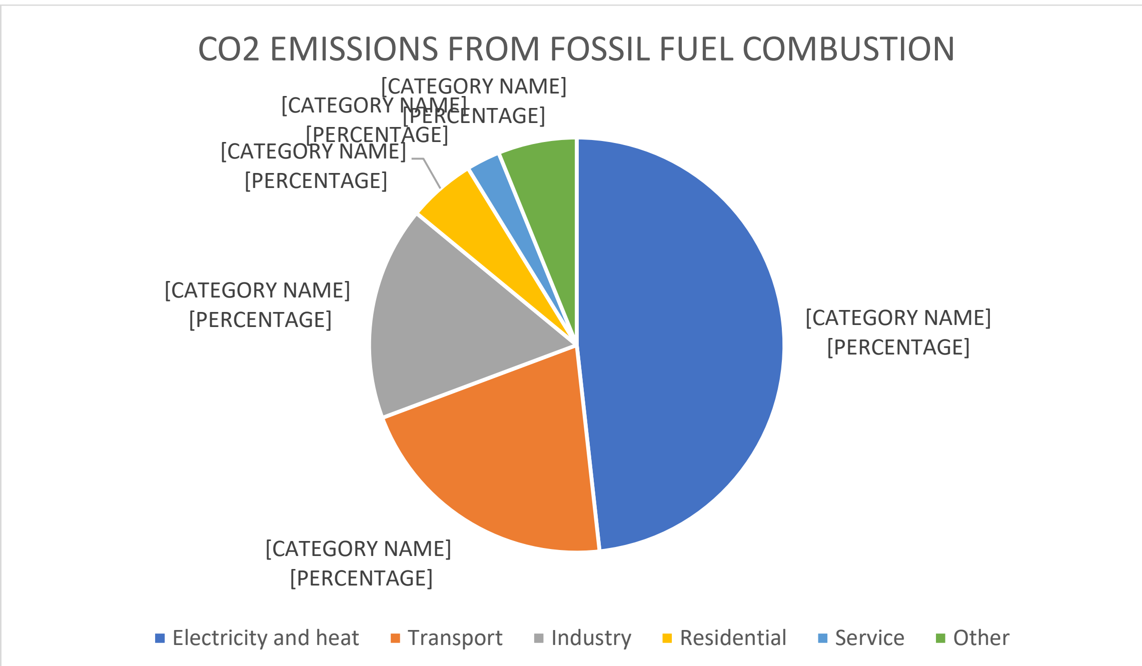


Fig. 1.2: CO2 Emissions from Fossil Fuel Combustion

From the Fig.2, we can analyze that electricity and heat generation are the main reason for global warming. Global warming badly impacts our society and environment. On the other hand, the reservoir of fossil fuel is decreasing day by day because the abundant use. So, the time has come to think about the alternative source of energy. As a renewable energy, solar energy is the best option in Bangladesh. Bangladesh government has understood the importance of solar energy and mandatory to set up a solar panel on rooftops of every multistoried and hi-rise building. Everywhere in the earth, solar energy is available to generate electricity. Infrastructure Development Company limited (IDCOL), BPDB, NGO's are working for sustainable solar energy in Bangladesh. The demand of energy is increasing because of the industrialization, urbanization, food production. In the rural area, solar energy plays a vital role in their livelihood.

1.7 Top Ten Countries Using Solar Power

Solar energy is becoming more and more popular among the develop and developing countries. Solar energy has become the most cost-effective source of renewable energy day by day. Solar energy is the fastest-growing new source of energy in the modern era**.** Table-2 and Fig. 3 represents top ten solar generation country respectively.

Table-1.1 Top ten solar countries

Country	Generation(GW)
China	130.4
United States	85.3
Japan	63.3
India	57.4
Germany	48.4
Italy	22.6
United Kingdom	14.2
France	12.8
Australia	12.2
Pakistan	10

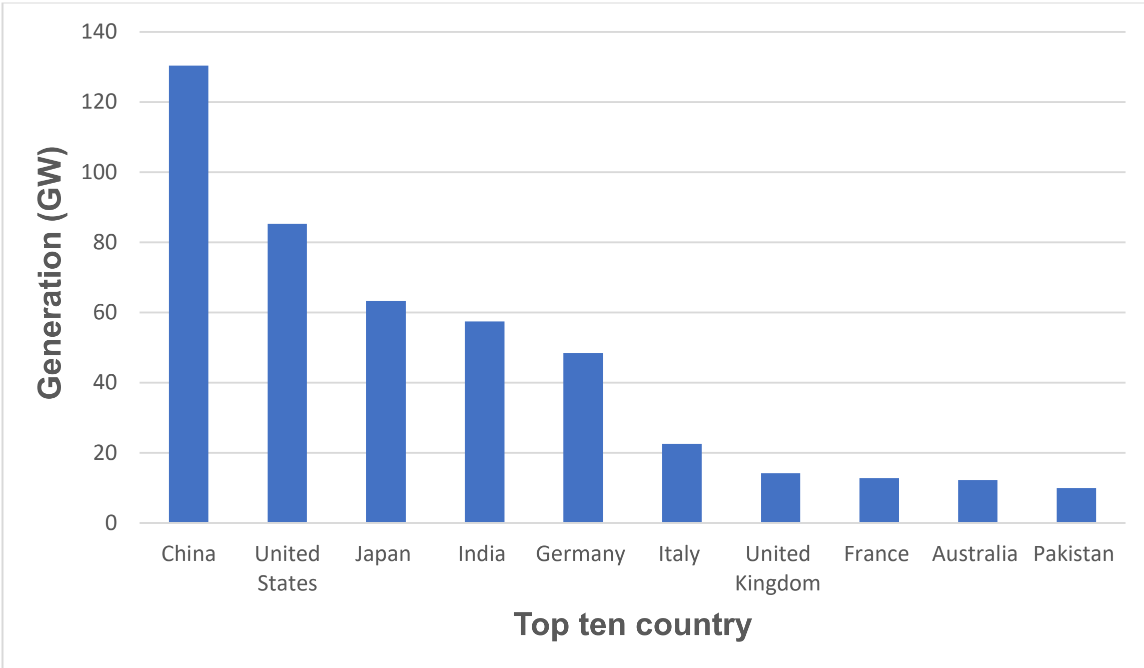


Fig 1.3: Generation Top Ten Solar Country

1.8 Objectives of the Research

- To observe and record solar irradiation and maximum power generation capability from sunlight in Dhaka for (September & October) two months.
- To analyze the data to get average irradiation and find the relationship between solar irradiance and power.
- To study efficiency of solar PV system of Bangladesh.
- To assess the role of SHS on socio-economic development in Bangladesh.
- To introduce Renewable Energy (RE) as an alternative solution for power generation.

1.9 Significance of this Research

Bangladesh is a tropical country of enormous solar energy. But a very little amount of this energy is used. Though the inception of SHS in Bangladesh was occurred in 1988 but it was untapped for a long period. By this time various applications of solar electricity are seen throughout the world. Solar irradiation of a specific place (DHAKA) is not still measured in hourly basis in every day. So, the data of irradiation is not accurate and by this study, we will fill up the research gap and get the accurate data of sun radiation of Dhaka and its corresponding electric power. As of now there is very limited academic study on the socio-economic or environmental impact of solar electricity in rural area. So, the study would assist the concern policymakers and implementers to take necessary measures for sustainable rural development in Bangladesh. Identifying the new innovative use of solar electricity in rural areas would help the implementers for effective planning and undertaking programs. On the other hand, Now-a-days Solar Panel provides electricity for solar vaccine refrigerator, solar water disinfection (SODIS), solar food drier and solar pasteurization. This helps for reducing waterborne diseases. Solar phone, solar Wi-Fi, solar radio increase rural communication, reduces transport cost and reduce digital divide. Beside solar cooker and solar water heating, reliance on traditional fuels such as wood or charcoal, reduces indoor pollution and carbon emission. This increases the quality of life in rural areas, improve health and education, reduce oil dependency, increase local employment and reduce deforestation. Solar power activities lead rural development. Due to lack of information and study SHS is used only for household lighting in Bangladesh. Solar irrigation technology is also getting popular in Bangladesh. As agriculture-based country, using solar power irrigation system would be a major driving force for rural development. Government organization, Academic institutions, NGOs and private companies are involved in renewable energy sector in the country.Researcher, policy maker, development partner in Bangladesh acknowledged the immense prospect of solar electricity for rural transformation. But there is no integrated study of the prospect and scope of solar electricity for socio-economic development in rural area of Bangladesh.

1.10 Outline of the Study

Following the introduction, the second chapter of this report will focus on review of selected literature and conceptual overview of SHS in socio-economic development. In third chapter, it will discuss the solar PV equipment. In fourth chapter, it will discuss the methodology of the research. The fifth chapter contains the result of this thesis. The sixth chapter is conclusions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction:

Duan, C., Wang, C., Li, Z., Chen, J., Wang, S., Snyder, A., & Jiang, C, [17] they mainly focus on the balancing system such as solar, storage & charge balancing. Moreover, a battery balancing system helps to run an electric vehicle. To verify the idea, they established a prototype system which result verifies that every 13.2km battery energy can save 2.1%~3.3%. Moreover, Commerell, W., Müller, R., & Shanmuganandam, V.,[18] research paper based on the component and cost relations in SHS. Lifetime costs of solar home systems can minimize by proper maintenance of charge controller and battery. To make components especially charge controller, required highest technology, solid construction, well-designed electronics, elaborate thermal management and mechanical stability.

Prodip Chandra Pal, Shanta Islam, Rasel ahmed, Najmul islam, Sanjoy kumar shill, Ashikur Rahman munsi, Mim, M. S., Rafy, M. F., Pervej, M. S., & Ahad, A. R,[19] study to observe the current condition of SHS, highlighting the limitations and finding the predictions of solar energy in Bangladesh, after studying find out such as production cost, rainy season, shading, lack of battery support etc..Moreover, Komatsu, S., Kaneko, S., & Ghosh, P. P, [20] they first recognize the effect of SHS on the reduction and compare purchasing energy costs. The result of this research examines the benefits of adopting and beside the micro-benefits form substantive influence for dwelling in village households.

Cojocaru, E. G., Vasallo, M. J., Bravo, J. M., & Marín, D, [21] paper based on a simulator for a concentrated solar power plant with thermal energy storage. This teaching tool has been built to afford a clear image of the system and from the simulation, after they get setpoint profile of generation, maximum power profile of SF and the initial values of the thermal energy storage energy and turbine state. Moreover, Hua, C. C., Fang, Y. H., & Wong, C. J., [22] the context of the paper to improve the solar system with point of maximum power tracking. The converter controlled by a processor with digital signal. The low-power rating 12

Converter reduces the system cost. The empirical results display that the proposed PV system can produce more output power with high efficiency.

Islam, T., & Awal, M. A., [23] context of the paper about solar powered home system lighting of Bangladesh. They design a system which is capable in future to communicate remote control station and service provider can observe remotely. In the rural area, people livelihood will change due to the blessing of solar light. Deb, A., Bhuiyan, M. A., & Nasir, A.,[24] they observe the prospects of solar energy from aspects of Bangladesh. Solar cooking helps to reduce fossil fuel consumption. The off-grid DC solar system which helped to solve our irrigation problem and keep our environment fresh for our future generation. Moreover, Biswas, W. K., Diesendorf, M., & Bryce, P, [25] research paper base on the sustainable rural improvement and poverty palliation in Bangladesh. Income-generating opportunities are created and improve of rural people life for quality of Photovoltaic technologies. Grameen Bank and BRAC models help poor people to provide micro-credit individuals.

Rebane, K. L., & Barham, B. L,[26] paper firstly they collect data in Nicaragua to investigate characteristics so that they can predict the knowledge and adoption of a solar home system among the rural population. After studying, they identify numerous determinants of solar home systems information and adoption, offers several useful recommendations to project planners, and affords an analytic framework for upcoming work in this policy-relevant field. Stated that the application of demand characterized by very low levels or the procurement cost of fuel is very high. However, with rising fuel prices SHS technologies may become more cost-efficient than off-grid alternatives based on fossil fuels [27]. Photovoltaic sun powered power change is that the immediate change of sunlight into power. A little electric flow delivers when sunlight falls on the semiconductors of the cell. Panels consist of several cells connected to provide voltages and currents high enough for practical use. More common in rural electrification programs is 'Solar Home System' (SHS). The SHS is providing low load but can be sufficient for powering of radios, lights, television sets and to refrigerate medicines at rural clinics. Though at first glance SHS seems to be luxurious, it is cost-effective electricity at small scales in areas without access to grid electricity. 13

2.2 Socio-Economic of SHS

Rural electrification SHS Programs are contributing a sustainable socio-economic growth of the rural people in Bangladesh. Numerous jobs will create which helps to decrease the unemployment rate. Moreover, socio-economic impacts include computer and internet connections to remote areas. It's not only improvements in the standard of living of the people like a better light for child education but also reduced indoor air pollution. Furthermore, studies identify that burning fossil fuels helps naturalize global warming. On the other hand, solar energy does not damage the atmosphere because solar panels emit a very low amount of hazardous pollution into the air. Thus, solar energy is an abundant cleaner source of energy than the burning of fossil fuels. Foreign oil dependence would be shortened if more companies and households used solar energy to produce electricity instead of fossil fuels. With the help of SHSs Businesses such as rice/sawmills, tailoring shops, restaurants, market etc. have increased their revenue. In addition to these developments, women are enjoying hazard fewer lighting systems in their daily life. After dusk, they are utilizing their time by sewing, poultry farming or set up home-based industries to earn extra income. Two very successful applications of SHS are Micro-utility model, SHS powered Polly-phone. In this way, a significant reduction of home or office greenhouse gas emissions is possible. Installing a grid-connected system is also the perfect way to meet rising building energy efficiency standards.

2.3 Solar Energy for Rural Electrification in Bangladesh

In 1971, the year of independence of Bangladesh, only 250 out of 87,928 villages had access to electricity [28]. Government of Bangladesh (GOB) committed itself to develop a program for providing electricity to rural areas. Article 16 of the Constitution of Bangladesh states: “The State shall adopt effective measures to bring about a radical transformation in the rural areas through the promotion of an agricultural uprising, the provision of rural electrification, the growth of cottage and other industries and the improvement of education, communications and public health, in those areas, so as progressively to remove the inequality within the standards of living between the urban and also the rural areas” [29]. BPDB was formed to operate and expand the electricity network, which mainly concentrated.

On electrification of urban centers. To increase rural electrification NRECA was commissioned to conduct an extensive study. NRECA developed a master plan emphasizing on the provision of electricity for agricultural mechanization, irrigation and rural industries. The master plan was adopted in 1977, closely followed by the establishment of the REB in the following year [30]. By January 2014, more than 50,194 villages had been electrified through the REB program serving more than 84, 22, 246 domestic line and 53.34% people get access to electricity service and the rest 46.66% depends on kerosene and other sources. The REB has defined an objective to bring all towns of Bangladesh under electrification by 2020. However, it must be noted that the electrification of a village does not necessarily mean that all households will immediately get a connection, as affordability of the initial connection cost creates a problem for certain number of households. Therefore, only a small minority (10%) of rural Bangladeshis have access to electric power. Furthermore, the quality of supply is often unsatisfactory due to frequent load shedding and voltage variability [31]. In more remote areas, distribution line setup is costlier due to its landscape dominated by extensive areas of water, regular flooding, hilly and certain regions of river islands. In this situation decentralized electricity supply with RETs might represent a viable and cost-effective alternative to conventional grid-based electrification. Natural gas reserves estimated to be exhausted very soon and Bangladesh's petroleum consumption being totally import-based, increased use of renewable energy sources seems to be a reasonable step for the development of a sustainable long-term energy scenario [32]. Even though Bangladesh's physical landscape is shaped by enormous amounts of water, the potential for hydroelectric power generation is quite limited. Country's only hydroelectric plant, Karnafuli power plant, has a total generating capacity of 230MW, accounting for about 5% of the total installed capacity of electricity in the country. The construction of the dam and the reservoir for the Karnafuli power plant led to severe negative environmental and social affects creating long drawn social unrest among the local population. Again, electricity generation from wind power is also more limited in Bangladesh for scarcity of usable wind speed. Besides, generation of electricity from biomass such as animal waste or crop residues is still in the early stage of development and testing.

Bangladesh is geographically located in a favorable position for harnessing sunlight, available abundantly for most of the year. Average daily radiation of solar energy is about 4.5 kWh per square meter making it technically quite feasible to use photo voltaic energy for electrification purposes [33].

2.4 Solar Home System in Bangladesh

The only form of modern renewable energy technology that has had some success in Bangladesh is solar PV. With the help of soft loans and grant facilities of donors, more than 100,000 SHSs (Fig. 25) have been installed in different parts of Bangladesh. The principal sun powered PV-based rural electrification project in Bangladesh was begun with the financial help of France, with an aggregate introduced limit of 62 kilowatts peak (KWp), of which 29,414 Wp originated from battery charge stations and the rest from sun originated Solar Home System framework (SHS). Infrastructure Development Company Limited (IDCOL) has upheld NGOs to install of solar home systems (SHSs). In rural electrification programs is the use of solar PV as stand-alone systems in households, social institutions, or places of productive or business activities. Generally, the system is referred to as 'Solar Home System' (SHS). The SHS providing load is low (below 100 W), but can be enough for powering of lights, radios, television sets, and to refrigerate medicines at rural clinics. Even though SHS seems to be expensive at first glance, it is cost-effective in providing electricity at small scales in areas without access to grid electricity or any other renewable energy source. Its application can furthermore be reasonable where demand is characterized by very low levels or the procurement cost of fuel is very high [34] [35]. However, with rising fuel prices SHS technologies may become more cost-efficient than off-grid alternatives based on fossil fuels.

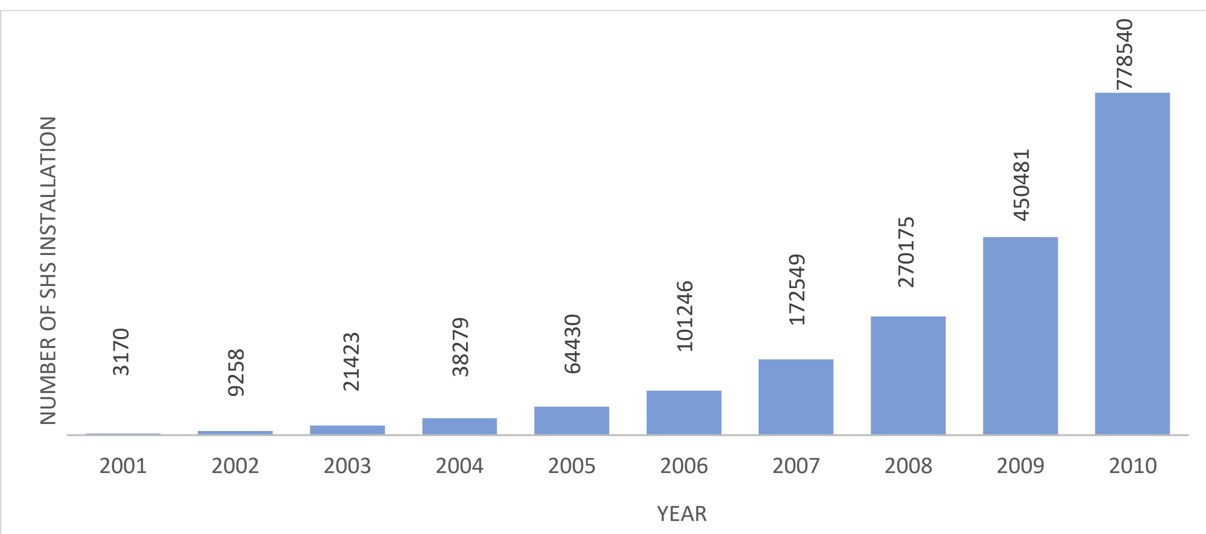


Fig. 2.1: SHS Installation in Bangladesh

2.5 Progression of Worldwide SHS Dissemination

The utilization of sunlight-based power expanded at the disclosure of photo voltaic cell in 1839 by French physicist Edmond Becquerel. Successive researchers have developed cells with more efficiency. The first interest in solar technologies for rural stand-alone electrification arose in the 1970s. The 1973 oil embargo and 1979 energy crisis caused a reform of energy policies around the world and brought renewed attention to developing solar technologies. Between 1970 and 1983 photo voltaic installations grew rapidly but falling oil prices in the early 1980s moderated the growth of solar photo volt from 1984 to 1996 [37].

Dissemination of SHS depends on afford ability. According to F. D. J. Nieuwenh out adequate service infrastructure is required to make projects viable. Smaller systems sold for cash can be a good alternative to credit systems by offering to increased affordability [38]. Depending on their size, prices of SHS scan vary between US$ 100 and US$ 1,100. There are also important price variations for various countries observable. Local prices depend on factors such as duties, taxes, and subsidies, the scale of manufacturing and assembly processes, the scale and cost of marketing and other services, the degree of competition, capacity utilization in manufacture, sales & servicing and the cost of funds for working capital and capital costs. The other major issues to be considered are the high initial costs, the formation of a responsive and sustainable infrastructure and the guaranteeing of quality products and services. Reducing the market prices of SHSs by influencing the above factors is an important strategy of many SHS dissemination programs [39]. As of late the vast majority of the worldwide development in SHS deals has focused on a couple of Asian nations, to be specific India, Sri Lanka, Nepal, Bangladesh, Thailand, and China. In these countries, the problem of afford ability has been overcome either with micro-credit or by selling small systems for cash.

CHAPTER 3

SOLAR PV EQUIPMENT

3.1 Introduction

In this modern era people have taken solar energy as the alternate of grid electricity. Solar Energy is a great source for resolving power crisis in Bangladesh. A solar PV system is a significant emerging option to supply electricity with quality light, reliable service & long-term sustainability.

3.2 Photovoltaic Technology

A more common term for photo voltaic cells is "solar cells", although the cells work with any kind of light and not just sunlight.

A solar cell is a converter. It changes energy of light into electrical energy. A cell does not store any energy, so when the source of light (typical the sun) is removed, there is no electrical current from the cell. If electricity is needed during the night, some form of electrical storage (typical a battery) must be included in the circuit.

3.3 Solar Cells

PV or solar cells (Fig.3.1) are PN junction Semiconductor devices. It converts sun light into direct electricity. Solar cells typically are distinguished by their sort of semiconductor junction-

(A) Homo junction (n + p layer is of the same material)

(B) Hetero junction (n + p layer is of different material)

(C) MIS (Metal -Isolator - Semiconductor)

(D) SIS (Semiconductor - Isolator - Semiconductor).

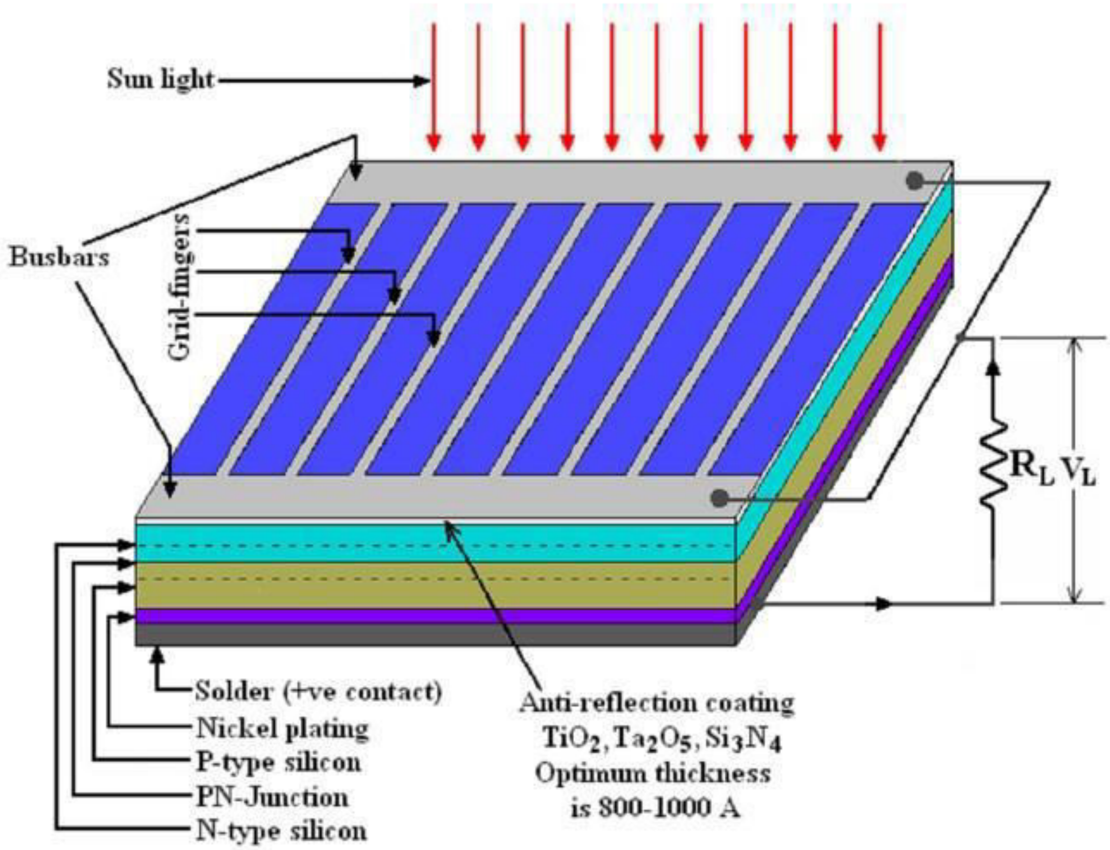


Fig. 3.1: Solar Cell [40]

3.4 Design of Modules

There is some characteristic given below-

- Producing voltage of one silicon solar cell is 0.5V to 0.6V.
- Basic building block of a PV power system is PV Module.
- To produce more power Modules, need to connect.
- Module can be designed by connecting 36 cells
- Panel can be designed by connecting the modules on the other hand, by connecting the panels array is designed (Fig. 3.2)

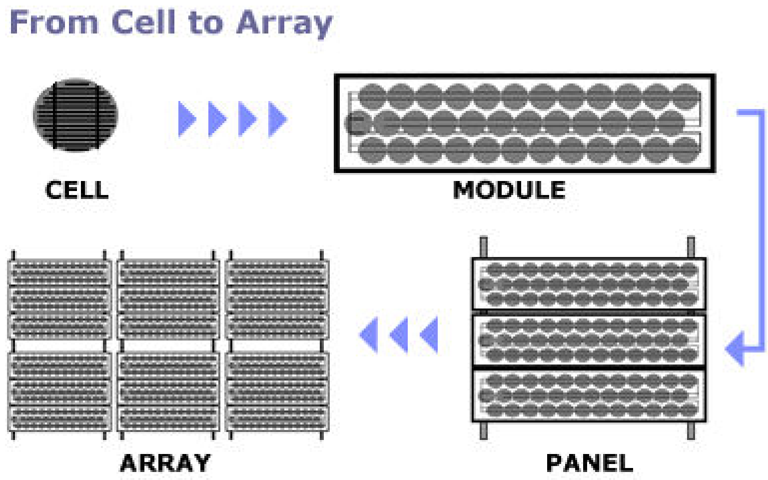


Fig. 3.2: Cell to Array

3.5 Types of Solar Cells

Solar cells can be classified according to the semiconductor materials of the cell, according to the crystalline structure of the material, and according to the number of junctions of the cell. According to the crystalline structure of the material there are three kinds of solar cells.

1. Single-crystalline or monocrystalline cells (Fig.3.3)
2. Multi-crystalline or polycrystalline cells and (Fig. 3.4)
3. Amorphous cell (Fig. 3.4)

Fig. 3.3: Single-crystalline Cells

Fig. 3.4: Polycrystalline Cells

Fig. 3.5: Amorphous cell

3.5.1 Monocrystalline Cells

Mono crystalline cells as shown in (Fig.3.6) are the most important type, because they have the highest conversion efficiency (25%), and the base material, which is extremely pure silicon, is already well established in the field of semiconductor production. Currently, the strategies of manufacturing element single-crystals are primarily either the Czochralsky method or the floating zone technique. In the Czochralsky process, mono crystalline silicon grows on a seed, which is pulled slowly out of the silicon melt. With both methods, silicon rods are formed, which are cut into slices of 0.2 to 0.4-millimeter thickness. The discs (wafers) produced in this way then undergo several further productions steps. These are, for instance:

a. Grinding and cleaning

b. Doping

c. Metallization

d. Antireflection coating

Fig. 3.6: Monocrystalline Cells

3.5.2 Polycrystalline Cells

The manufacturing process for mono crystalline silicon is highly energy-intensive and therefore very expensive and for this reason, in many cases polycrystalline silicon (Poly-Si) is preferred. Poly-Si develops, when a Si melt is cooled down slowly and controlled. The yielded silicon ingot is sliced for further processed. The pulling of the single-crystal can be given up this way. Inside the Poly-Si crystal, there are crystalline areas, which are separated by grain boundaries. The losses occurring at these grain boundaries cause the lower efficiency (less than 20%) of polycrystalline cells as shown (Fig.3.7) compared with mono crystalline ones. Despite this disadvantage, the importance of polycrystalline cells is growing, because of the lower production costs [40]

Fig. 3.7: Polycrystalline Cells

3.5.3 Amorphous Cells

To avoid the energy-intensive production method mentioned above, and to avoid the cutting loss of the slicing process, a vapor-phase technique has been developed in which a thin film of silicon is deposited from a reactive gas like silane (SiH_4) on a carrier material like glass and doped in a further step. The semi conducting material grown in this way is called amorphous silicon (Fig.3.8). This technology has 2 disadvantages: initially, the conversion efficiency is considerably low, i.e., less than 10%; second, the cells are affected by a degradation method during the initial months of operation, which reduces the efficiency furthermore. These disadvantages are compensated by the –

- Relatively simple and inexpensive manufacturing process
- The scope of producing cells with a larger area
- Easy to use in small electronic equipment and lower energy consumption.

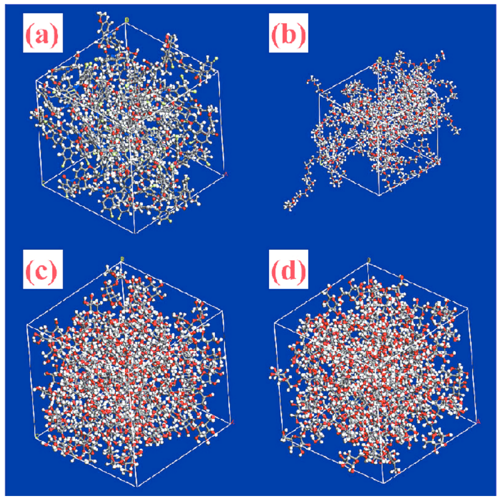


Fig. 3.8: Amorphous Cells

3.6 Charge Controller

Charge controller is an electronic device which is used in alternative solar energy system. A solar charge controller is required in virtually all solar power systems that utilize batteries. The job of the solar charge controller is to control the facility going from the solar panels to the batteries. Overcharging batteries will at the least significantly reduce battery life and at the worst damage the batteries to the purpose that they are unusable. The most basic charge controller merely monitors the battery voltage, opens the circuit, and stopping the charging, when the battery voltage rises to a certain level. Older charge controllers used a mechanical relay to open or close the circuit, stopping or beginning power going to the batteries. Modern charge controllers use (PWM) to slowly lower the amount of power applied to the batteries as the batteries get closer or closer to fully charged. This type of controller permits the batteries to be more fully charged with less stress on the battery, extending battery life. It can also keep batteries in associate passing fully charged state (called ―float) indefinitely. Pulse Width Modulation (PWM) is more complex but does not has any mechanical connections to break. The electricity produced in the solar panel and keep stored in the battery. The electricity stored in the battery is used at night. This whole method is monitored by the charge controller. A typical charge controller with PWM technique is shown in the Fig.3.9

Fig. 3.9: Charge Controller

3.7 Function of Charge Controller

The main function of a charge controller or regulator is to completely charge a battery while not allowing overcharge whereas preventing reverse current flow at night. Other functions are-

Stop the process of the battery when it is fully charged

- Disconnect the load during low voltage.
- Disconnect the load during high voltage.
- Monitor the battery voltage, state of charge (SOC) etc.
- To give alarm during fault condition.
- Current measurement.
- Detect when no energy is coming from the solar panels and open the circuit, disconnecting the solar panels from the batteries and stopping reverse current flow.

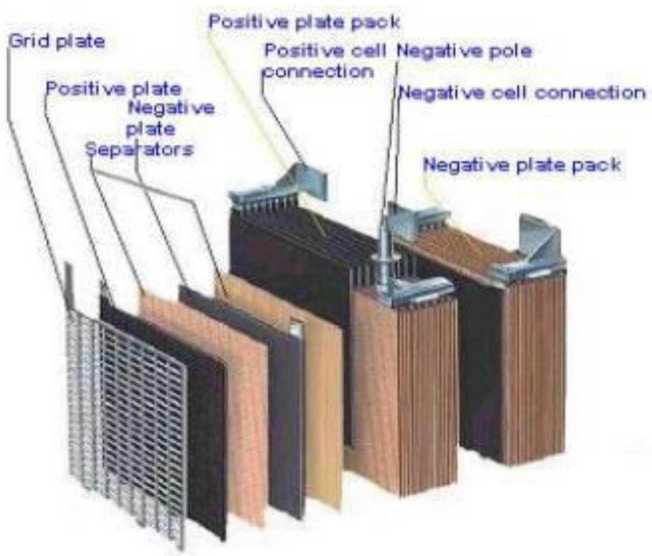
Charge controller is employed for co-ordination and control among the battery, load and solar panel. Charge controller stores the electricity within the battery throughout day time and provides a like the load (mainly lamp) at night. On the opposite hand, if battery is totally charged, then charge controller will directly provide electricity to the load (Fan, mobile charger etc.) from the solar panel throughout day time. A charge regulator or charge controller is mainly worked as a voltage regulator. Generally, it controls the current and voltage of the solar panel to save in battery. Solar panel mainly produces 16 volts to 21 volt and 14 volts to 14.4 volt is required to keep the battery in full charged state. The charge controller works as a buck converter to reduce this voltage level. Charge controller is mainly a DC-AC or DC-DC converter. Buck converter is usually used in the solar panel which converts the high-level DC voltage to the low-level DC voltage [40].

3.8 Battery Storage

Batteries are often used in Photo voltaic systems for storing energy produced by the PV array during the day and to supply it to electrical loads as needed (during the periods of cloudy weather and night). Other reasons batteries are used in PV systems are to operate the Photo voltaic array near its maximum power point, to power electrical loads at stable voltages, and to supply surge currents to electrical loads and inverters. In most cases, a battery charge controller is used in these systems to keep the battery from overcharge and over discharge. Figure 17 in an example of solar battery and industrial battery and the external and internal part of the battery as shown Fig. 3.10.

Fig. 3.10: 12-volt, 100 Ah solar battery & 2-volt, 200 Ah Industrial battery

(a)



(b)

Fig. 3.11: Battery (a) External & (b) Internal

3.9 Inverter

An inverter (Fig.3.12) is an electrical device that converts DC to AC; the resulting AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. Inverters are commonly used to convert power DC to AC such as solar panels or batteries. The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters was made to work in opposite, and thus was "inverted", to convert DC to AC.

Fig. 3.12: Inverter designed to provide 115 VAC from the 12 VDC source provided in an automobile.

3.9.1 String Inverter

Fig. 3.13: String Inverter

- There is some characteristic of string inverter (Fig. 3.13) -
- Good quality
- Available in small- and medium-sized Photo voltaic power station
- User-friendly Interface
- Power level 1.5KW to 6KW

3.9.2 Power Plant Inverter

Fig. 3.14: Power Plant Inverter

There is some characteristic of power plant inverter (Fig. 3.14) -

- Professional design for large-sized PV power station.
- Transformer type and transformer less type.
- Satisfy different requirement, predigest design of power plant.

3.9.3 Grid-tie Inverter

A grid-tie inverter (Fig. 3.15) or a (GTI) is a special type of Inverter (electrical) that is used in a renewable energy power system to convert direct current into alternating current and feed it into the utility grid. Grid interactive inverter which is used as the technical name for a grid-tie inverter. They may also be called synchronous inverters. Grid-interactive inverters typically cannot be used in standalone applications because there is no utility power available.

Fig. 3.15: Inverter for Grid Connected PV

3.10 Solar Home System

3.10.1 Why Suitable Technology for Our Country

Bangladesh is a populated country. Present population of this country is 16 cores and 71 lacks. About 63.5% people are living in villages [13]. There are many villages in our country having no electricity and some other villages have about 8-10hour load shedding daily. So, solar home system can give an alternate solution for electricity in these villages. It is an investment for a longtime completes the project of SHS because it is a renewable energy source. Solar radiation intensity is also suitable for this technology.

3.10.2 Components of Solar Home System

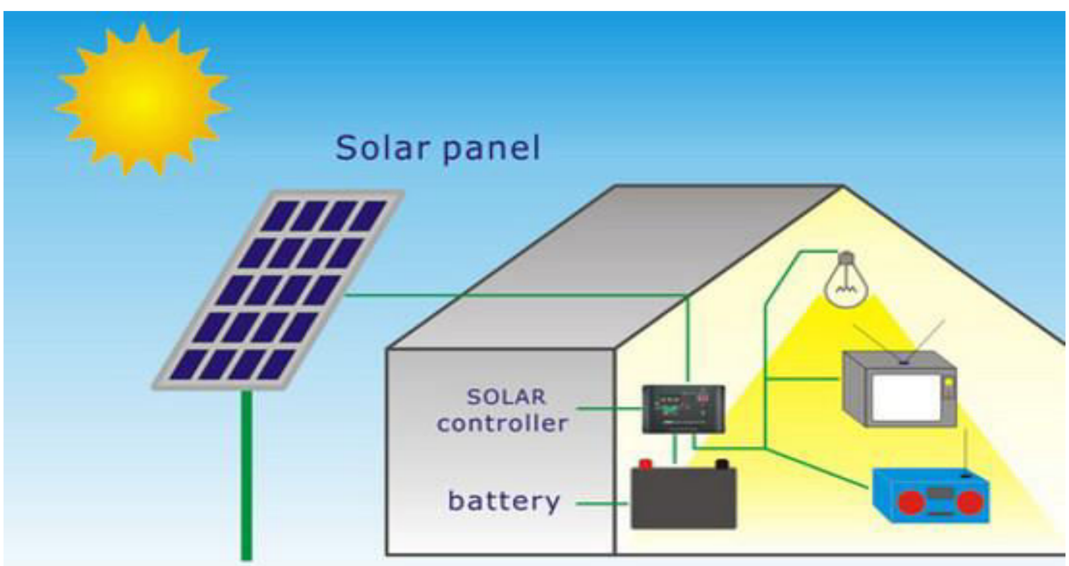


Fig. 3.16: Solar Home System

There are components of solar home system (Fig.3.16) -

- Solar PV module
- Charge controller
- Battery
- PV module supporting structure
- Load (light, fan, television etc.)

3.10.3 OFF-grid Solar Systems

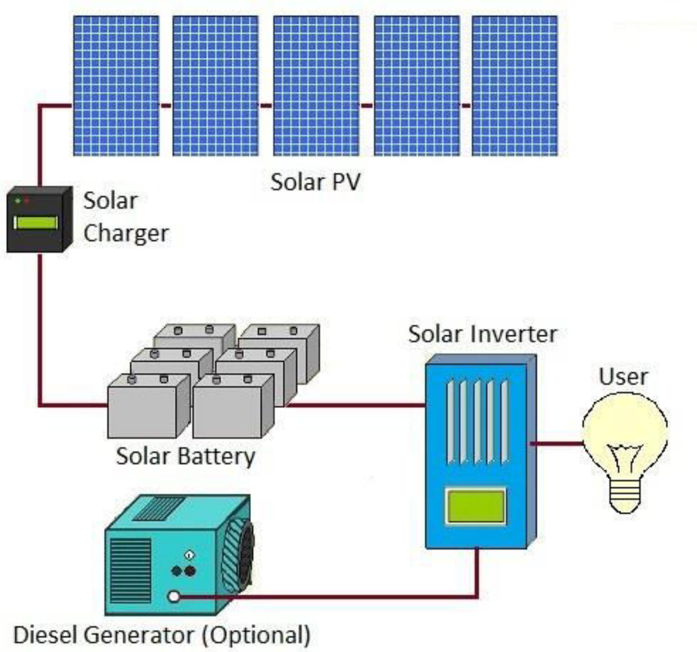


Fig. 3.17: Solar Off-Grid

In Bangladesh, people do not use inverter for AC load. They use only battery for DC load. But many countries they have both battery and inverter with their SHS. There are components of off-grid solar home system (Fig.3.17) -

- Solar module
- Charge controller
- Inverter
- Battery bank

CHAPTER 4

METHODOLOGY

4.1 Introduction

In this section, we will discuss the process of data collection method and research tools. The primary data that we have collected from our study area and secondary data we have collected from various paper.

4.2 Site Selection

A study area (Fig.4.1) is a place where we collect data for our necessary work and the selected place was Daffodil International University, Administrative Building rooftop. It is situated in 102 Sukhrabad, Dhaka 1207, Bangladesh. Different capacity types of solar panel have installed their -such as 45W, 60W and 100W. We study the performance analysis the power of 100W off grid solar panel.

Fig. 4.1: Off & On Grid Solar System on Rooftop of Daffodil International University

4.3 Satellite View

The satellite view of the working zone is shown in Fig. 4.2.

Fig. 4.2: Satellite View

4.4 System Design

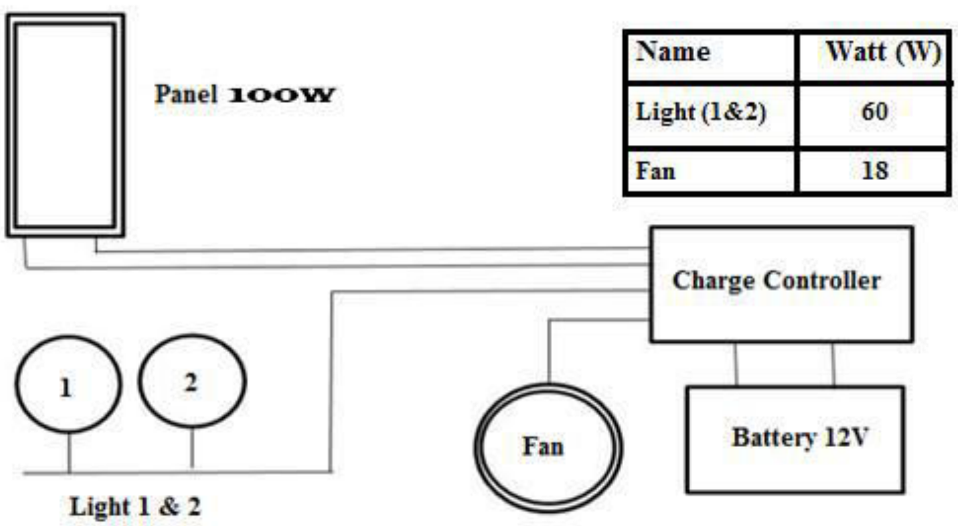


Fig. 4.3: System Design

4.5 Research Machineries & Tools

Some tools have been used to collect data such as I-V 400w, temperature sensor, 100W solar panel, irradiation sensor (HT304N).

4.5.1 100W Solar Panel

The solar cell is made in Germany. To measure the power in Standard Test Condition (STC), the cell temperature is 25°C. These solar cells are made in Germany and the efficiency of the 100W panel (Fig.4.3) is 14%.

4.5.1.1 Electrical Specifications

Maximum power: 100W

Open circuit voltage: 22.68V

Short circuit current: 5.60

Voltage at maximum power: 19.12V

Current at maximum power: 5.23A

Module dimension: 1100*680*3mm

Module weight: 8.1KGS±3%

Fig. 4.4: Solar Panel (100W)

4.5.2 I-V 400W

I-V400 W (Fig. 4.5) allows field detection of I-V Curve an of the main characteristic parameters both of a single module and of strings of modules for PV installations up to a maximum of 1000V and 15A. For calculating I-V Curve, I-V400 W manages an internal database of the modules, which can be updated at any time by the user and comparison between the measured data with the rated values permits immediately evaluating whether the string or the module fulfills the efficiency parameters acknowledged by the manufacturer.

Fig. 4.5: I-V 400 W Photovoltaic Panel Analyzer

4.5.2.1 Electrical Specifications of I-V 400 W

Table-4.1: Range and Accuracy of Photovoltaic Solar Panel Analyzer (I-V 400 W)

Parameter	**Range (V)**	**Accuracy**
VDC Voltage @ OPC	**5.0 - 999.9**	**±1.0%**
IDC Current @ OPC	**0.10 - 10.00**	**±1.0%**
Max Power @ OPC (Vmpp>30V, Impp>2A)	**50 - 9999**	**±1.0%**
VDC Voltage (@ STC and OPC)	**5.0 - 999.9**	**±4.0%**
IDC Current (@ STC and OPC)	**0.10 - 10.00**	**±4.0%**
Max Power @ STC (Vmpp>30V, Impp>2A)	**50 - 9999**	**±5.0%**
Irradiance (with reference cell)	**50 - 1400**	**±1.0%**
Temperature of module (with auxiliary PT1000 probe)	**-20.0 - 100.0**	**±1.0%**

4.5.2.2 General specifications of I-V 400 W

- **Display and memory of IV 400:**

  Features: 128x128pxl custom LCD with backlight

  Memory capacity: 256kbytes

- **Power supply:**

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

  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 interface**
  PC communication port: optical/USB
  Interface with SOLAR-02: wireless RF communication (max distance 1m)

- **Mechanical features**
  Dimensions: 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

4.5.3 Temperature Sensor

Temperature sensor (Fig. 4.6) senses temperature from the solar cell and sends data to the I-V 400w.

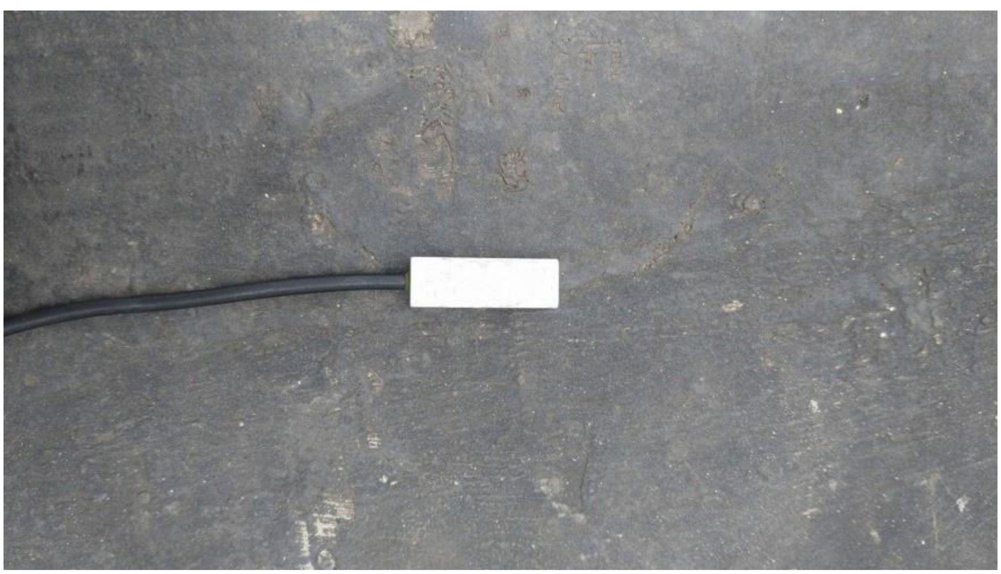


Fig. 4.6: Temperature Sensor

4.5.4 Irradiation Sensor (HT304N)

This device (Fig. 33) can able to measure as MONO PANELS or MULTI PANELS. It is a passive sensor and does not need any power supply.

Fig. 4.7: Irradiation Sensor

4.5.4.1 Technical Specifications of Irradiation Sensor

Table-4.2: Range & Accuracy of Irradiation Sensor

Parameter	Range [W/m2]	Accuracy
Irradiation	50 - 1400	±3.0% of readings

4.5.4.2 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 (LxWxH): 120x85x40 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.

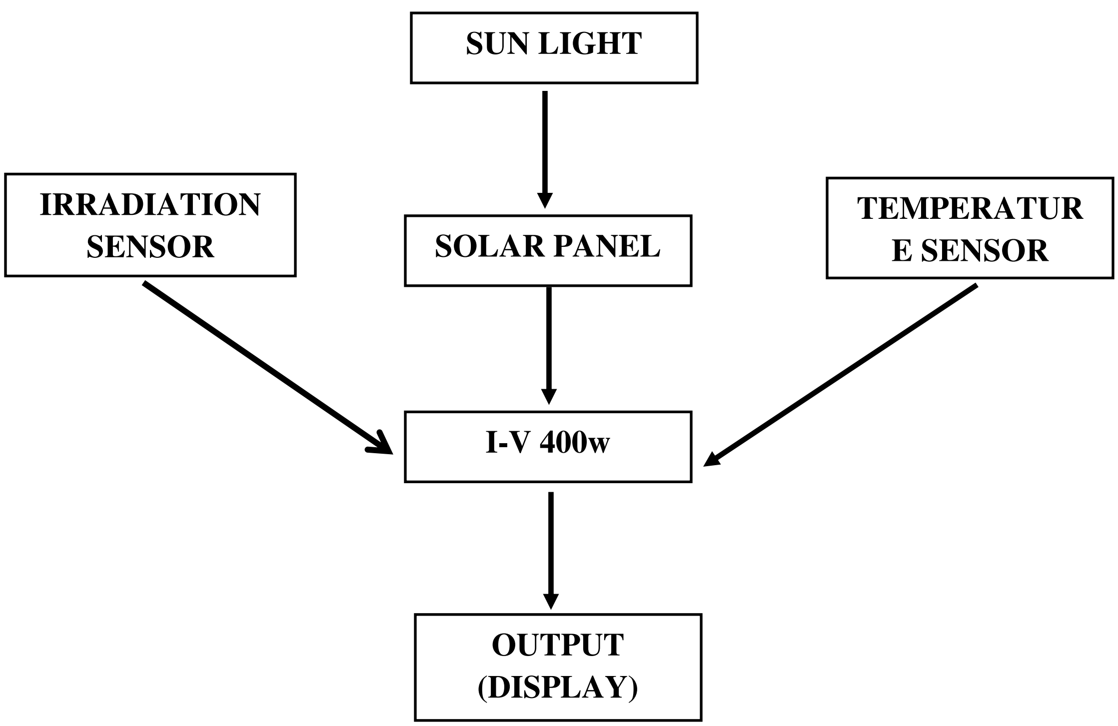


Fig. 4.8: Flow Chart of Data Measuring

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-4.1

Table-4.3: I-V 400 W Calibration.

Pmax	100 W
Voc	22.68 V
Vmpp	19.12 V
Isc	5.60 A
Impp	5.23 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

On May, we collected data (Fig. 35) from sunrise to sunset (time 5.14 to 18.35) and used I-V 400w photovoltaic panel analyzer to measure data. Firstly, the measurement tools of irradiation and temperature sensor related to I-V 400 W photovoltaic panel analyzer. Secondly, 45 W solar panel output cables related to I-V 400 W. The measured data was in Standard Test Condition (STD) and it was converted into Operational Condition (OPC) mode to measure the data.

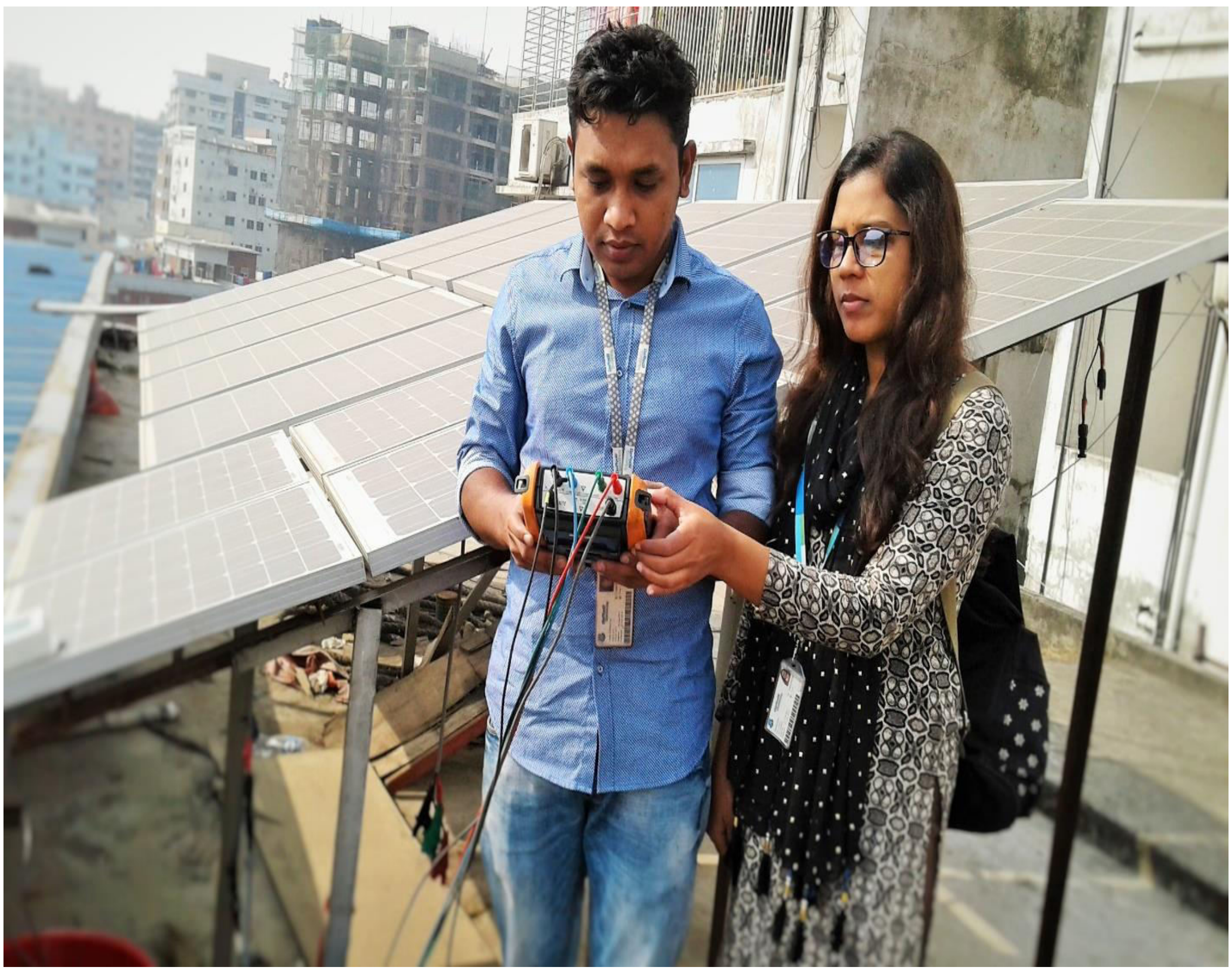


Fig. 4.9: Data Measurin

Table- 4.4: Measured Data of Solar System on 5 July 2018

5-Jul-18									
SL	Time (Sunrise to Sunset)	Irradiance (W/m2)	Voltage (V)	Current (I)	Vmpp(V)	Impp(I)	Fill factor	Pmax (W)	Efficiency (%)
1	5:16	0	0	0	0	0	0	0.00	0
2	6:16	0					0	0.00	0
3	7:16	0	0	0	0	0	0	0.00	0
4	8:16	377	20.4	2.12	18.9	1.25	0.54	23.53	0.83
5	9:16	400	20.3	2.32	18.6	1.77	0.70	32.92	1.18
6	10:16	344	20.3	2.19	18.5	1.80	0.75	33.30	1.2
7	11:16	171	19.4	0.96	16.9	0.68	0.62	11.53	0.65
8	12:16	752	19.6	3.29	17.8	2.90	0.80	51.62	2.9
9	13:16	170	20	1.15	16.7	0.82	0.59	13.68	0.78
10	14:16	959	20.1	5.23	17.8	4.02	0.68	71.56	2.68
11	15:16	536	20	2.40	17.2	2.01	0.72	34.49	1.91
12	16:16	307	19.9	1.46	17.6	1.10	0.67	19.40	1.05
13	17:16	112	18.9	0.68	16.1	0.51	0.64	8.21	0.34
14	18:49	0	0	0	0	0	0	0.00	0

Table-7 represents parameter-wise data of a single day (July 5, 2018) starting from sunrise to sunset. Where, Voc=Open Circuit Voltage, Isc=short circuit current, Vmpp=Maximum Power Point Voltage, Impp=Maximum Power Point Current, Fill factor=the ratio of maximum obtainable power to the product of the open-circuit voltage and short-circuit current, Pmax=maximum power, Efficiency= to the portion of energy in the form of sunlight that can be converted via photovoltaics into electricity.

CHAPTER 5

DATA ANALYSIS & RESULTS

5.1 Introduction

Bangladesh receives an average daily solar irradiation of 4 - 6.5 kWh/m2. The focus of this thesis is the measurement of solar irradiation, and the corresponding power generated by this panel.

5.2 Solar Data Analysis

In our solar lab, 100-Watt Solar Panel has been established in the top floor of DIU and area is 0.75 m2. The focus of this thesis is the measurement of solar irradiation, and the corresponding power generated by this panel. There are some parameters such as irradiance, Equivalent power, Pmax. Equivalent power is the multiplication between irradiance and panel area. Furthermore, Equivalent power is the input power of total solar panel (100W) & Pmax is the output generated power (Table-8). We have measured the data by I-V 400W Photovoltaic Panel analyzer (Operational Condition). The time duration of this experiment was 2 months (July and august 2018).

We can classification July and August between sunny and rainy day. This classification helps to find out clear analysis between irradiance and power.

We have measured our required data (Table-8) from sunrise to sunset (time 5.23 to 18.27). In time (514.) irradiance was zero and for the reason, we got maximum power zero. On the other hand, time (6.14) irradiance was 70 W/m2 and maximum power generated 4.68 W. Because we have got sunlight between time 5.14 and 6.14 that helps to produce irradiance. We collect our data every one-hour.

The equation of power, $P = V \times I$ & efficiency, $\eta = (Output/Input) \times 100\ \%$

Table-5.1: Represents Single Day (01 September 2018) Solar Irradiance, Equivalent Power and Generated Power.

01-Jul-18									
SL	Time (Sunrise to Sunset)	Irradiance (W/m2)	Voltage (V)	Current (I)	Vmpp(V)	Impp(I)	Fill factor	Pmax (W)	Efficiency (%)
1	5:14	0	0	0	0	0	0	0.00	0
2	6:14	70	19.4	0.40	15.6	0.30	0.60	4.68	0.3
3	7:14	53	18.4	0.33	14.5	0.23	0.55	3.35	0.21
4	8:14	496	20.4	2.85	18.2	2.19	0.69	39.86	1.46
5	9:14	342	19.6	2.12	17.4	1.83	0.77	31.84	1.22
6	10:14	355	18.6	1.35	17.8	1.19	0.84	21.18	1.19
7	11:14	410	19.4	1.80	17.3	1.20	0.59	20.76	1.2
8	12:14	608	20.6	4.85	18.7	3.18	0.60	59.47	2.12
9	13:14	900	20.6	4.63	18.1	3.64	0.69	65.88	3.64
10	14:14	736	20.2	4.23	18.6	3.23	0.70	59.99	2.15
11	15:14	403	19.8	2.12	17.6	1.54	0.65	27.10	1.4
12	16:14	0	0	0	0	0	0	0.00	
13	17:14	102	19.3	0.64	16.3	0.53	0.69	8.56	0.35
14	18:49	0	0	0	0	0		0.00	0

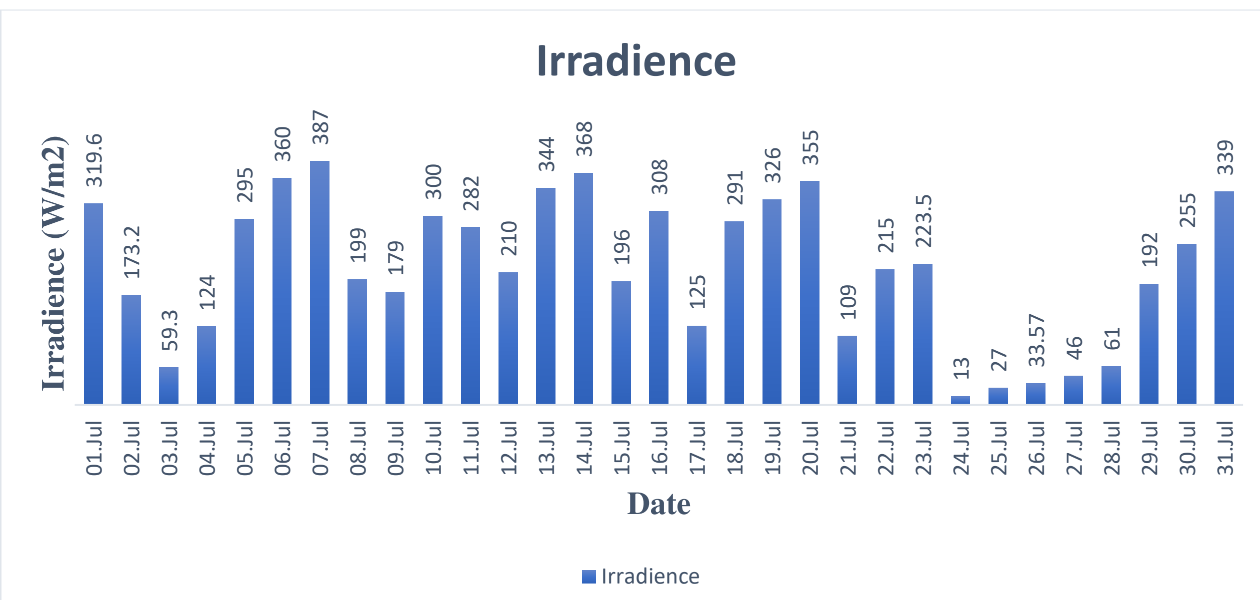


Fig. 5.1: Solar Irradiance, July 2018

Figure-36 shows the data of solar irradiation of July 2018. On 7 July 2018, the highest value of solar irradiance was measured that was 387 W/m2 and on 24 July 2018, the lowest value of irradiance was found that was 13 W/m2 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 216.61 W/m2 /day.

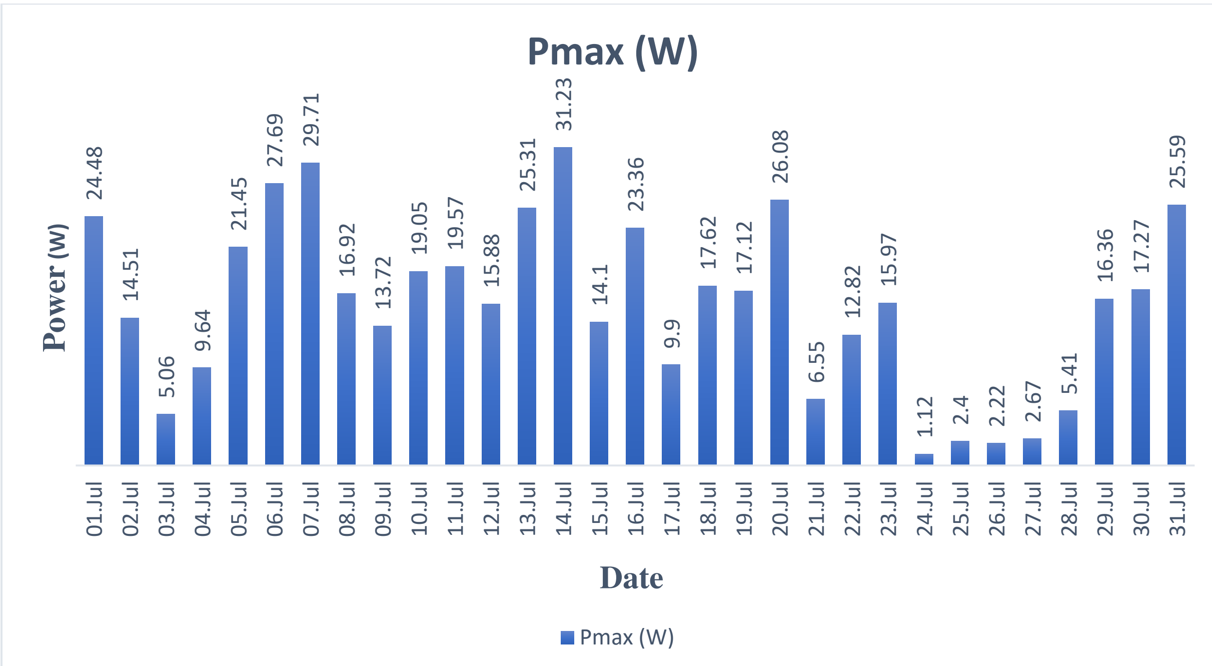


Fig. 5.2: Maximum Power, July 2018

Figure-37 represents the maximum power generation curve of 100 W solar panel in July 2018. On 14 September 2018, we have found the highest value of maximum power (31.23W) and the lowest value of minimum power (1.12W) in 24 July 2018. Monthly average power is 15.83 W.

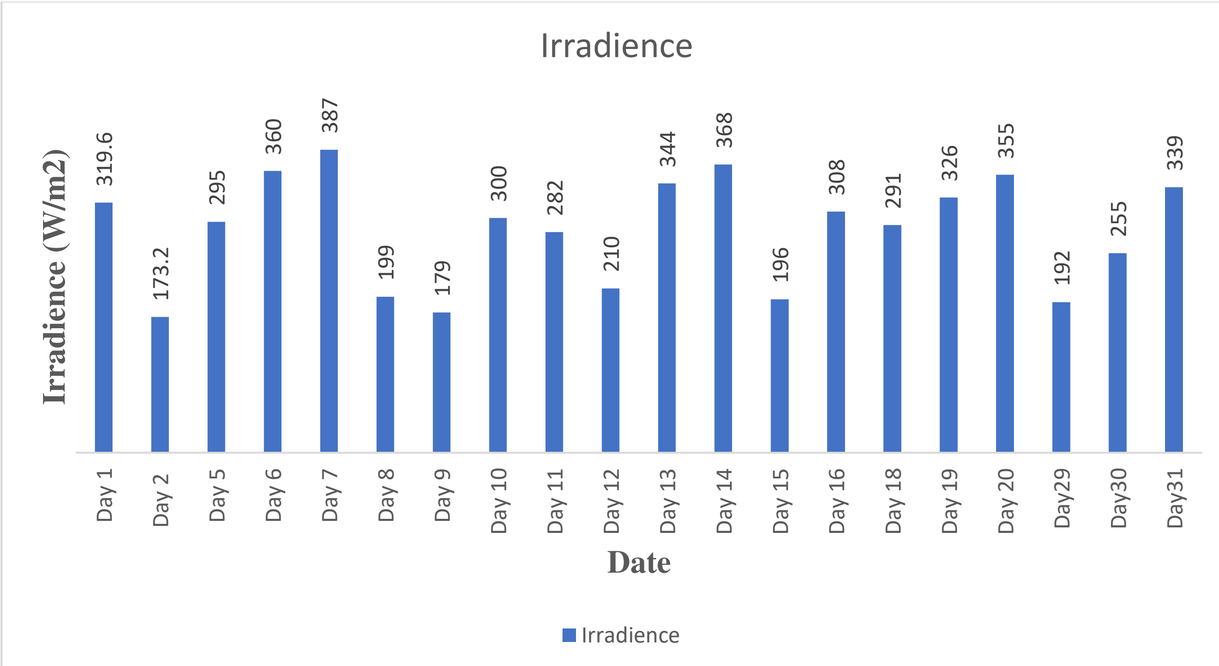


Fig. 5.3: Sunny Day Irradiance, July 2018

Figure-38 shows the data regarding the irradiance of sunny day in July 2018: During sunny day, we get the highest irradiance 387 W/m2. In sunny day, we measured our data every hour. The average irradiance of sunny day is 253.5W/m2.

.

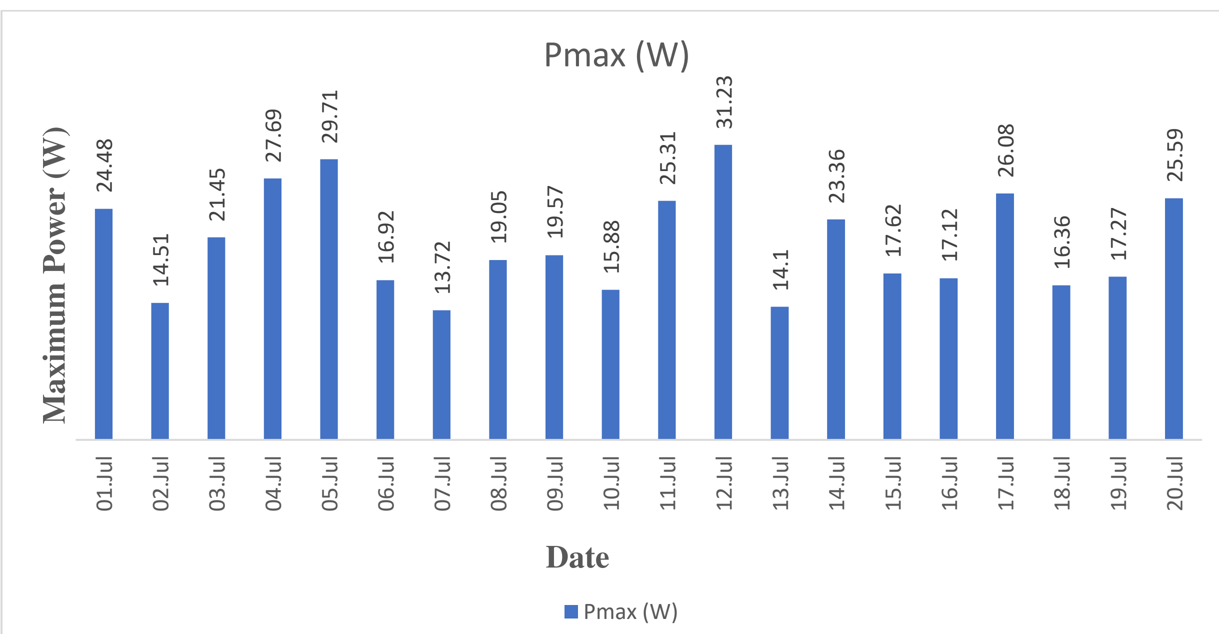


Fig. 5.4: Only Sunny Day Maximum Power, July 2018

Figure-39 shows the data regarding the generated power on sunny day (July 2018) from 100W solar panel.

On 7 July 2018, the measured irradiance was 387 W/m2 and the corresponding power produced by that panel was 29.71 W. However, the matter of concern that, on 7 & 14 September 2018, the measured irradiance was 387 & 368 W/m2 but the power produced by the panel was 29.71W& 31.23W which was higher than the previous one.

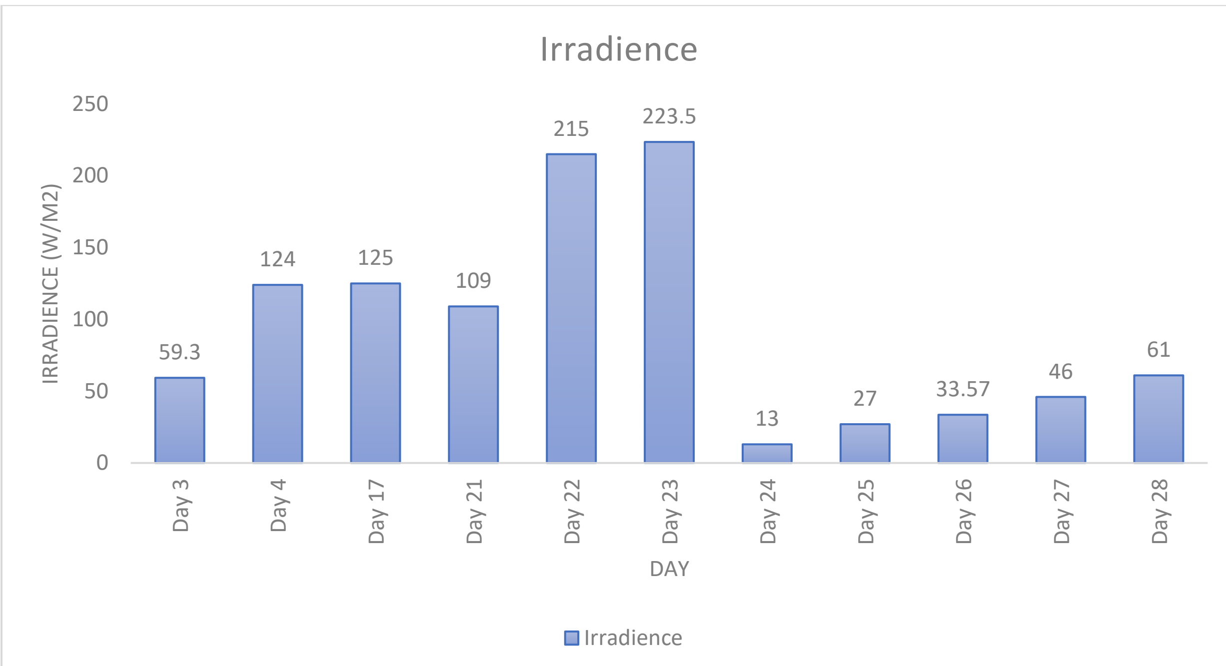


Fig. 5.5: Only Rainy-Day Irradiance, July 2018

Figure- 40 shows only rainy-day irradiance in July 2018: in rainy day, average irradiance is 194.18 W/m2. We got the highest & lowest irradiance 223.5/m2 & 15 W/m2 respectively. In rainy day, maximum time we cannot measure our required data in time.

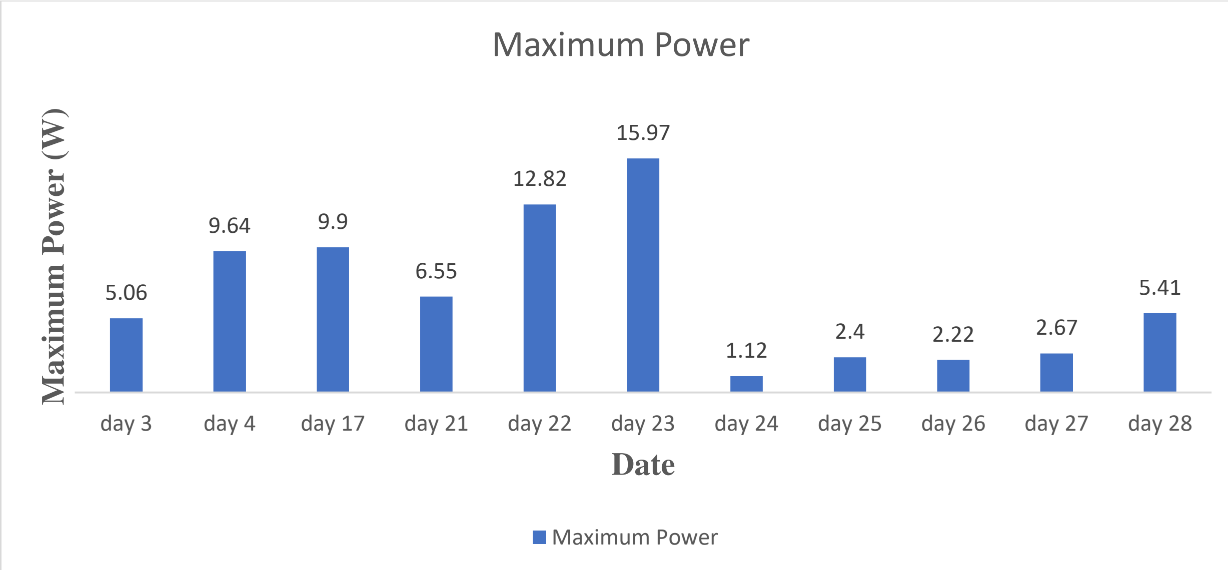


Fig. 5.6: Only Rainy-Day Maximum Power, July 2018

Figure- 41 shows. On 23 July 2018, we have found the highest value of maximum power (15.97W) and the lowest value of minimum power (1.12W) in 24 July 2018.

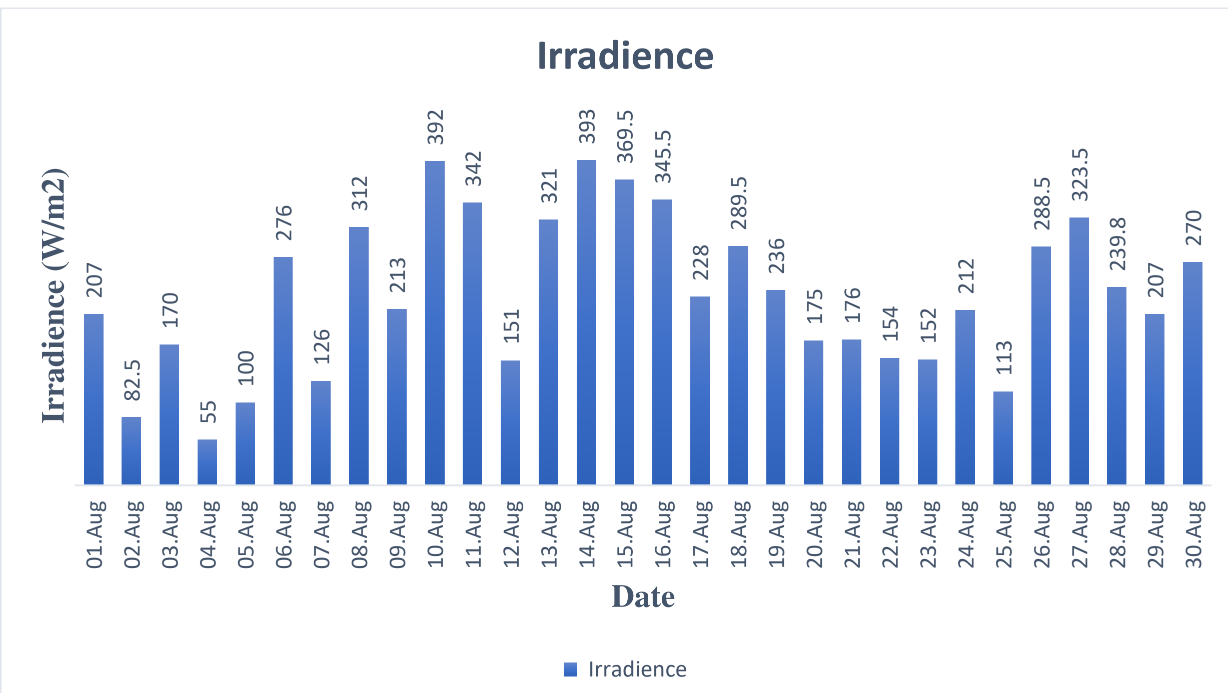


Fig. 5.7: Solar Irradiance, August 2018

Figure-42 shows the data of solar irradiation of August 2018. On 14 August 2018, the highest value of solar irradiance was measured that was 393 W/m2 and on 4 August 2018, the lowest value of irradiance was found that was 55 W/m2 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 got the lowest value. Moreover, August 2018 monthly average irradiation is 230.66 W/m2 per day or 18.21 kWh/m2/day.

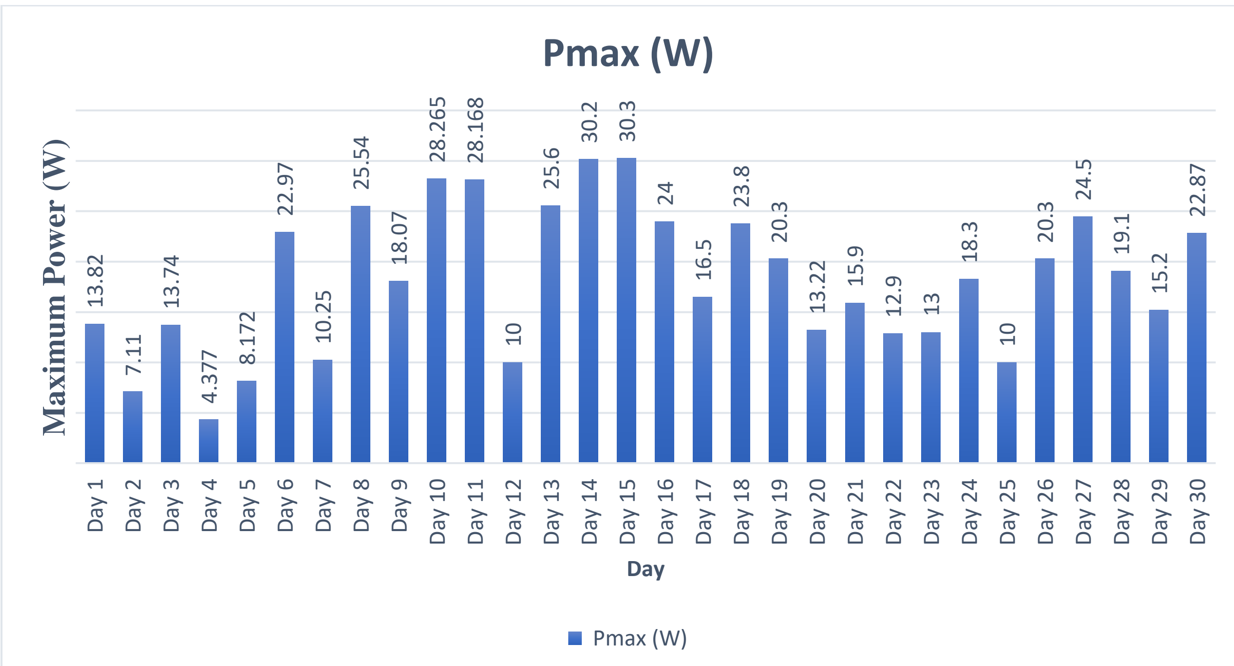


Fig. 5.8: Maximum Power, August 2018

Figure- 43 represents the maximum power generation curve of 100 W solar panel in August 2018. On 15August 2018, we have found the highest value of maximum power (30.3 W) and the lowest value of minimum power (4.377 W) in 4 August 2018. Moreover, October 2018 monthly average generated power is 18.215 W.

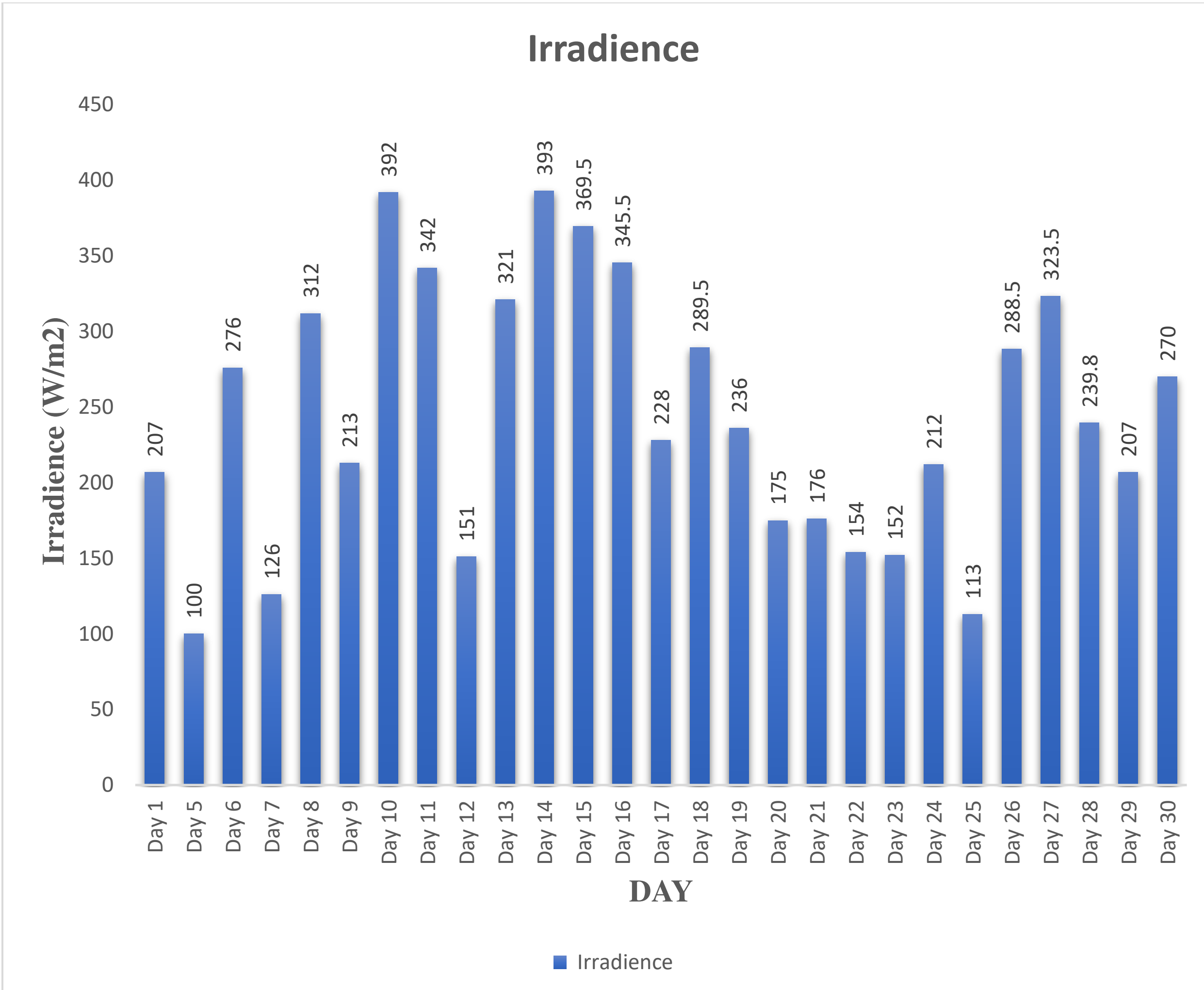


Fig. 5.9: Only Sunny Day Irradiance, August 2018

Figure-5.9 shows the data regarding the solar irradiance of sunny day in August 2018, the average irradiance in sunny day is 244.9W/m2. In sunny day, we measured our data every hour.

5.3 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 5.01 $kWh/m^2/day$ and the value of irradiation in 2009 was decreased and that was 4.73 $kWh/m^2/day$. 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.

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

Solar radiation data were collected from Renewable Energy Research Center (Dhaka University), National Renewable Energy Laboratory and Development and Research is given in Table-5.3. Most of these solar radiation data were collected from DU for Dhaka with different cities in Bangladesh. 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 Data from 1985-2005, 2008-2010, 2018 and Compare Irradiance Among them were Presented Below

Year	Month	Irradiance kWh/m^2/day
1985-1991	July	3.96
	August	4.7
1987-89	July	4.5
	August	4.61
1992	July	5.38
	August	4.93
2000-2003	July	3.76
	August	4.19
2003-2005	July	3.78
	August	3.57
2008	July	4.55
	August	4.31
2009	July	4.00
	August	4.53
2010	July	3.97
	August	4.20
2018	July	8.91
	August	7.62

Table 5.4 after analyzing we can say that in the month of September, we got the highest amount of Irradiance than October. In the year 1985-1991, September & October average solar irradiation was 3.96 & 4.7 kWh/m^2/day and it was increased into 5.38 & 4.93 kWh/m^2/day in 1992. But in 2000-03, September & October average irradiation was 3.76 & 4.19 kWh/m^2/day which was decreased into 3.78 & 3.57 kWh/m^2/ day in 2003-05. In 2008, irradiation was increasing, and the value was 4.55 & 4.31 kWh/m^2/day. Again in 2010, irradiation was

decreasing, and the value of 3.97 & 4.2 kWh/m^2/day. Moreover, in 2018, irradiation was increasing, and the value of 8.91 & 7.62 kWh/m^2/day.

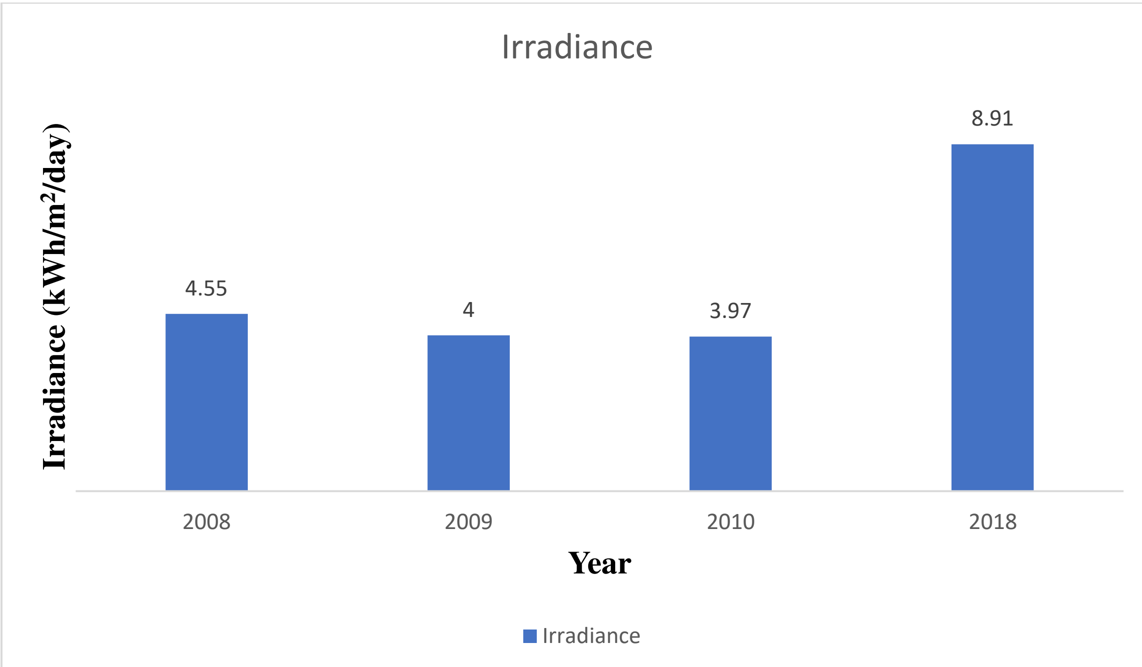


Figure 5.10**:** Irradiance on different years

Furthermore, in 2018, Irradiance is highest than another year, for that reason, we can certainly say that global warming is increasing day by day.

CHAPTER 6

CONCLUSIONS

6.1 Conclusion

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 September and October 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 May 255.44 W/m^2 and June was 236.24 W/m^2. And corresponding power produced by 60W solar panel was 7.29 W and 7.11 W respectively.

The summary of this paper exhibits that, there is a considerable opportunity to meet the future power demand of Bangladesh by SHS technology. Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east latitude which is a good location for solar energy utilization. Daily average solar irradiation varies between 4 to 6.5 kWh per square meter. Most extreme measure of radiation is accessible in the long stretch of April-May and least in December-January.

Solar energy sources discussed above can help Bangladesh to produce more power to reduce Load-shedding problem. Time has come to look forward and work with these renewable energy fields to generate electricity rather than depending wholly on conventional method. Already SHS established in our country. Now-a-days the momentum, dynamics and sustainability of a civilization depend on energy. Hence, a country can be considered as civilized one if it has enough access to energy as required for the industrial, agricultural and economic growth. There are lots of sectors to use solar electricity in rural area of Bangladesh

6.2 Future scope

In this research, we try to clarify that how much power can be produced in the month of May & June 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.

Innovation in solar technology continues to improve efficiency, size and cost, making it more pervasive throughout society. The trend is leaning toward incorporating solar into more buildings beyond panels placed upon the roof. Cool applications include: solar shingles, solar film, solar roadways, and solar windows.

Other innovations being explored are: the solar orb, solar cars (commercially available), solar balloons, nanowires, and working with the infrared spectrum. As the manager of the Green Mountain Energy Sun Club, I'm excited about these advances in solar technology and the growing part this pollution-free resource will provide in our lives. A solar future is closer than you may think!

REFERENCES

[1]http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=8A305DC0E2D69CCAEAACE562C3A0ADB0?doi=10.1.1.685.1465&rep=rep1&type on 12 August 2018.

[2] Bahauddin KM, Salahuddin TM. Prospect and trend of renewable energy and its technology towards climate change mitigation and sustainable development in Bangladesh. Int J Adv Renew Energy Res 2012; 1:158.

[3] Biswas WK. Empowering rural poor through renewable energy technologies in Bangladesh, (unpublished Ph.D. thesis). NSW, Sydney, Australia: University of Technology; 2002.

[4] Islam MR, Baksi BK, Momotaz SN. Prospects of renewable energy in Bangladesh focus on biomass plant. J Bus Res 2002; 4:1–18.

[5]https://www.dhakatribune.com/bangladesh/power-energy/2017/08/31/first-ever-solar-plant-connects-national-grid/ on 15 August 2018.

[6]https://www.dhakatribune.com/bangladesh/power-energy/2017/10/27/beximco-set-200mw-solar-power-plant-gaibandha-chinese-company/ on 17 August 2018.

[7] http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=26 on 17 August 2018.

[8]http://www.daily-sun.com/arcprint/details/239333/PDB-in-deal-with-China-firm-for-solar-power-plant-at-Kaptai/ on 17 August 2018.

[9] https://cleantechnica.com/2018/02/27/scatec-solar-plans-800-megawatt-solar-project-bangladesh/ on 21 August 2018.

[10] Rasel MAI, Siraj S, Rahman KM. Prospect of renewable energy as the solution of the existing energy crisis of Bangladesh. Int J Sci Eng Res 2012; 3:3–5.

[11] https://www.thedailystar.net/frontpage/bangladesh-leads-clean-energy-use-1418806.On 21 August 2018.

[12] http://www.worldometers.info/world-population/bangladesh-population/ on 7 November 2018.

[13] https://en.wikipedia.org/wiki/World_energy_consumption on 7 November 2018.

[14] Source: http://www.sreda.gov.bd on 21 August 2018.

[15]http://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustion2017Overview.pdf on 22 August 2018.
[16]http://www.powerdivision.gov.bd/user/brec/50/91 on 22 August 2018.
[17] Duan, C., Wang, C., Li, Z., Chen, J., Wang, S., Snyder, A., & Jiang, C. (2018, June). A Solar Power-Assisted Battery Balancing System for Electric Vehicles. IEEE Transactions on Transportation Electrification, 4(2), pp. 432-443. doi:10.1109/TTE.2018.2817123.
[18] Commerell, W., Müller, R., & Shan uganandam, V. (2014). Life time costs in solar home systems. 2014 3rd International Conference on the Developments in Renewable Energy Technology (ICDRET), pp. 1-5. Doi: https://doi.org/10.1109/ICDRET.2014.6861700. 60
[19] Islam, T., & Awal, M. A. (2014). Efficient load and charging method for solar powered home lighting system of Bangladesh. 2014 3rd International Conference on the Developments in Renewable Energy Technology (ICDRET), Dhaka, Bangladesh, pp.1-3. doi: https://doi.org/10.1109/ICDRET.2014.6861666.
[20] Deb, A., Bhuiyan, M. A., & Nasir, A. (2013, Jan. - Feb.). Prospects of Solar Energy in Bangladesh. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), 4(5), PP 46-57.Retrievedfrom http://www.iosrjournals.org/iosr-jeee/Papers/Vol4-issue5/H0454657.pdf. On 23 August 2018.
[21] Biswas, W. K., Diesendorf, M., & Bryce, P. (2004, July). Can photovoltaic technologies help attain sustainable rural development in Bangladesh? Energy Policy, 32(10), pp. 1199-1207. Retrieved from https://www.sciencedirect.com/science/article/pii/S0301421503000831.
[22] Rebane, K. L., & Barham, B. L. (2011, June). Knowledge and adoption of solar home systems in rural Nicaragua. Energy Policy, 39(6), pp. 3064–3075. doi: https://doi.org/10.1016/j.enpol.2011.02.005.
[23] GOLDEMBERG, J. (2000): Rural Energy in Developing Countries. In: GOLDEMBERG, J. (Ed.): World Energy Assessment: Energy and the Challenge of Sustainability. New York: 367-389.
[24] BARKAT, A. (2004): Bangladesh Rural Electrification Program: A Success Story of Poverty Reduction through Electricity. Dhaka.
[25] Government of Bangladesh (GOB) (2004): The Constitution of the People's Republic of Bangladesh. Internet: http://www.pmo.gov.bd/constitution/index.htm (02.03.2007).

[26] BARNES, D.F. (Ed., 2005): Meeting the Challenge of Rural Electrification in the Developing World: The Experience from Successful Programs. Washington, D.C.
[27] MIYAN, M. and John RICHARDS (2004): Energy Policy for Bangladesh.
[28] ISLAM, K. (2004): The “Road Map to Renewable” for Bangladesh. Bangladesh Renewable Energy Newsletter. Enlarged Issue. Vol. 4 (1&2); Vol. 5 (1&2). 3-30.
[29] ISLAM, K. (2005): Photovoltaic (PV) Market Potential in Bangladesh. Constraints, Future Potential Diversification. In: EUSUF, M. (Ed.): Solar Photovoltaic Systems in Bangladesh. Experiences and Opportunities. Dhaka. 75-84. 61