SOLAR RADIATION PATTERN ANALYSIS FOR ELECTRICITY GENERATION OF BANGLADESH

This thesis presented in partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical and Electronic Engineering.

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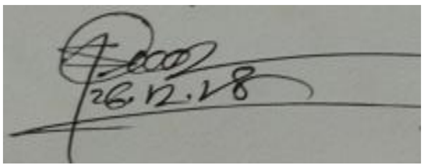

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APPROVAL

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LIST OF ABBREVIATIONS

AC	Alternating Current
BRAC	Bangladesh Rural Advancement Committee
BAEC	Bangladesh Atomic Energy Commission
BPDB	Bangladesh Power Development Board
BCSIR	Bangladesh Council of Scientific and Industrial Research
CMES	Centre for Mass Education in Science
DC	Direct Current
DU	Dhaka University
DLR	Research and Development
EJ	Exajoule (10^{18}joules)
GTI	Grid Tie Inverter
GHI	Global Horizontal Insulation
GOB	Government of Bangladesh
IDCOL	Infrastructure Development Company Limited
IFRD	Institute of Fuel Research and Development
IFST	Institute of Food Science and Technology
LPG	Liquefied Petroleum Gas
MPPT	Maximum Power Point Tracking
NGO	Non-Government Organization
NREL	National Renewable Energy Laboratory

NRECA	National Rural Electric Cooperative Association
OPC	Operational Condition
PV	Photovoltaic
PWM	Pulse Width Modulation
PW	Peta Watts
REB	Rural Electrification Board
RETs	Renewable Energy Technologies
RERC	Renewable Energy Research Centre
SHS	Solar Home System
STC	Standard Test Condition
SOC	State of Charge
SDGs	Sustainable Development Goals
SODIS	Solar Water Disinfection System
USAID	United State Agencies for International Development
WB	World Bank

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ABSTRACT

Power is one of the most important factors in a developing country and for a sustainable economy. Like the rest of the countries of the planet, in Bangladesh, the demand for power is increasing day by day. The existing reserve of oil and gas will be exhausted very soon. In that case, we have to think about another source of energy. Solar energy can be that alternative source of energy. Solar energy has the greatest potential of all the sources of renewable energy. If only a small amount of solar energy could be used, it will be one of the most important supplies of energy. The main aim of our research is to find out the irradiation of sun in Dhaka city so that the power production by the solar panel can be estimated. For this reason, we collect the solar irradiation and the maximum power data from the solar panel in Dhaka for (October & November) two months and then analyze the data to get average irradiation. We also find out the relationship between solar irradiation and power. From this analysis, we can easily understand the electricity production by the solar home system and create a standard form of power production of the solar home system in 2018. For analyzing the irradiance and power we take all day data in each of hour in daytime. Then we convert the data into all day average data. We also find out the efficiency of the solar panel. We also collect some data from previous years and compare them with our data. In this research, we try to clarify that how much power can be produced in the month of October and November 2018.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Bangladesh is one of the thickly populated nations which have not sufficient supply of energy. In Bangladesh, about 80% of the general population live in the village and just 32% of the aggregate populace is associated with grid electricity. Thinking about the present interest for electricity; by 2020 the energy blend will be changed significantly from what it is today. The chances of utilizing solar power are as of now being tried and will generally increment. Yet, most families meet they're every day prerequisites with biomass fuel. With just 60% of Bangladeshis approaching electricity, the per capita energy utilization is just 292 kWh per annum [1]. Solar power frameworks are contributing a colossal measure of energy with the goal that it can moderate the present energy emergency, particularly in rural regions of Bangladesh. Additionally, 30 associations in Bangladesh are directing solar energy organizations [2]. Bangladesh is situated between 20.30 – 26.38 degrees north scope and 88.04 – 92.44 degrees east longitude.

Day by day normal solar light rate is 4 to 6.5 KWh per square meter. The greatest measure of radiation is accessible on the long stretch of March-April (6.5h) and least on December-January (4h). At present, just 62% (counting renewable energy) of the aggregate populace in Bangladesh approaches electricity however in the rural zone, they are denied from electricity. Roughly 60 million individuals or 38% of the populace in Bangladesh have no entrance to electricity and they rely upon characteristic sources.

Bangladesh Rural Advancement Committee (BRAC), a Non-Government Organization (NGO) began the Solar Energy Program for supportable improvement in 1997 [3,4]. The 3MW solar power plant has been built up at Sarishabari in Jamalpur by a neighborhood organization, Engreen Sharishabari Solar Plant Ltd [5]. Which is the principal solar power plant in Bangladesh? Bangladesh Power Development Board (BPDB) is getting 33/11 KV power from this segment. PV frameworks use daylight to produce electricity. Notwithstanding the panels, a PV framework ordinarily contains an inverter to change over solar power from DC to the AC of the utility grid power transmission and conveyance framework. Beximco with the Chinese organization is setting up a 200MW solar power plant in Gaibandha [6]. Under the Hill Tracts Electrification Project BPDB, the aggregate of 173.81 kW, Solar PV Systems has installed in Juraichori, Barkal and Thanchi Upazila of Rangamati District. In Angoorpota and Dohogram Chitmohol BPDB actualized 1.06 kW solar PV frameworks in 2008-09. Additionally, BPDB actualized 20.16 KW solar PV framework at the workplace of the head administrator on December 2009 [7]. In Chittagong, a 7.4 MW solar power plant was built up at Kaptai hydropower station [8]. An 800MW solar power undertaking will set up by Scatec Solar at Chandpur in southern Bangladesh [9].

The solar home framework assumes a fundamental job for the rural jolt in Bangladesh and thus SHS is expanding step by step. As indicated by power and energy service information, 2.86% of all power created in this country originates from renewable energy, including solar power. Then again, Renewable energies like breeze, solar, biomass, geothermal, hydropower energy are ecologically inviting.

Presently multi day's solar energy is particularly mainstream in our country. Essentially, wind energy power is specifically relative to the speed of the breeze. In addition, the wind is an accessible renewable energy source. Bangladesh Council of Scientific and Industrial Research (BCSIR), Institute of Fuel Research and Development (IFRD) and Center for Mass Education in Science (CMES) cooperated to make a minimal effort and lightweight solar cooker and they have done it effectively. However, the manual sun following framework is the main issue of the cooker. On a brilliant bright day, it will take around three hours to cook for 5– 6 relatives. IFST is chipping away at a practical Solar Dryer. They have advanced a bureau dryer for drying organic products, vegetables and so forth. IFRD planned it and solar radiation has consumed by a covered level plate and changes over into warmth, after that it exchanges the subsequent warmth to flowing water. This sort of radiator is appropriate for providing second-rate warm energy at temperatures underneath 90 °C [10].

Then again, other renewable like breeze, biomass can be an incredible energy hotspot for Bangladesh. Wind energy is specifically corresponding to the speed of the breeze. Biomass energy can be delivered by consuming natural material that originates from plants and creatures. Wood is biomass energy. Biomass is a renewable energy as well as the economic wellspring of energy. Also, hydropower is one of the most seasoned sources of energy to create mechanical and electrical energy. In addition, Hydropower utilized a huge number of years prior to turn paddle wheels to enable granulate to grain. In this way, hydroelectric power is created by moving water. Here, water is the primary source. Kaptai dam is the main hydroelectric power station which is arranged in Bangladesh. The greatest measure of power is produced by the Kaptai hydro-electric power station, which is near the waterfront region.

In 2012, interests in solar advancements were just $3 million. By 2015, that figure had expanded to $158 million, developing to $223 million out of 2016. The activity division in the solar is quickly rising. With regards to Bangladesh, the number of occupations in solar PV rose 10% in 2016. The most astounding number of SHS have installed in Bangladesh and accomplished the best position among a worldwide rundown of nations [11]. The data identified with power renewable energy appeared in table-1.

Table-1: Present Power Generation from Renewable Energy in Bangladesh (2018) [12]

Technology	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	268.29	17.35	285.64
Wind	2	0.90	2.90
Hydro	-	230	230
Biogas to Electricity	0.68	-	0.68
Biomass to Electricity	0.40	-	0.40
Total	271.37	248.25	519.62

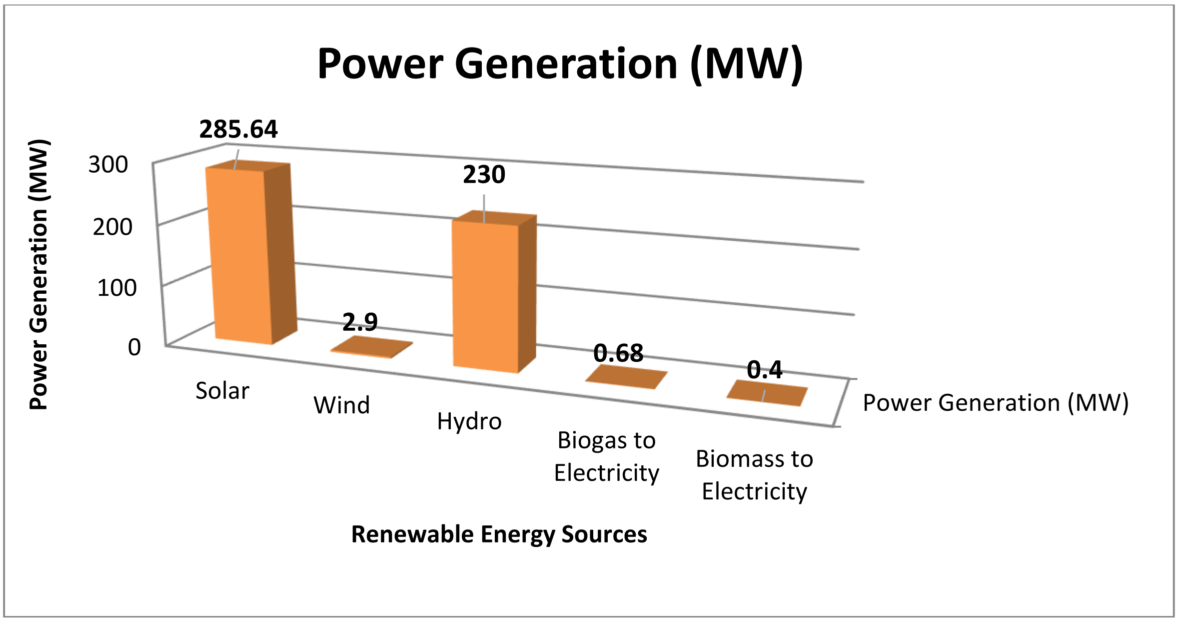


Fig. 1 Power Generation curve in Bangladesh

From the Fig.1, we can investigate how much power generation from renewable energy in 2018. Add up to generate power from solar energy is 285.64 MW which is the most noteworthy power generation among other renewable energy. The least power generation is 0.40 MW from the biomass in Bangladesh.

1.2 Energy Crisis in Bangladesh

Around 140 million populace of Bangladesh has for quite some time been experiencing energy starvation, of which 80% live in towns. Bangladesh will look in not so distant future an emergency in energy division. Kindling, straws and bovine compost are as yet the primary wellsprings of energy in the towns. Gaseous petrol discovery does not make any assistance to the villagers. All through the country trees are being fallen haphazardly by the thousands to consume block which may offer ascent to an appalling scene of deforestation and cause biological unevenness in not so distant future. With a view to tackling the issues incompletely, the time has come to consider renewable sources of energy as an enhancement to the current customary resources. Nature gives us a few renewable sources of energy, for example, daylight, wind and tidal power. Dissimilar to non-renewable energy source energy from these resources can be utilized for a very long time. Science approached with catching the huge energy that the sun surges the earth each day. A few gadgets have been worked out for catching and putting away solar energy.

Utility and possibility of the renewable sources of energy ought to be examined with due thought. It is mandatory since dread of lack in traditional energy sources. This is effortlessly comprehended when we put a measurement on the energy asset accessibility, utilization, and reliance on the import of fuel.

1.3 Articulation of the problem

Bangladesh is a little nation with extensive populace and land is the most serious issue in Bangladesh. The non-agribusiness unused land isn't accessible in Bangladesh. Securing land is the most concerning issue for fast development of on-grid solar power system. Besides, the panel, charge controller and battery quality are bad enough. Moreover, the power factor of the heaps does not mull over. Non-renewable energy sources greatly use in Bangladesh. The majority of the general population in Bangladesh live in the rural region where they severely need vitality. We have an absence of research data in the solar field. Bangladesh has no processing plant to create a battery, solar cell, controller and other essential equipment. Unscrupulous agent supplies low-quality equipment which seriously impacts. The equipment is exorbitant and thus, here and there it is outlandish for the general population to supplant new equipment.

1.4 Objectives

The objective of this thesis is

- To col1ect solar irradiation and maximum power data in Dhaka for (October and November) two months.
- To analyze data to get average irradiation and find the relationship between solar irradiance and power.
- To study the 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.

1.5 Significance of this Research

Bangladesh is a tropical country of colossal solar energy. In any case, a next to no measure of this energy is utilized. Despite the fact that the initiation of SHS in Bangladesh happened in 1988 yet it was undiscovered for a significant lot. At this point, different utilizations of solar electricity are seen all throughout the world. Presently a-days Solar Panel gives electricity to solar immunization icebox, solar water sterilization (SODIS), solar sustenance drier and solar purification. This helps for diminishing waterborne ailments. Solar telephone, solar Wi-Fi, solar radio increment rural correspondence, decreases transport cost and lessen computerized separate. Alongside solar cooker and solar water warming, dependence on customary energizes, for example, wood or charcoal, diminishes indoor contamination and carbon discharge. This expands the personal satisfaction in rural regions, enhance wellbeing and training, lessen oil reliance, increment nearby business and diminish deforestation. Solar power exercises lead rural improvement. Because of the absence of data and study, SHS is utilized just for family unit lighting in Bangladesh.

Solar water system innovation is likewise getting prominent in Bangladesh. As horticulture based country, utilizing solar power water system framework would be a noteworthy main thrust for rural advancement. Government Association, Academic establishments, NGOs and privately owned businesses are engaged with renewable energy division in the country. Specialist, approach creator, improvement accomplice in Bangladesh recognized the enormous prospect of solar electricity for rural change. Be that as it may, there is no coordinated investigation of the prospect and extent of solar electricity for financial improvement in the rural zone of Bangladesh. Then again solar illumination of an explicit place (DHAKA) isn't in any case estimated in hourly premise inconsistently. Along these lines, the information of light isn't precise and by this investigation, we will top off the examination hole and get the exact information of sun radiation of Dhaka and its relating electric power. Starting at now there is exceptionally restricted scholarly investigation into the financial or natural effect of solar electricity in the rural region. In this way, the examination would help the worry policymakers and implementers to take important measures for feasible rural improvement in Bangladesh. Distinguishing the new inventive utilization of solar electricity in rural regions would help the implementers for powerful arranging and undertaking programs.

1.6 The Layout of Study

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

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this advanced time, individuals have accepted solar energy as the other of grid electricity. Solar Energy is an incredible hotspot for settling the power emergency in Bangladesh. A solar PV framework is a critical rising choice to supply electricity with quality light, dependable administration, and long-haul manageability.

2.2 What is Energy

The ability to do work is called energy. The SI unit of energy is joule or newton-meter. Likewise, the SI unit of work is joule. While moving a question, the mechanical energy changed over into the active energy of the body. Energy can be characterized as renewable energy and non-renewable energy.

2.3 Renewable Energy

Renewable energy will be energy delivered from normal resources, for example, daylight, wind, rain, tides, and geothermal warmth—which are renewable (normally recharged). Hydroelectricity was the following biggest renewable source, 15% of worldwide electricity generation and giving 3% of worldwide energy utilization. Wind power is developing at the rate of 30% every year, with an overall installed limit of 121,000 MW in 2008 and is broadly utilized in European nations and the United States. The yearly assembling yield of the photovoltaic business achieved 6,900 MW in 2008, and PV power stations are famous in Germany and Spain. Solar warm power stations work in the USA and Spain, and the biggest of these is the 354 MW Solar Electric Generating System (SEGS) power plant in the Mojave Desert.

The world's biggest geothermal power establishment is The Geysers in California which limit of 750 MW. Brazil has one of the biggest renewable energy programs on the planet which is including the generation of ethanol fuel from sugar stick, and ethanol currently gives 18% of the country's car fuel. Ethanol fuel is additionally comprehensively accessible in the USA. While most renewable energy activities and generation is extensive scale, renewable advancements are likewise suited to little off-grid applications, here and there in rural and remote zones, where energy is frequently significant in human improvement. Kenya has the world's greatest family unit solar possession rate with approximately 30,000 little (20– 100 watt) solar power frameworks sold every year. Some renewable-energy innovations are reprimanded for being discontinuous or unattractive and the renewable-energy advertise keeps on developing. Environmental change nerves, combined with high oil costs, top oil, and expanding government bolster, are driving expanding renewable energy enactment, motivations, and commercialization.

2.4 Renewable Energy Sources

Bangladesh is an extensive and vigorously thickly populated country in South Asia, flanking Burma, India, Nepal, and Bhutan. Bangladesh has an expected 2016 populace of 168.9 million. For destitution lightening, quick and manageable monetary development, innovative improvement energy all the more unequivocally electricity is the most principal pre-imperative. The country has been confronting extreme power deficiency for most recent couple of decades and it a matter of distress in one decade from now the entirety of our normal resources will complete and we fall in a profound sea of lack of resources, so now the time has come to contemplate the common resources and progressively about the renewable energy sources. Our country is honored with the number of potential and renewable sources. Energy sources which are recovered after a specific timeframe cycle are commonly known as renewable sources of energy. Generally utilized renewable energy sources are Solar, Wind, Hydro, Biomass, and Biogas. In Bangladesh, solar energy, biomass, biogas is being utilized since the time immemorial. Particularly regions which are out of grid association and gas inclusion, utilization of biogas for cooking, bridling wind power and solar energy for drying of various grains and garments is known to all. Anyway, for the absence of legitimate mechanical headway, approach requirement, and usage, we are as yet lingering behind in advancement and mass utilization of renewable sources contrasted with other created and creating nations on the planet.

Renewable energy is perfect, sound and condition cordial. A brief outline of all the accessible renewable energy sources that are found in this country domain is given in the area [10]. In figure 2.1 we can see the situation of the creation of renewable energy in 2008.

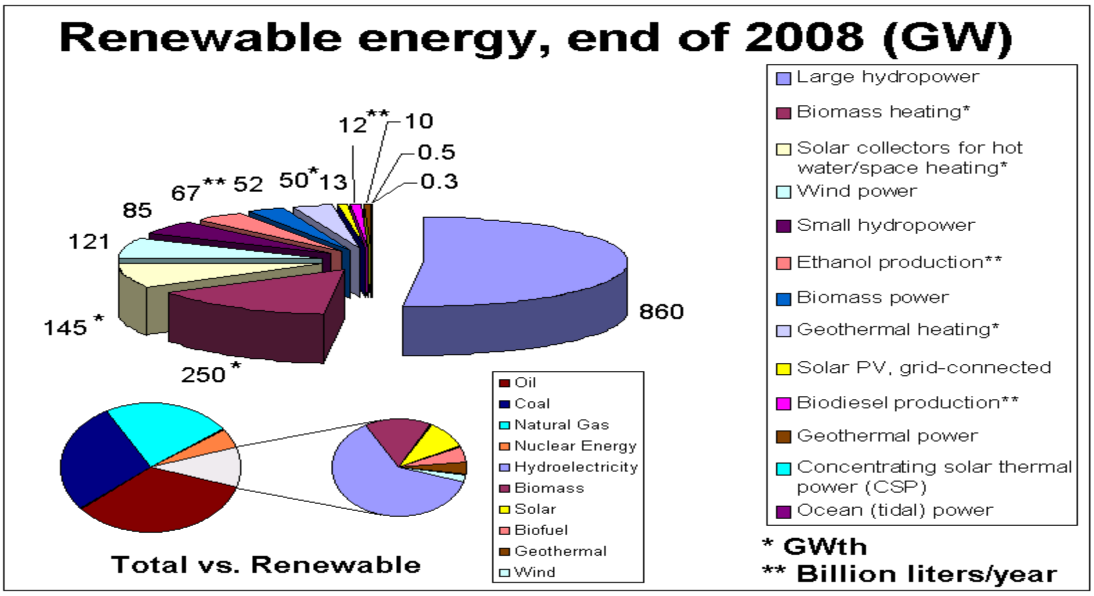


Fig 2.1: Renewable energy end of 2008

2.4.1 Biomass Energy

The energy which is discharged by copying and can be changed over into biomass energy. We get this energy by consuming Organic material that originates from plants and creatures. Wood is biomass energy. Biomass isn't just a renewable energy yet in addition reasonable wellspring of energy.

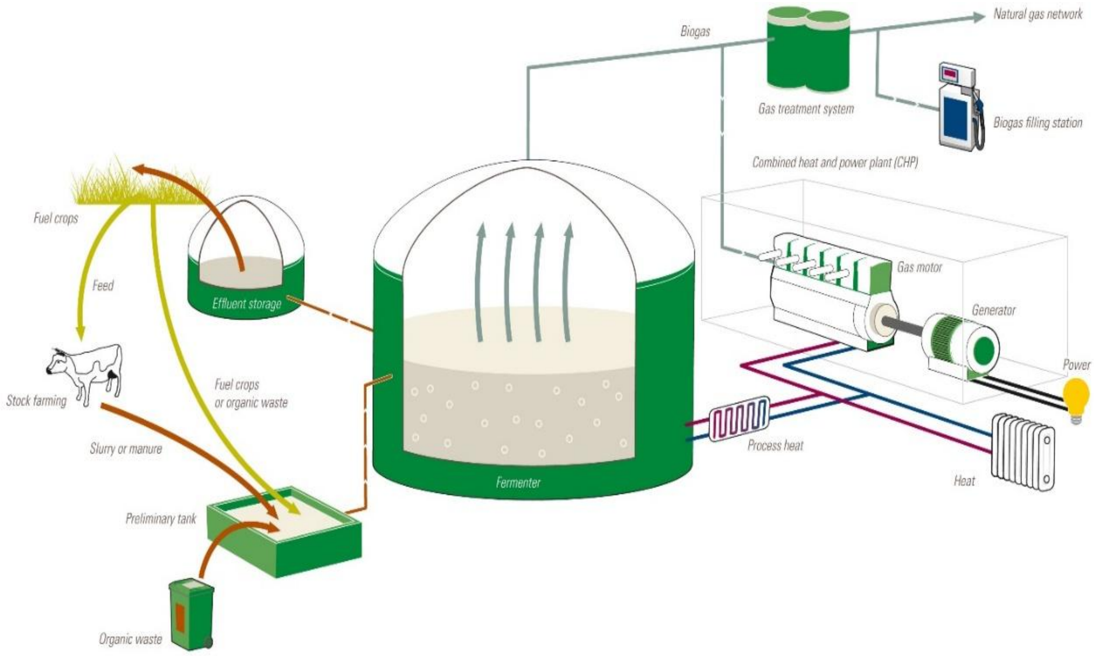


Fig 2.2: Inside of Biomass power plant

2.4.2 Hydro-power

Hydro-power is one of the most established sources of energy to create mechanical and electrical energy. In addition, Hydro-power utilized a large number of years back to turn paddle wheels to enable granulate to grain. Consequently, hydroelectric power is created by moving water. Here water is the primary source. Kaptai dam is the main hydroelectric power which is arranged in Bangladesh. The fundamental burden of a pressure-driven power station is its high introductory esteem and longer approval sum. In any case, these impediments are counterbalanced by the low estimation of generation and also the administration of surges and expanded water system offices.

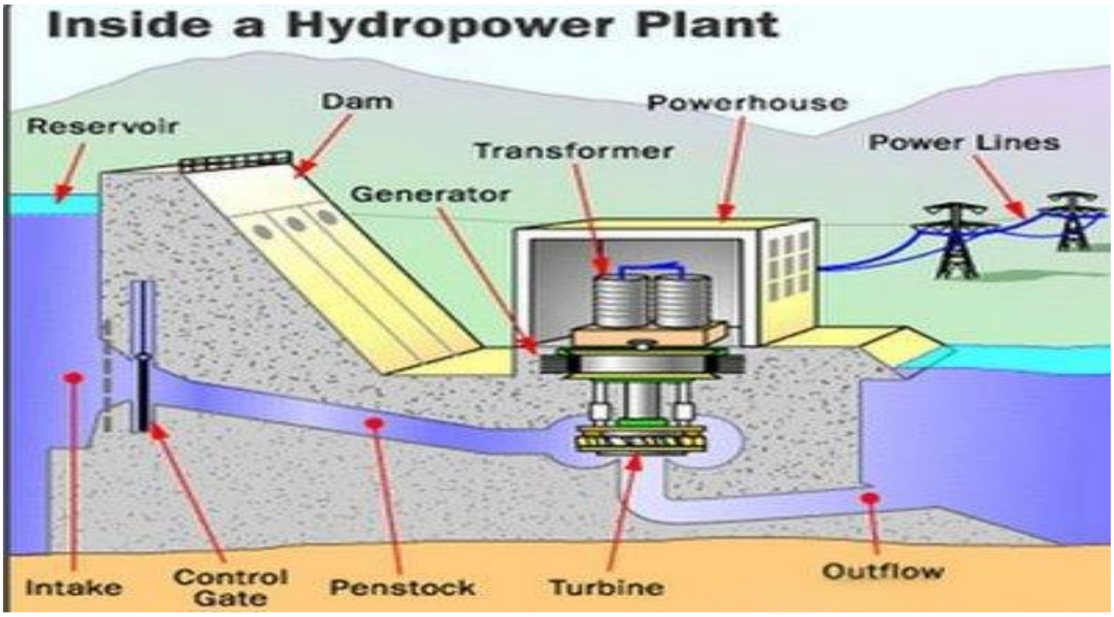


Fig 2.3: Inside of a Hydropower plant

2.4.3 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.

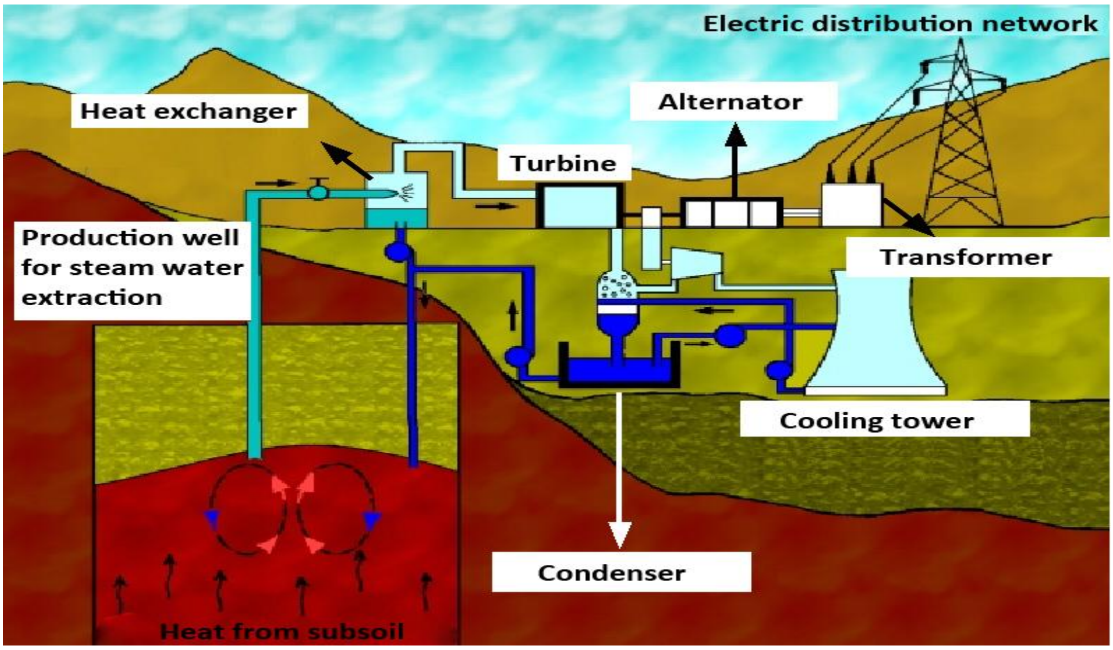


Fig 2.4: Inside of a Geothermal power plant

2.4.4 Wind Energy

Presently multi-day wind is an accessible renewable energy source. Consistently, around the globe, wind turbines are changing over it to electricity by catching the breeze's power. This wellspring of power generation assumes an undeniably noteworthy job.

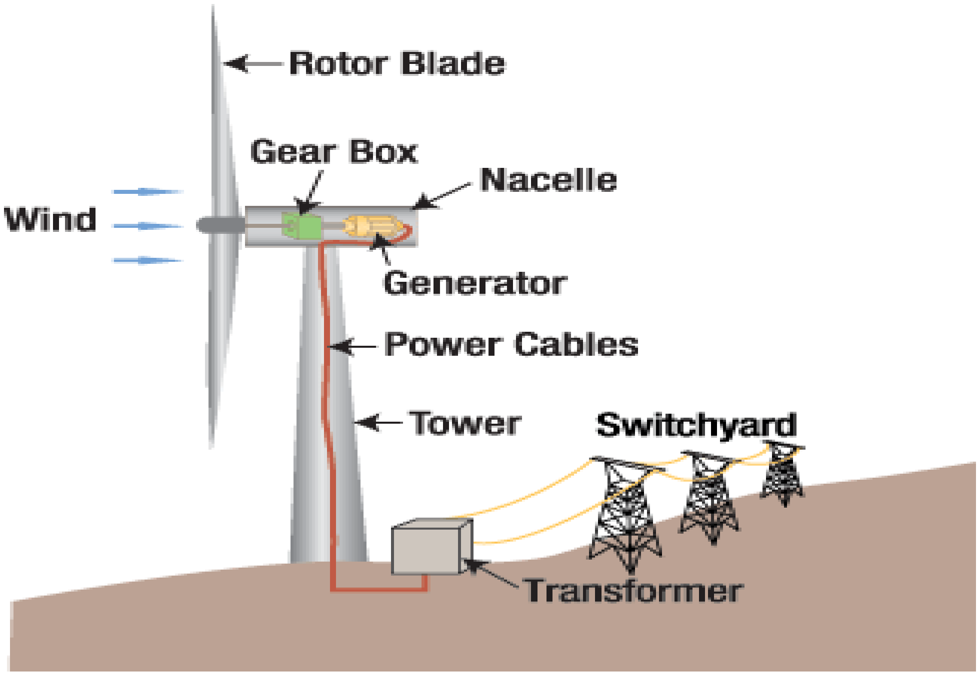


Fig 2.5: Inside the wind power station

However, some wind energy power sources from various foundations are accessible in Bangladesh, however, their commitment to the national grid is insignificant. In this manner, government intercession is enormously required in such manner.

2.4.5 Solar Energy

Solar power originates from atomic responses in the sun and is the 'ultimate' renewable energy sources. PV frameworks use daylight to create electricity. Notwithstanding the panels, a PV framework normally contains an inverter to change over solar power from DC to AC of the utility grid power transmission and conveyance framework. 3 MW plant has set up at Sarishabari in Jamalpur. In our country, solar PV application basically focuses on rural home lighting. The absence of mindfulness at the ground level and nonattendance of financing facilitators are the significant hindrances SHS in Bangladesh. In addition, govt. Administration and inconvenient cost awareness of some improvement organizations are likewise mindful.

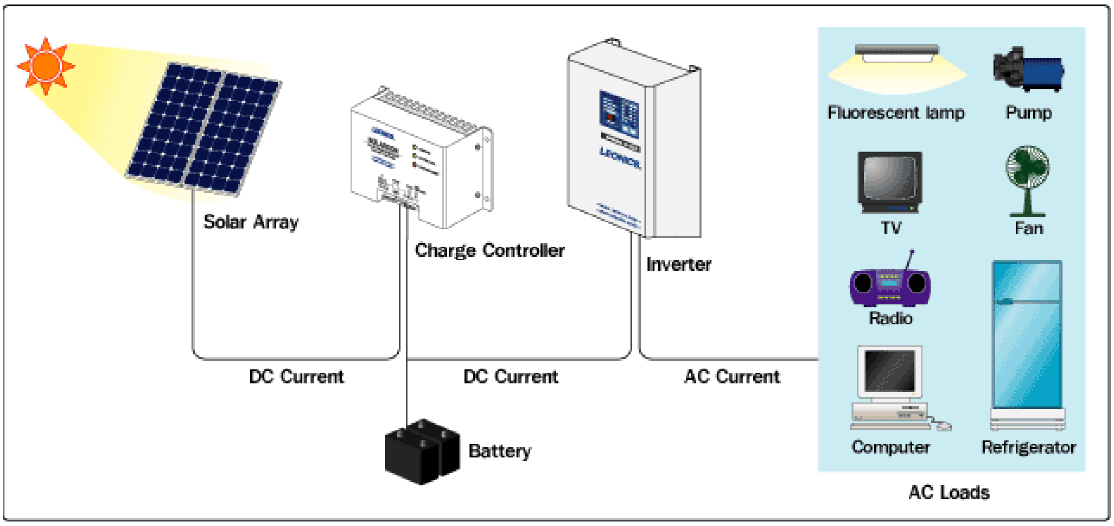


Fig 2.6: Inside of solar home system

Solar photovoltaic (PV) frameworks are being used all through the country with more than 200,000 family level establishments having the limit of around 12 MW (June 2008). Scaling-up of solar PV frameworks helped by the advancement accomplices are being executed through the Rural Electrification Board (REB), Local Government Engineering Department (LGED), Bangladesh Power Development Board (BPDB) and different offices actualizing solar energy program. There is a powerful potential for elective energy at interims the country.

Solar Thermal Power/Concentrating Solar Power (CSP): The innovation includes outfitting solar radiation for generation of electricity through various advances, at last, producing mechanical energy to run a generator. This innovation should be spread in the country to enhance the power supply.

2.5 Potential of Solar Energy

There is a gigantic potential for solar energy. It is subsequently vast that the full energy needs of the whole world will be culminated by the elective energy. The aggregate energy utilization of the entire world in the year 2008 was 474 exajoule (1EJ=1018 J) or roughly 15TW (1.504*1013 W) [13]. Relatively 80%-90% of this energy originated from the non-renewable energy source. Which is comparable to 174 pet watts (1 PW=1015 W). The earth doesn't hold all the energy, a piece of it reflects. After reflection earth gets 89 PW of energy. Of this expansive amount, just under 0.02% is sufficient to exchange the petroleum derivative and atomic energy supply in the entire world these days. By this, we can see effectively the incredible capability of solar energy. Considering about nursery impact natural effect, cost, chance [14]. From the sun-earth gets, there 3,850,000 EJ of energy.

2.6 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 on our atmosphere.

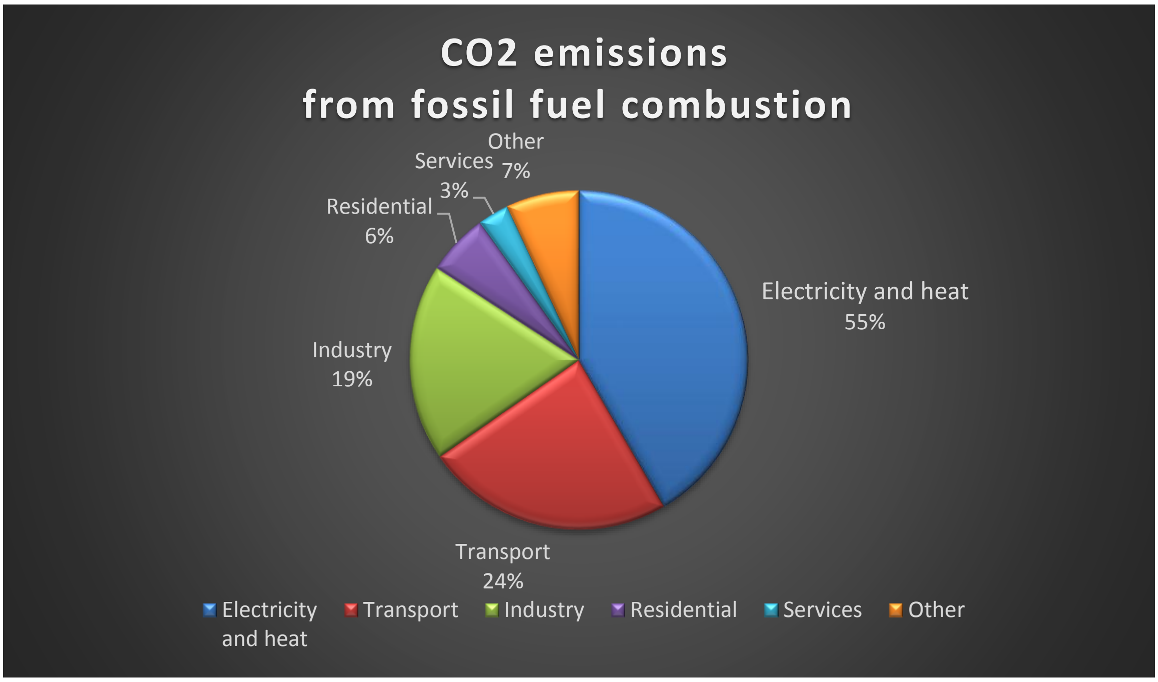


Fig. 2.7: CO_2 Emissions From Fossil Fuel Combustion [15].

From the Fig.2.7, we can analyze that electricity and heat generation is 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 of 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 the rooftops of every multi-storied and hi-rise building. Everywhere on 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 for energy is increasing because of the industrialization, urbanization, food production. In the rural area, solar energy plays a vital role in their livelihood.

2.7 Top Ten Countries Using Solar Power

Solar energy is becoming more and more popular among the developers 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 the top ten solar generation country respectively.

Table-2: 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

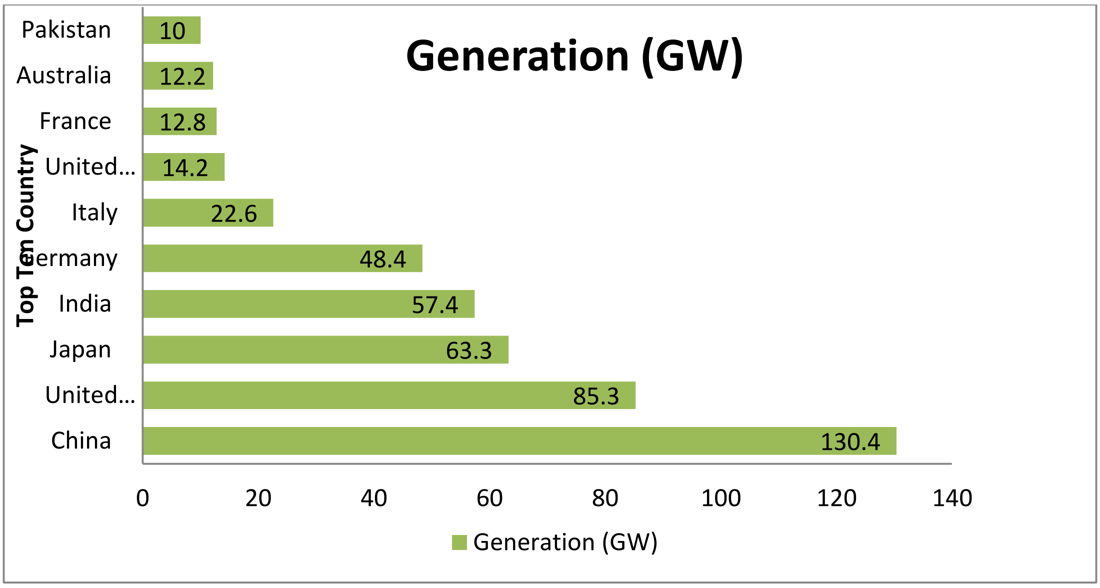


Fig. 2.8: Generation Top Ten Solar Country

The Bangladesh government already took 500 MW PV base solar projects and has set an objective to produce 5% electricity by 2015 and 10% by 2020 from renewable sources which are in term of the limit of 80 MW and 2000 MW separately. Additionally, the government has attempted different exercises to advance renewable energy from various sources like solar, wind, biomass, biogas, and hydro, tidal and wave to accomplish the objective. Among those, the government has recognized solar power as a standout amongst the most strong sources for maintainable energy improvement. The methodology of the mission is to grasp 500 MW solar power by 2016 as a piece of the arrangement at a reasonable cost. To this end, the government will empower privet division association of this mission. The mission will be actualized openly and privet division. A noteworthy segment of this mission which is proportionate to 340 MW, will be executed in broad daylight and privet division [16].

2.8 Photovoltaic Technology

A more common term for photovoltaic 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 the 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.

2.9 Benefits of PV Electricity

- Renewable source of energy: PV system converts sunlight into electricity which is a renewable and free source of energy. Since sunlight is the fuel, unlike other conventional energy, there is no need for transportation of fuel.
- Decentralized source: One of the most important benefits is that power can be generated locally where the power is to be consumed. PV generator can be as small as a few watts, therefore, the combination of appropriate sizes of panels can give just the amount of power that is needed at each site
- Minimal maintenance and maximum reliability: PV systems typically require very minimal maintenance because there are no moving parts. Time and money required for maintenance are quite low. This is the primary advantage of a solar system when compared to any other form of electrical power generation.

2.10 Solar Cells

PV or solar cells (Fig. 2.9) are PN junction Semiconductor devices. It converts sunlight into direct electricity. Groups of solar cells are electrically connected into PV modules, arrays. Photovoltaic modules or arrays can be used to charge batteries and This system can be used to power any number of electrical loads. PV systems can produce alternating currents by using the inverter. Solar cells typically are distinguished by their sort of semiconductor junction-

(A) Homojunction (n + player is of the same material)

(B) Heterojunction (n + player is of different material)

(C) MIS (Metal –Isolator - Semiconductor)

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

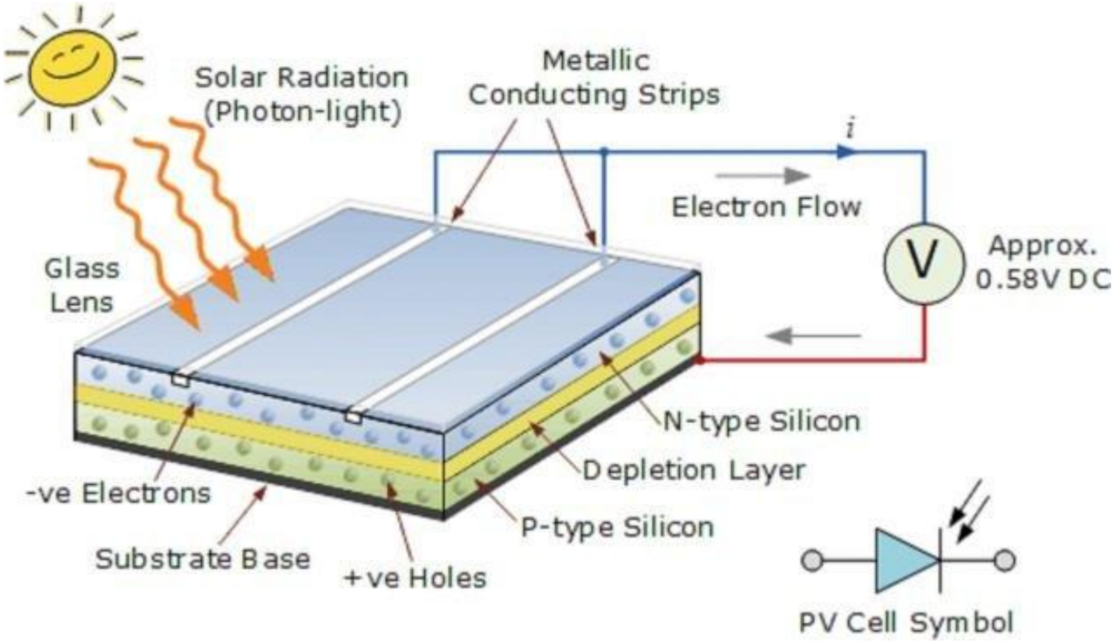


Fig. 2.9: Solar Cell

2.11 Design of Modules

There is some characteristic given below-

- producing voltage of one silicon solar cell is 0.5V to 0.6V.
- to make a Module usually 36 cells are connected.
- Such one Module has enough voltage to charge 12-volt batteries which are used to run pumps and motors.
- the basic building block of a PV power system is the PV Module.
- to produce more power Modules, need to connect.
- The module can be designed by connecting 36 cells
- The panel can be designed by connecting the modules on the other hand, by connecting the panels array is designed (Fig. 5)

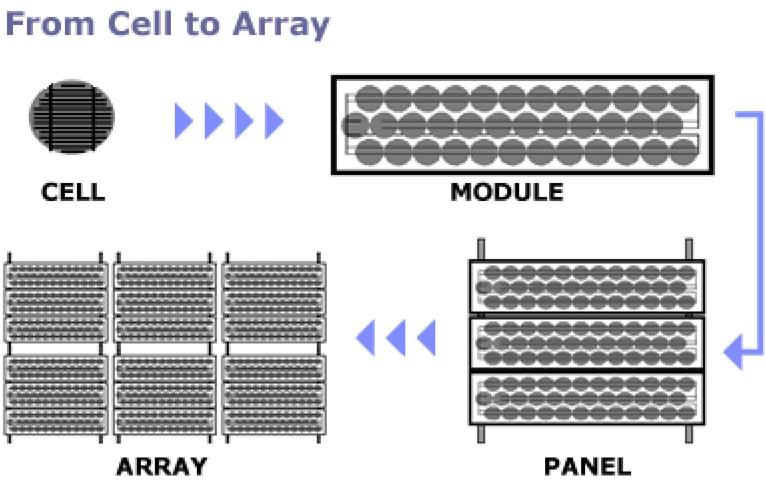


Fig. 2.10: Cell to Array

2.12 Types of Solar Cells

Solar cells can be classified according to 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 types of solar cells.

1. Single-crystalline or monocrystalline cells (Fig. 2.11.a)
2. Multi-crystalline or polycrystalline cells and (Fig. 2.11.b)
3. Amorphous cell (Fig. 2.11.c)

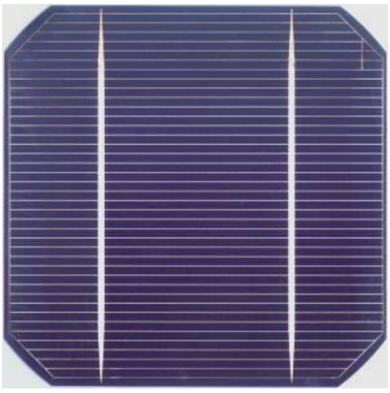


Fig. 2.11.a : Single-crystalline Cells

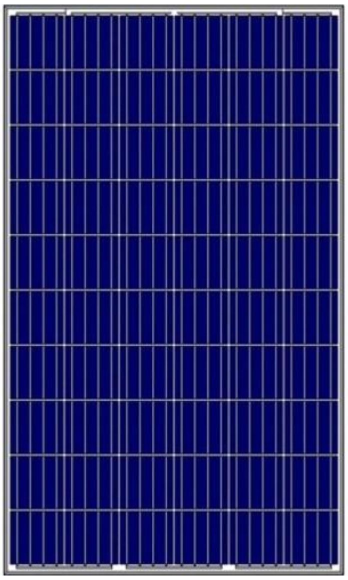


Fig. 2.11.b : Polycrystalline Cells

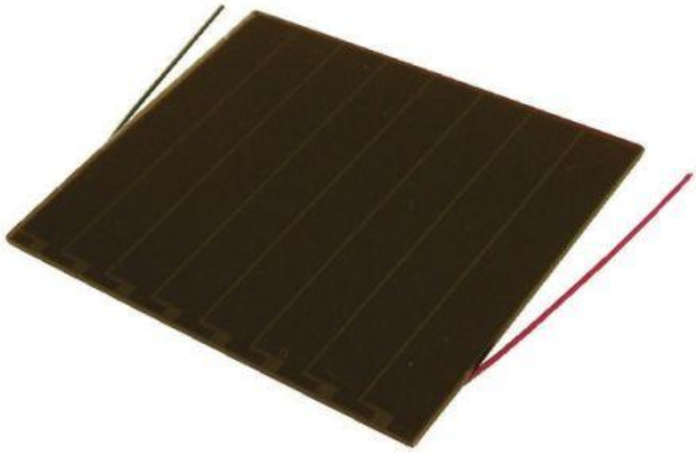


Fig. 2.11.c: Amorphous cell

2.12.1 Monocrystalline Cells

Monocrystalline cells 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 methods of producing silicon single-crystals are primarily either the Czochralsky process or the floating zone technique. In the Czochralsky process, monocrystalline silicon grows on a seed, which is pulled slowly out of the silicon melt. With both methods, silicon rods are produced, which are cut into slices of 0.2 to 0.4 mm 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

2.12.2 Polycrystalline Cells

The manufacturing process for monocrystalline 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 silicon 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 regions, which are separated by grain boundaries. The losses occurring at these grain boundaries cause the lower efficiency (less than 20%) of polycrystalline cells compared with monocrystalline ones. Despite this disadvantage, the importance of polycrystalline cells is growing, because of the lower production costs [17]

2.12.3 Amorphous Cells

To avoid the energy-intensive production process 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 such as silane (SiH_4) on a carrier material like glass and doped in a further step. The semiconducting material grown in this way is called amorphous silicon. This technology has two disadvantages: first, the conversion efficiency is considerably low, i.e., less than 10%; second, the cells are affected by a degradation process during the initial months of operation, which reduces the efficiency furthermore. These disadvantages are compensated by the –

- 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.

2.13 Charge Controller

The charge controller is an electronic device which is used in the 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 Fig. 2.12

Fig. 2.12: Charge Controller

2.14 Principle of Charge Controller

The primary capacity of a charge controller or controller is to totally charge a battery while not permitting 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 a 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.

The charge controller is used for coordination and control among the battery, load and solar panel. Charge controller stores the electricity within the battery throughout the daytime and provides a like the load (mainly lamp) at night. On the opposite hand, if the battery is totally charged, then charge controller will directly provide electricity to the load (Fan, mobile charger etc.) from the solar panel throughout the daytime. 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 volts is required to keep the battery in full charged state. The charge controller works as a buck converter to reduce this voltage level. The 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 [17].

2.15 Types of Charge Controller

Charge controller connection is mainly two types-

- Parallel or shunt controller
- Series controller

2.15.1 Shunt Controller

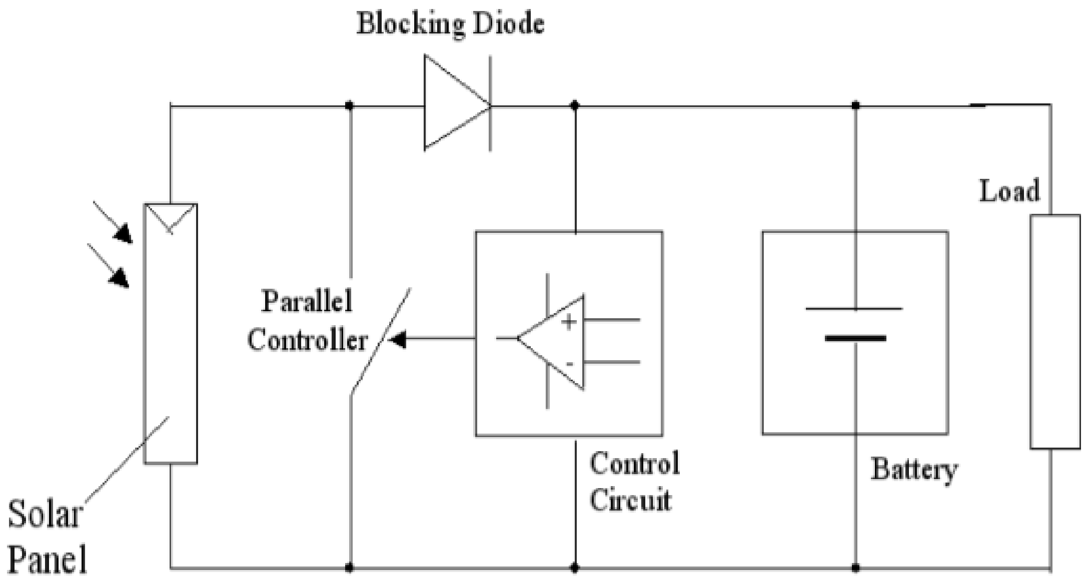


Fig. 2.13 Use of Parallel Controller in SHS

In this system (Fig. 2.13), a charge controller is in parallel with the battery and load. When the battery is absolutely charged, then the solar panel is short-circuited by the controller. In this system, a blocking diode is needed. So that reverse current would not flow from battery to the panel. When the battery is charged through this block diode, it gets hot. There are some disadvantages of shunt controller such as:

- Loss of electricity
- The huge amount of short circuit current (Isc) flows through the switch (FET) when the panel is short-circuited,
  Compared to a series controller, the shunt controller gets hotter.

2.15.2 Series Controller

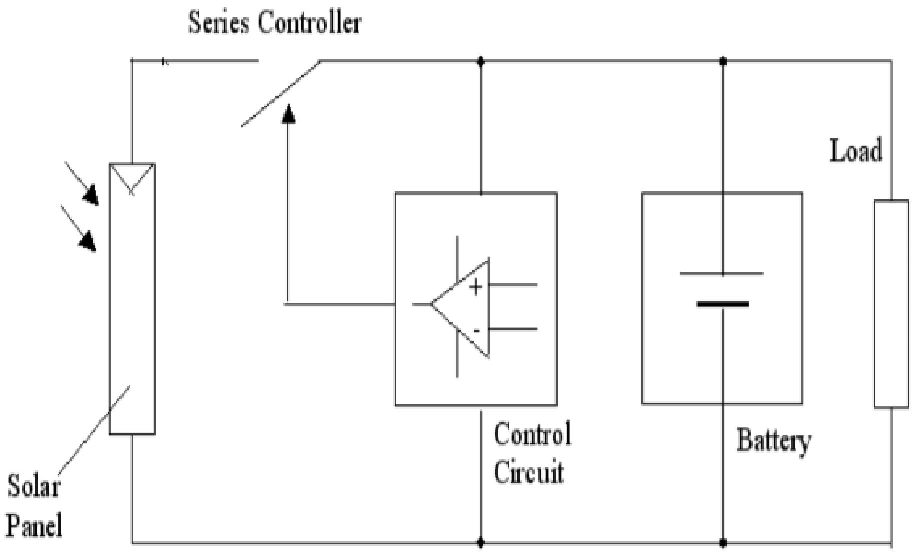


Fig. 2.14 Use of Series Controller in SHS

In this system (Fig. 2.14), the charge controller is connected in between with the solar panel and battery. To terminate the flow of electricity to the battery, the series controller should be off from the battery. There's no need for blocking diode during this system, but for several reasons, it is used to terminate the method of discharging at night. The resistance should be maintained as low as possible to minimize loss of the electricity. Advantages of the series controller:

- Blocking diode is not required.

- Compared to shunt controller, series controller switch is handled with low voltage.
- Low switching noise.
- It is possible of precision charge and PWM technique of the battery.

2.16 Battery Storage

Batteries are often used in Photovoltaic 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).

Fig. 2.15 : 12-volt, 100 Ah solar battery & 2-volt, 200 Ah Industrial battery

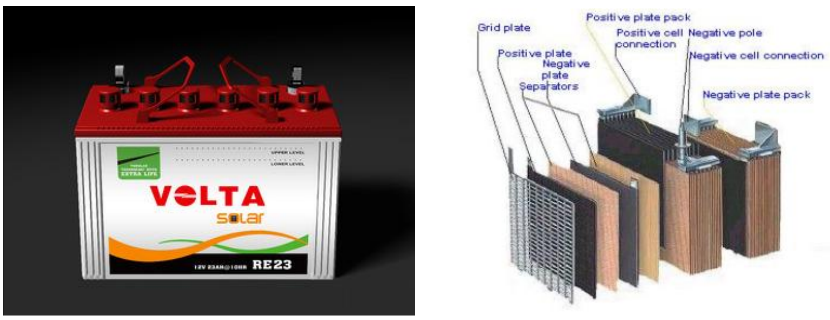


Fig. 2.16 : Battery External & Internal

2.17 Solar Home System

Bangladesh is a small country with a large population. Bangladesh is one of the most densely populated countries with 65% of the population living in rural areas. The energy crisis is one of the main problems in the ways of development. The solar home system is the most suitable technology to come out from this problem.

2.17.1 Why Suitable Technology for Our Country

Bangladesh is a populated country. The present population of this country is 16 cores and 71 lacks. Around 65% of people are living in villages. 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 [18].

2.17.2 Working Principle

Sunlight is converted to electrical energy when it passes through PV modules which contain silicon cells. At first silicon cells are connected electrically and placed between two layers of protective materials. This sandwiched silicon material with protective materials is then heated laminated to a protective glass sheet.

2.17.3 How Do Solar Cells Generate Electricity

PV is like a DC generator powered by the sun. When light photons of enough energy strike a solar cell, they knock free electrons in the silicon crystal structure forcing them through an external circuit (battery or DC load) and then returning them to the other side of the solar cell to start the procedure all over again. The voltage output from a single crystalline solar cell is about 0.5V with an amperage output that is directly proportional to cell's surface area (approx. 7A for a 6-inch square multi-crystalline solar cell). In each solar module, typically 30-36 cells are wired in series (+ to -). This produces a solar module with a 12V nominal output (-I7V at peak power) that can then be wired in series and/or parallel with other solar modules to form a complete solar array to charge a twelve, 24- or 48-volt battery bank [18].

2.17.4 Equipment of Solar Home System

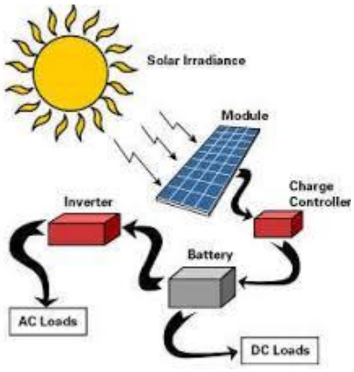


Fig. 2.17: Solar Home System

There are components of a solar home system (Fig. 2.17) -

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

2.17.5 OFF-grid Solar Systems

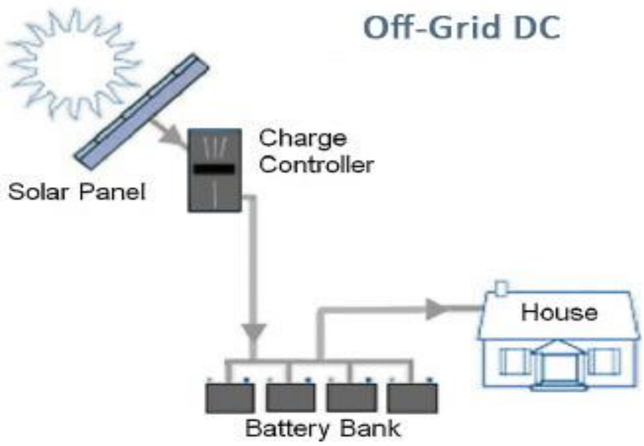


Fig. 2.18: Solar Off-Grid

There are components of an off-grid solar home system (Fig.2.18) -

- Solar module
- Charge controller

- Battery bank
- AC/DC loads

2.17.6 Advantages of Solar PV Systems

For using solar PV systems are

- The customer is the owner of his or her personal power-generating system,
- No billing for charges occurs,
- Electricity is produced for more than 20 years without any traditional fuels,
- No fuel cost is involved,
- Solar PV systems are durable,
- The systems are appropriate for any part of the country,
- No noise pollution is generated and
- The production of power is environmentally friendly.

2.18 Socio-Economic of SHS

Rural charge SHS Programs are contributing a practical financial development of the rural individuals in Bangladesh. Various occupations will make which helps to diminish the joblessness rate. Also, financial effects incorporate PC and web associations with remote territories. It's not just upgrading in the way of life of the general population like a superior light for youngster instruction yet, in addition, decreased indoor air contamination. Moreover, examines distinguish that consuming petroleum derivatives helps naturalize an unnatural weather change. Then again, solar energy does not harm the air in light of the fact that solar panels produce a low measure of perilous contamination into the air. In this manner, solar energy is a rich cleaner wellspring of energy than the consuming of petroleum derivatives. Outside oil reliance would be abbreviated if more organizations and family units utilized solar energy to create electricity rather than petroleum products. With the assistance of SHSs Businesses, for example, rice/sawmills, fitting shops, eateries, showcase and so on have expanded their income. Notwithstanding these improvements, ladies are getting a charge out of danger less lighting frameworks in their day by day life. After sunset, they are using their time by sewing, poultry cultivating or set up locally situated businesses to acquire additional pay. Two extremely fruitful utilization of SHS are Micro-utility model, SHS powered Polly-telephone. Along these lines, a huge decrease of home or office ozone-harming substance outflows is conceivable. Introducing a grid-associated framework is additionally the ideal method to meet rising building energy effectiveness norms.

2.19 Achievements with 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. 2.19) have been installed in different parts of Bangladesh. The first solar PV–based rural electrification project in Bangladesh was started with the financial support of France, with a total installed capacity of 62 kilowatts peak (KWp), of which 29,414 Wp came from battery charge stations and the rest from Solar Home System (SHS). Infrastructure Development Company Limited (IDCOL) has supported NGOs to install 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).

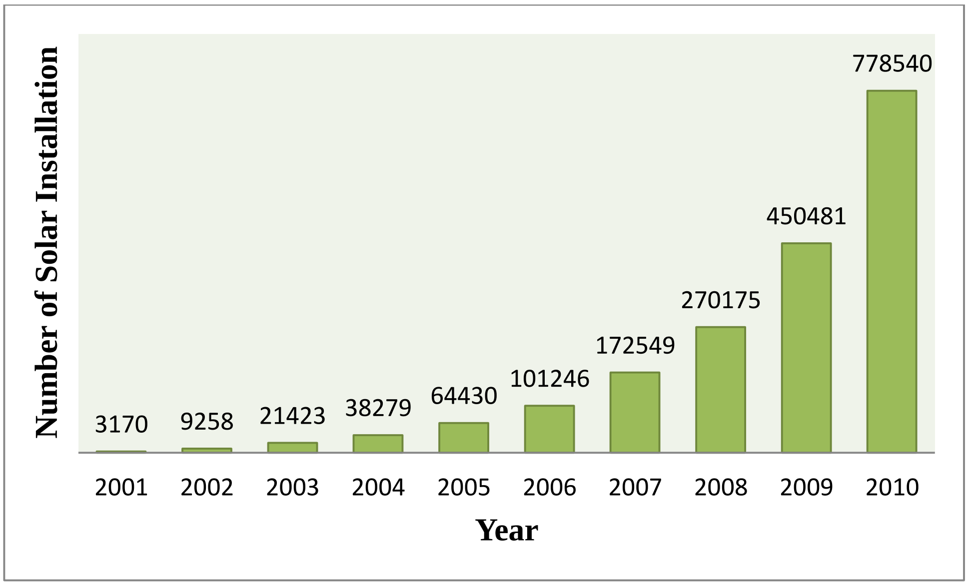


Fig. 2.19: SHS Installation in Bangladesh

2.20 Summary

Now a day's energy is important in our life. By anyhow necessity has to full fill. In this chapter, we try to present all the facts, scopes, and scenario of the energy field. It will help us to think about the problem and find a cure for it.

2.21 Selected Literature Review Regarding Solar Energy

Duan, C., Wang, C., Li, Z., Chen, J., Wang, S., Snyder, A., & Jiang, C, [31] 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.,[32] 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 the highest technology, solid construction, well-designed electronics, elaborate thermal management, and mechanical stability.

Islam, M. Z., Shameem, R., Mashsharat, A., Mim, M. S., Rafy, M. F., Pervej, M. S., & Ahad, A. R, [33] 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. on the other hand, Komatsu, S., Kaneko, S., & Ghosh, P. P, [34] 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, [35] 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.,[36] the context of the paper to improve the solar system with maximum power point tracking. The converter controlled by A digital signal processor. The low-power rating 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., [37] context of the paper about the 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.,[38] 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.

Biswas, W. K., Diesendorf, M., & Bryce, P, [39] research paper base on sustainable rural improvement and poverty palliation in Bangladesh. Income-generating opportunities are created and improve the quality of life of rural people for Photovoltaic technologies. Grameen Bank and BRAC models provide micro-credit to rural poor people individuals.

Rebane, K. L., & Barham, B. L,[40] 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 [41]. Photovoltaic solar energy conversion is the direct conversion of sunlight into electricity. a small electric current produce, when light 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.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this segment, we will talk about the procedure of data gathering strategy and research apparatuses. The essential data that we have gathered from our investigation zone and optional data we have gathered from a different paper.

3.2 Site Determination

An investigation zone (Fig 3.2) is where we gather data for our important work and the chosen place was Daffodil International University Administrative Building rooftop. It is located in Dhaka 1215, Bangladesh. Distinctive sorts of the solar board have installed there, for example, 45W, 60W, and 100W. We study the performance analysis the power of 60W and 100W off-grid solar panel and their comparison.

Fig. 3.1 Investigation zone

3.3 Satellite View

The satellite perspective of the working zone has appeared in Fig. 3.3.

Fig. 3.2 Satellite View

3.4 System Diagram

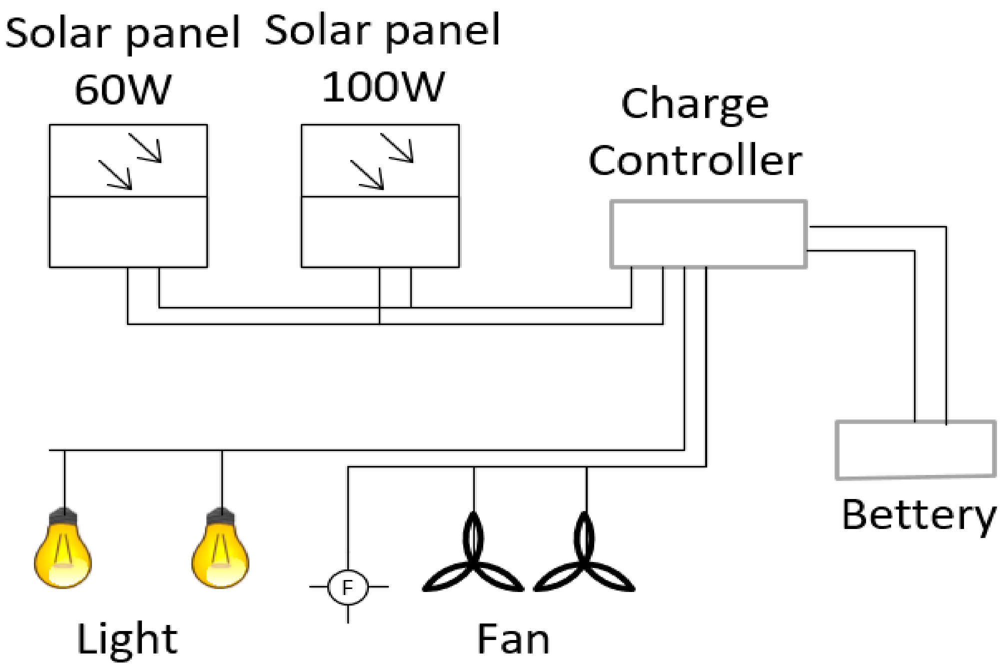


Fig. 3.3 System Diagram

3.5 Research Apparatuses and Instruments

A few devices have been utilized to gather data, for example, I-V 400w, temperature sensor, 60W, and 100W solar board, illumination sensor (HT304N).

3.5.1 60W And 100W Solar Panel

The solar cell is made in Germany. To quantify the power in Standard Test Condition (STC), the cell temperature is 25°C. These solar cells are made in Germany.

3.5.1.1 Electrical Determinations For 60W

Maximum power:	60W
Open circuit voltage:	21.5V
Short circuit current:	3.76A
The voltage at maximum power:	17.5V
Current at maximum power:	3.46A
Module dimension:	805*550*35mm
Module weight:	5.9kgs ±3%

Fig. 3.5.1.1 Solar Panel (60W)

3.5.1.2 Electrical Determinations For 100W

Maximum power: 100W

Open circuit voltage: 22.68V

Short circuit current: 5.60A

The voltage at maximum power: 19.12V

Current at maximum power: 5.23A

Module dimension: 1100*680*3 mm

Module weight: 8.1kgs ±3%

Fig. 3.5.1.2 Solar Panel (100W)

3.5.2 I-V 400W

I-V400 W (Fig. 32) 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. 3.5.2 I-V 400 W Photovoltaic Panel Analyzer

3.5.2.1 Electrical Determinations of I-V 400 W

Table-3: Range and Accuracy

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%

3.5.2.2 General Determinations 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 (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

3.5.3 Temperature Sensor

The temperature sensor (Fig. 33) senses temperature from the solar cell and sends data to the I-V 400w.

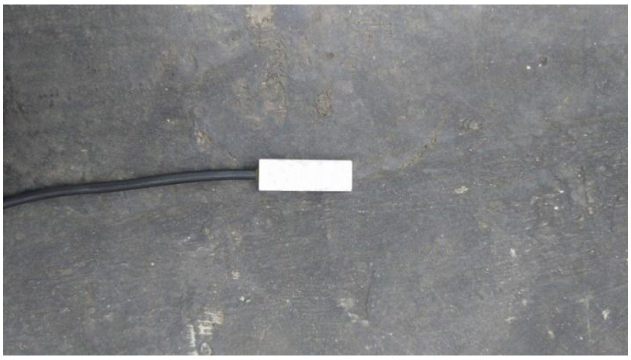


Fig. 3.5.3 Temperature Sensor

3.5.4 Irradiation Sensor (HT304N)

This device (Fig. 34) can able to measure as MONO PANELS or MULTI PANELS. It is a passive sensor and does not need any power supply.

Fig. 3.5.4 Irradiation Sensor

3.5.4.1 Technical Determinations of Irradiation Sensor

Table-4: Range & Accuracy

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

3.5.4.2 General Determinations

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

3.6 Flow Chart

A flow chart might be a sort of diagram that speaks to a work process or strategy. The flowchart shows the means as boxes of various sorts and their request by associating the containers with bolts. We utilized flowcharts (Fig. 35) in breaking down, recording or dealing with a procedure or program in different fields.

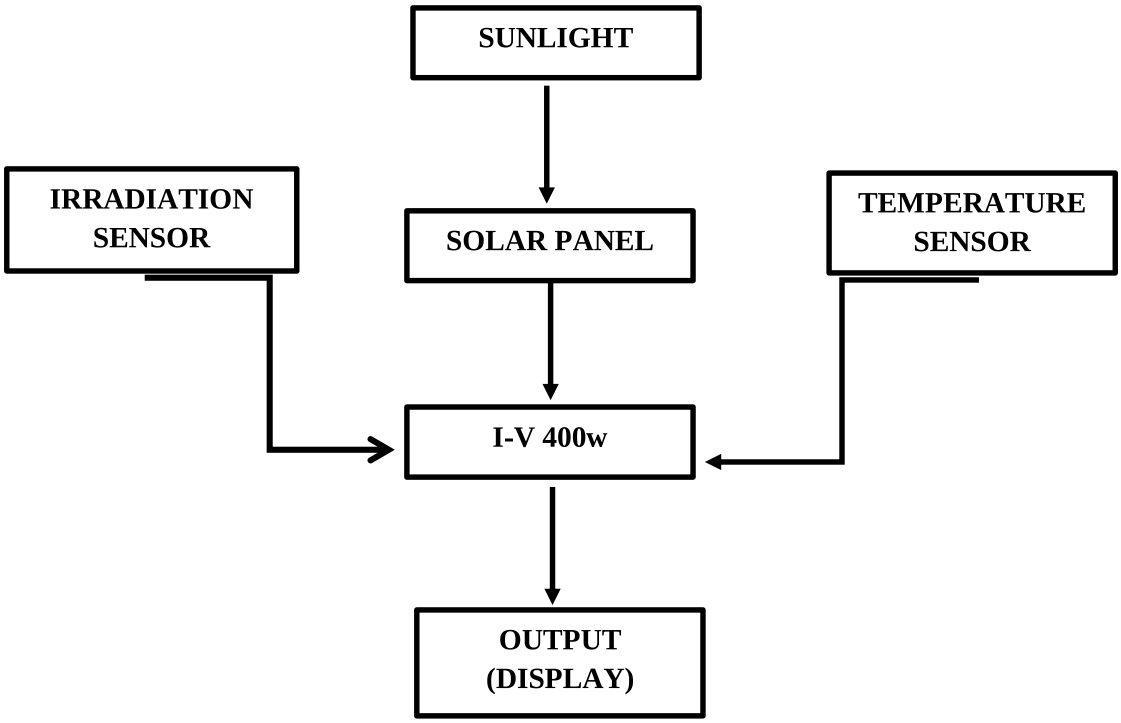


Fig. 3.6 Flow chart of Data Measuring

3.7 I-V 400 W Calibration

Before starting the measurement according to the manufactural, we must have to calibrate I-V 400 W. For I-V 400 W calibration parameters have given below Table-4.

Table-5: 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

3.8 Data Estimation Strategy

On October, we collected data from sunrise to sunset (time 5.49 to 17.45) 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, 60W and 100W 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. 3.7 Data Measuring

Table- 6: Measured Data of Solar System on 1 October 2018

SL	Time (Sunrise to sunset)	Irradiance (W/m^2)	Voltage (V)	Current (I)	Vmpp (V)	Impp (I)	Fill Factor	Pmax (W)
1	5.49	0	0	0	0	0	0	0
2	6.49	188	19.8	.69	16	.6	.7	9.6
3	7.49	315	19.9	.53	15.3	.42	.59	6.426
4	8.49	640	19.6	2	15.4	1.83	.72	28.182
5	9.49	640	19.6	1.7	15.5	1.8	.72	27.9
6	10.49	788	19.3	2.41	15.4	2.12	.7	32.648
7	11.49	823	19.4	2.53	15.3	2.24	.72	34.272
8	12.49	804	19.3	2.54	15.1	2.28	.7	34.428
9	13.49	753	19.3	2.33	14.5	2.12	.68	30.74
10	14.49	479	19.3	.96	18.5	.41	.41	7.585
11	15.49	412	19.4	.67	15.6	.59	.71	9.204
12	16.49	118	18.3	.29	16.1	.23	.69	3.703
13	17.49	0	0	0	0	0	0	0

Table-6 represents parameter-wise data of a single day (October 1, 2018) starting from sunrise to sunset. Where, Voc=Open Circuit Voltage, Isc=short circuit current, Vmpp=Maximum PowerPoint Voltage, Impp=Maximum PowerPoint 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 4

ANALYSIS OF THE DATA & RESULTS

4.1 Introduction

Bangladesh gets a normal day by day solar irradiation of 4 - 6.5 kWh/m2. The focal point of this proposal is the estimation of solar irradiation, and the comparing power created by this panel.

4.2 Solar Data Examination

In our solar lab, 60-Watt and 100-Watt Solar Panel have been established in the top floor of DIU and area is respectively 0.44 m^2 and 0.75 m^2. 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, Pirr, Pmax. Pirr is the multiplication between irradiance and panel area. Furthermore, Pirr is the input power of the total solar panel (60W&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 (October and November 2018).

We can classification October and November 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 5.49 to 17.45). In time 5.49 irradiance for both solar panels was zero and for the reason, we got maximum power zero. On the other hand, time at 6.49 irradiance for 60W was 188 W/m^2 and maximum power generated 9.6W and irradiance for 100W was 162 and maximum power generated 16.261W Because we have got sunlight between time 5.49 and 6.49 that helps to produce irradiance. We collected our data every one-hour.

Table-7: Represents Single Day (1 October 2018) Solar Irradiance, Irradiance Power Input (Pirr) of 60 W solar panel and Generated Power.

Time (Sunrise to Sunset)	Irradiance (W/m^2)	Average Irradiance (W/m^2)	Area of Panel (m^2)	Equivalent Power of Irradiance (Irr*Area)	Average Equivalent Power of Irradiance (W)	Pmax (W)	Average Generated Maximum Power (W)
5.49	0	458.46	0.44	0	201.72	0	16.96
6.49	188			82.72		9.6	
7.49	315			138.6		6.426	
8.49	640			281.6		28.182	
9.49	640			281.6		27.9	
10.49	788			346.72		32.648	
11.49	823			362.12		34.272	
12.49	804			353.76		34.428	
13.49	753			331.32		30.74	
14.49	479			210.76		7.585	
15.49	412			181.28		9.204	
16.49	118			51.92		3.703	
17.45	0			0		0	

Table-8: Represents Single Day (1 October 2018) Solar Irradiance, Irradiance Power Input (Pirr) of 100W solar panel and Generated Power

Time (Sunrise to Sunset)	Irradiance (W/m^2)	Average Irradiance (W/m^2)	Area of Panel (m^2)	Equivalent Power of Irradiance (Irr*Area)	Average Input Irradiance Power (W)	Pmax (W)	Average Generated Maximum Power (W)
5.49	0	473.69	.75	0	355.26	0	35.574
6.49	162			121.5		16.261	
7.49	332			249		22.263	
8.49	649			486.75		54.095	
9.49	720			540		52.36	
10.49	817			612.75		66.15	
11.49	798			598.5		68.403	
12.49	865			648.75		69.412	
13.49	802			601.5		63.688	
14.49	487			365.25		24.739	
15.49	410			307.5		17.696	
16.49	116			87		7.399	
17.45	0			0		0	

4.2.1 Shows the data of solar irradiation of October 2018 for 60W

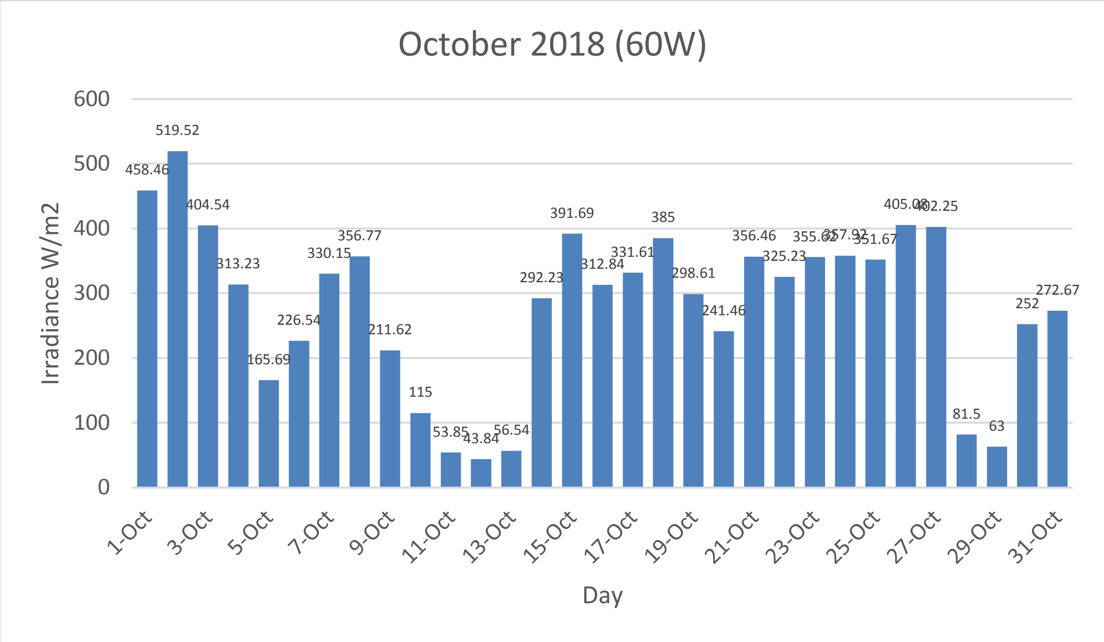


Fig 4.1 Solar Irradiance, October 2018

4.2.2 Shows the data of solar irradiation of October 2018 for 100W

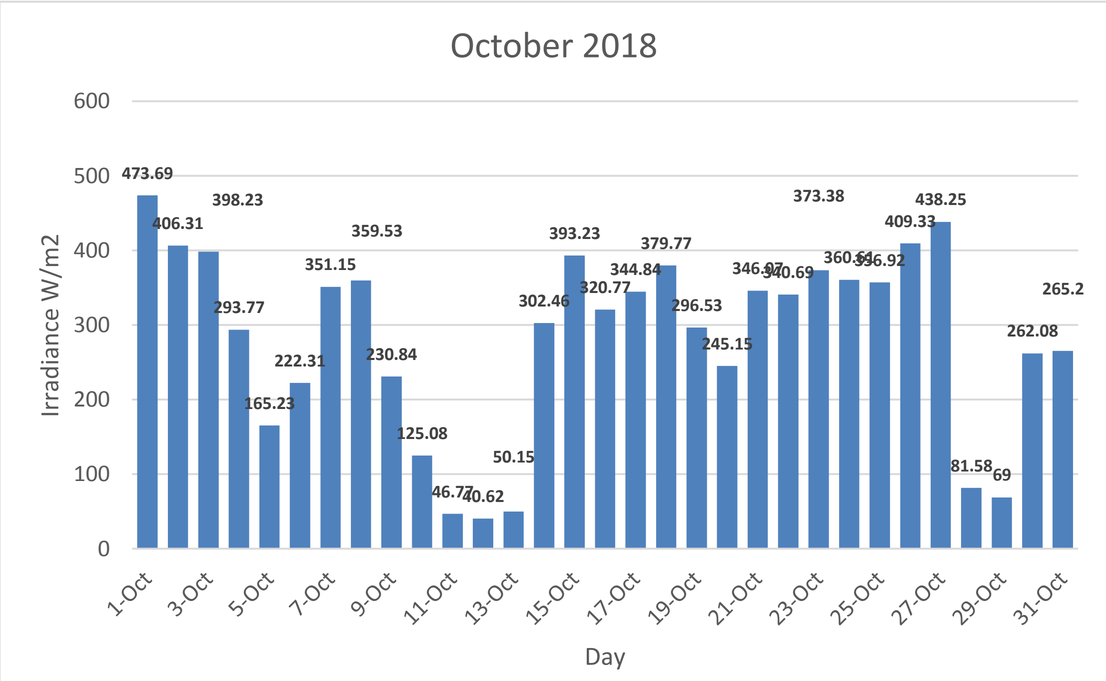


Fig 4.2 Solar Irradiance(100W), October 2018

Figure 4.1 and 4.2 shows the data of solar irradiation of October 2018 for 60W and 100W solar panel. The highest value of solar irradiance for 60W and 100W solar panel was measured respectively on On 2 and 1 October 2018, and their value was 524.8 W/m^2 and 473.69 W/m^2, the lowest value of irradiance was found 43.84 W/m^2 for 60W solar panel and 40.62 W/m^2 for 100W solar panel on 12 October. The main reason behind this situation was a sunny day and a rainy day. During the sunny day we have gotten the highest value and for the rainy day, we have gotten the lowest value. Moreover, October 2018 monthly average irradiation for 60W and 100W was respectively 281.69W/m^2 and 282.24 W/m^2 per day.

4.2.3 Shows the data of solar irradiation of November 2018 for 60W

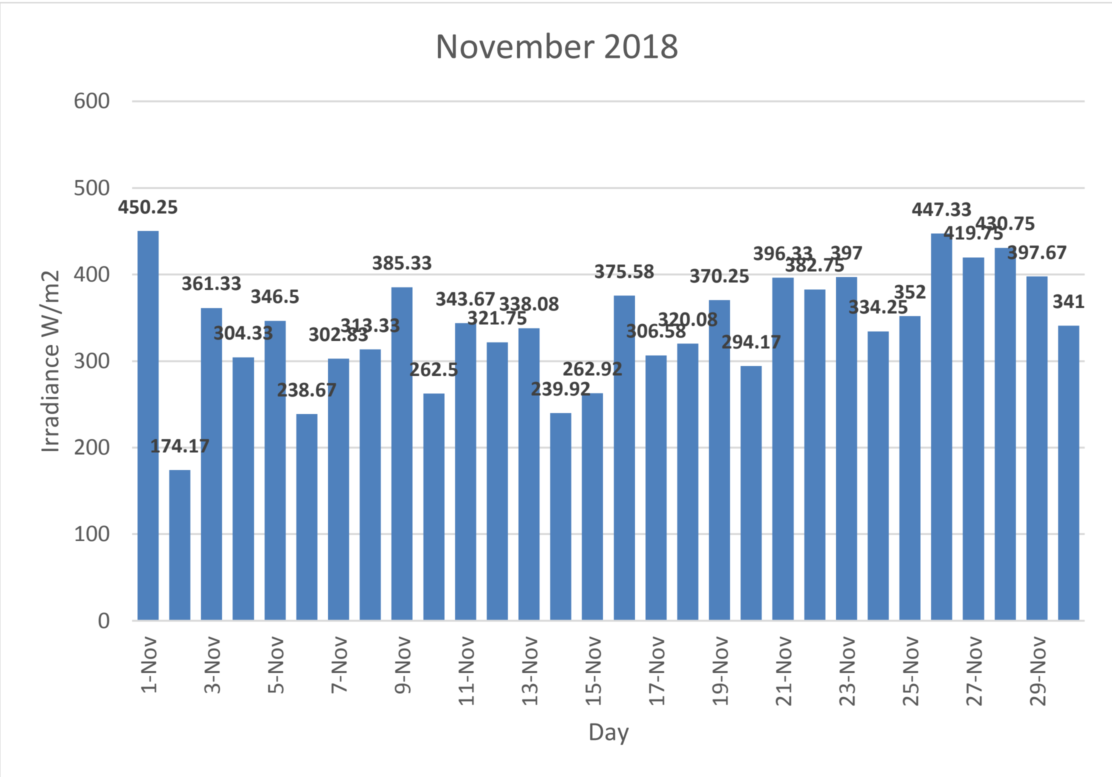


Fig 4.3 Solar Irradiance (60W), November 2018

4.2.4 Shows the data of solar irradiation of November 2018 for 100W

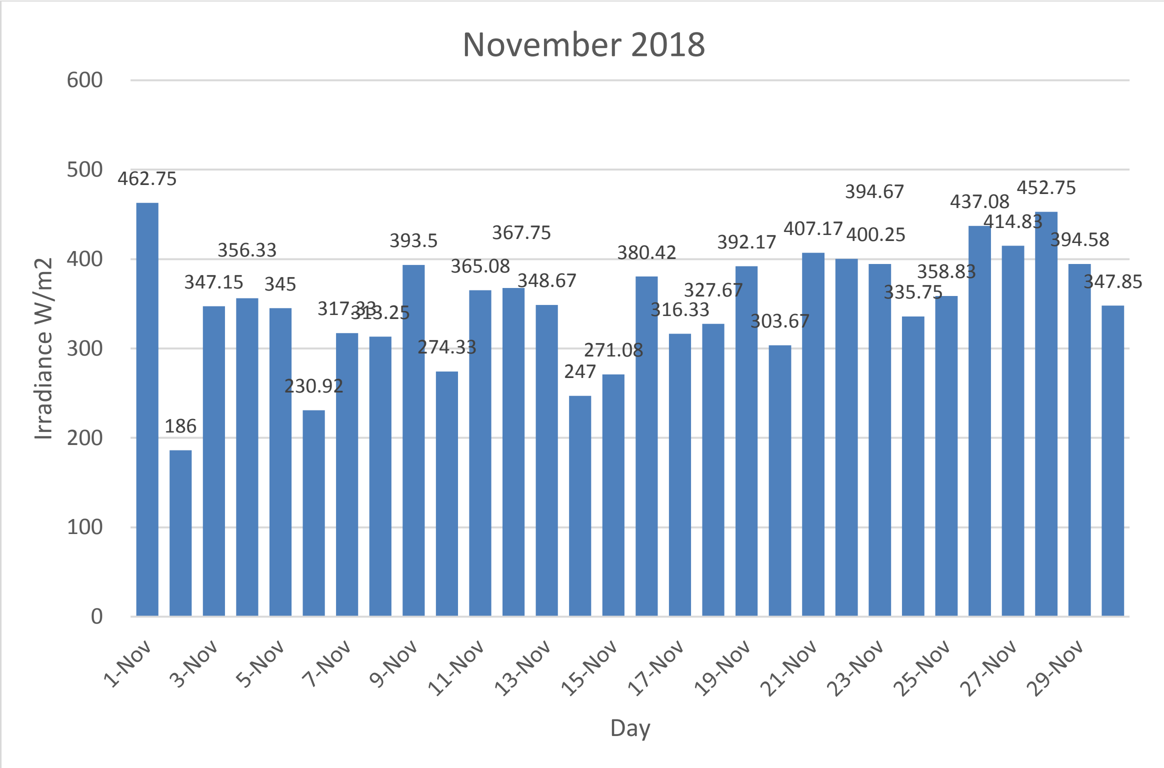


Fig 4.4 Solar Irradiance (100W), November 2018

Figure 4.3 and 4.4 shows the data of solar irradiation of November 2018 for 60W and 100W solar panel. The highest value of solar irradiance for 60W and the 100W solar panel was measured on 1 October 2018, and their value was 450.25W/m^2 and 462.75 W/m^2, the lowest value of irradiance was found 174.17 W/m^2 for 60W solar panel and 186 W/m^2 for 100W solar panel on 2 November. During the sunny day we have gotten the highest value and for the abnormal sunny day, we have gotten the lowest value. Moreover, November 2018 monthly average irradiation for 60W and 100W was respectively 340.37 W/m^2 and 349.67 W/m^2 per day.

4.2.5 Shows the data of maximum power in October 2018

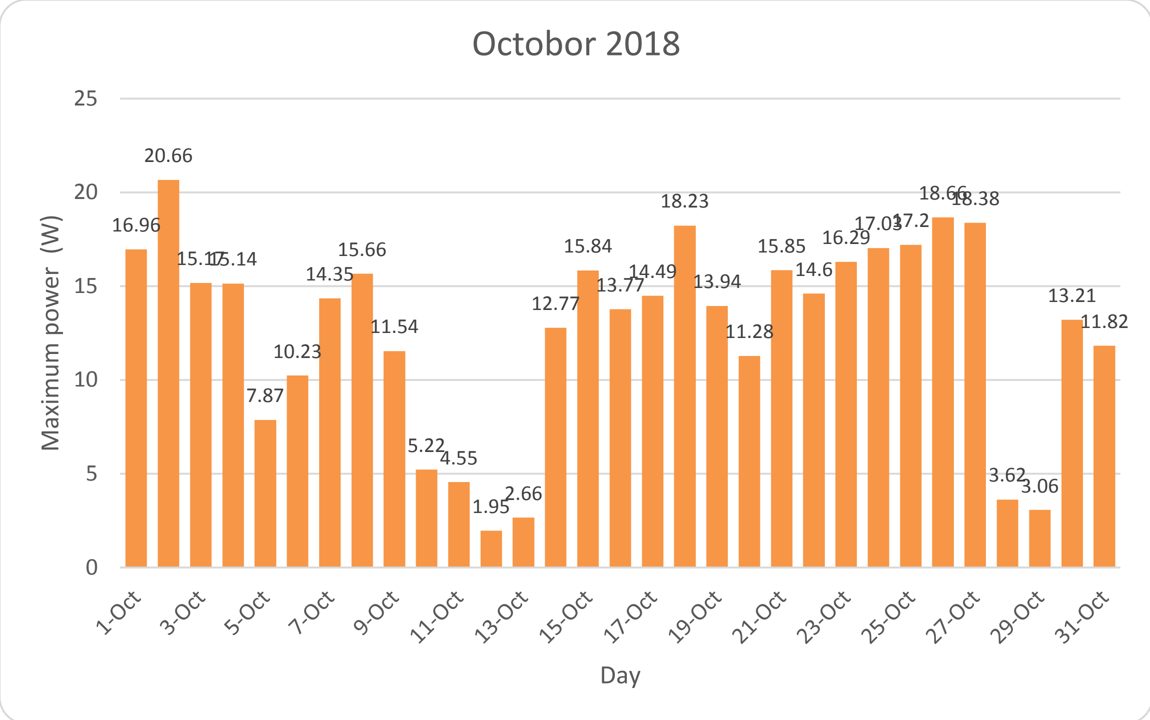


Fig 4.5 Maximum Power (60W), October 2018

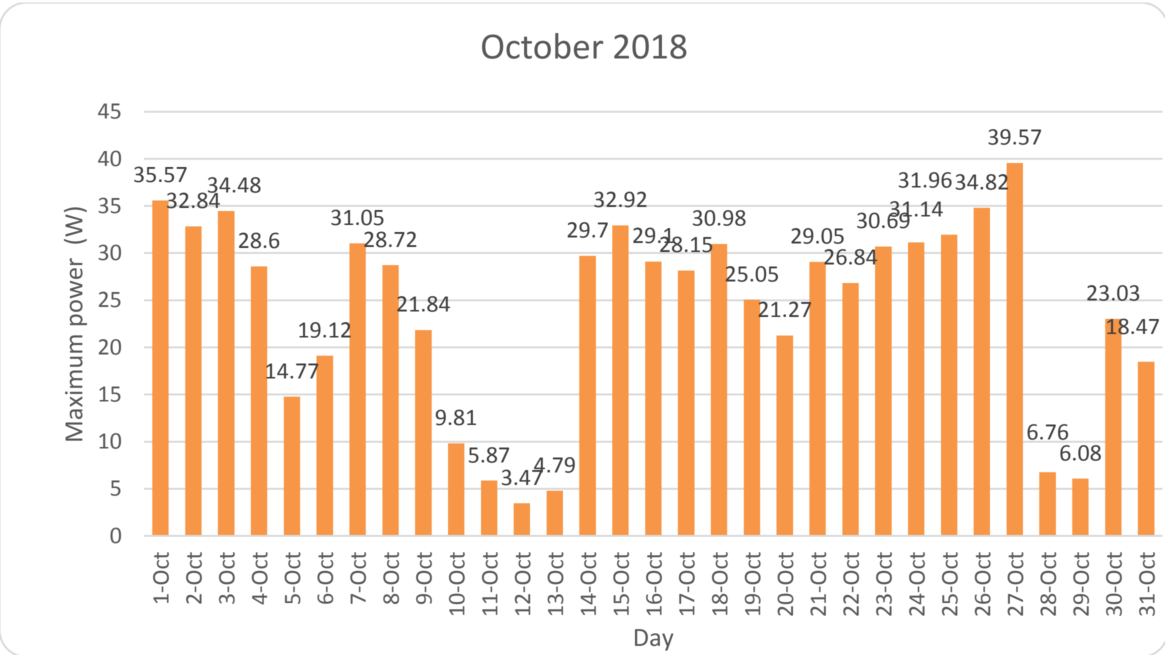


Fig 4.6 Maximum Power (100W), October 2018

Figure-4.5 and 4.6 represent the maximum power generation curve of 60W and 100W solar panel in October 2018. On 2 and 1 October 2018, we have found the highest value of maximum power respectively (20.66W) and (35.57W). And the lowest value of minimum power was (1.95W) and (3.47W) on 12 September 2018. Monthly average power is 12.64W and 24W respectively for 60W and 100W solar panel.

4.2.6 Shows the data of maximum power in November 2018

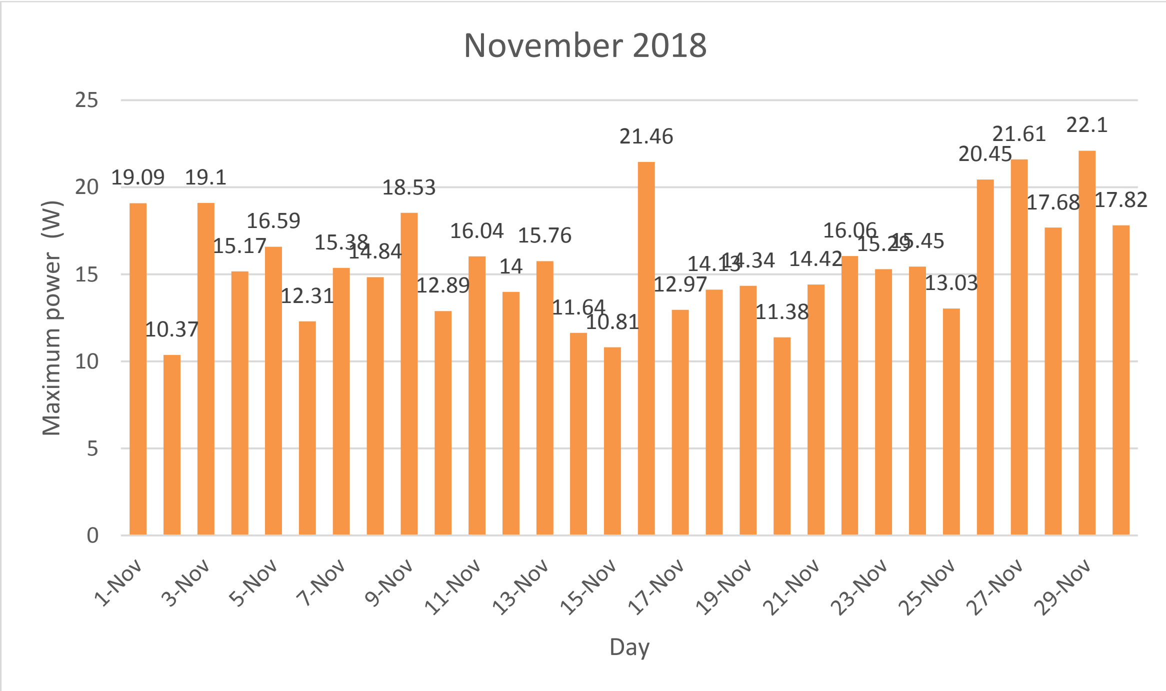


Fig 4.7 Maximum Power (60W), November 20

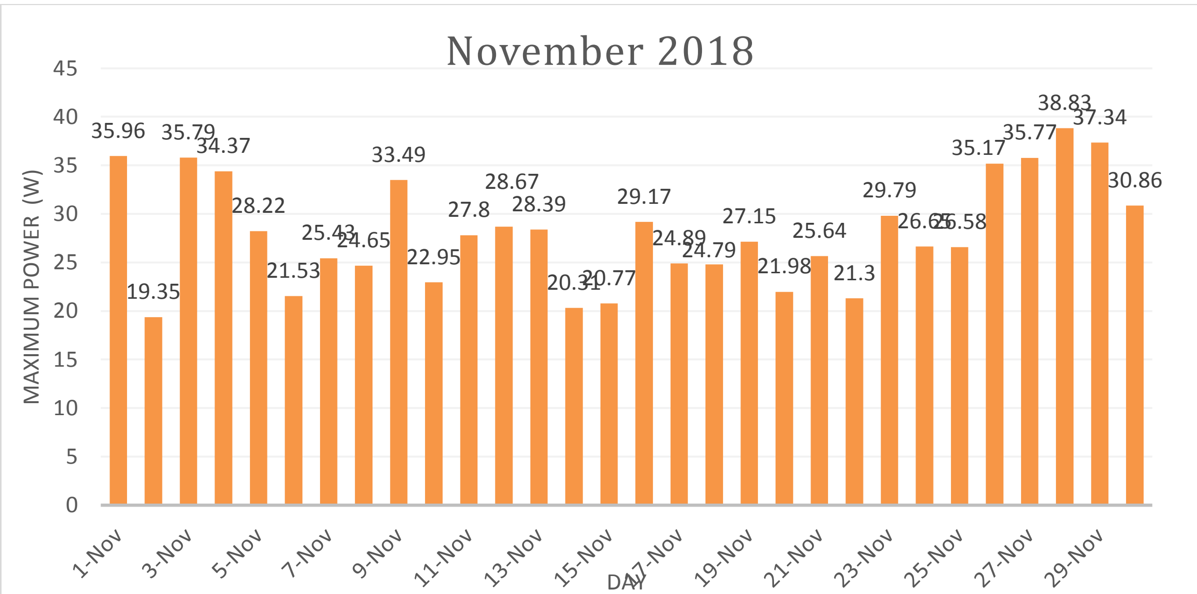


Fig 4.8 Maximum Power (100W), November 2018

Figure-4.8 and 4.9 represent the maximum power generation curve of 60W and 100W solar panel in November 2018. On 29 and 28 November 2018, we have found the highest value of maximum power respectively (22.01W) and (38.83W). And the lowest value of minimum power was (10.37 W) and (19.35W) on 2 November 2018. Monthly average power is 15.69W and 28.12W respectively for 60W and 100W solar panel.

4.2.7 Shows the data of Sunny day Irradiance in October & November 2018

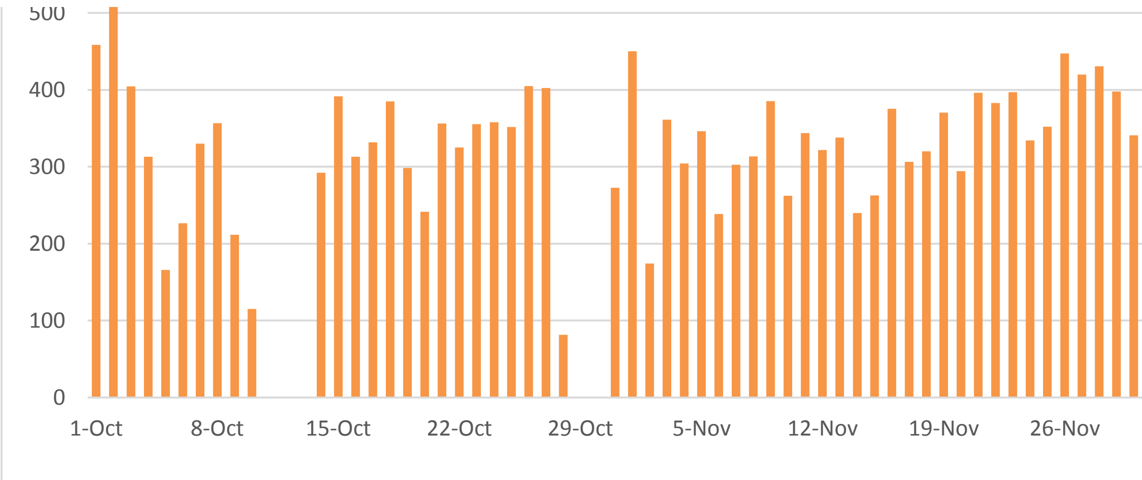


Fig. 4.9 Sunny Day Irradiance 60W

4.2.8 Shows the data of Sunny day Irradiance in October & November 2018

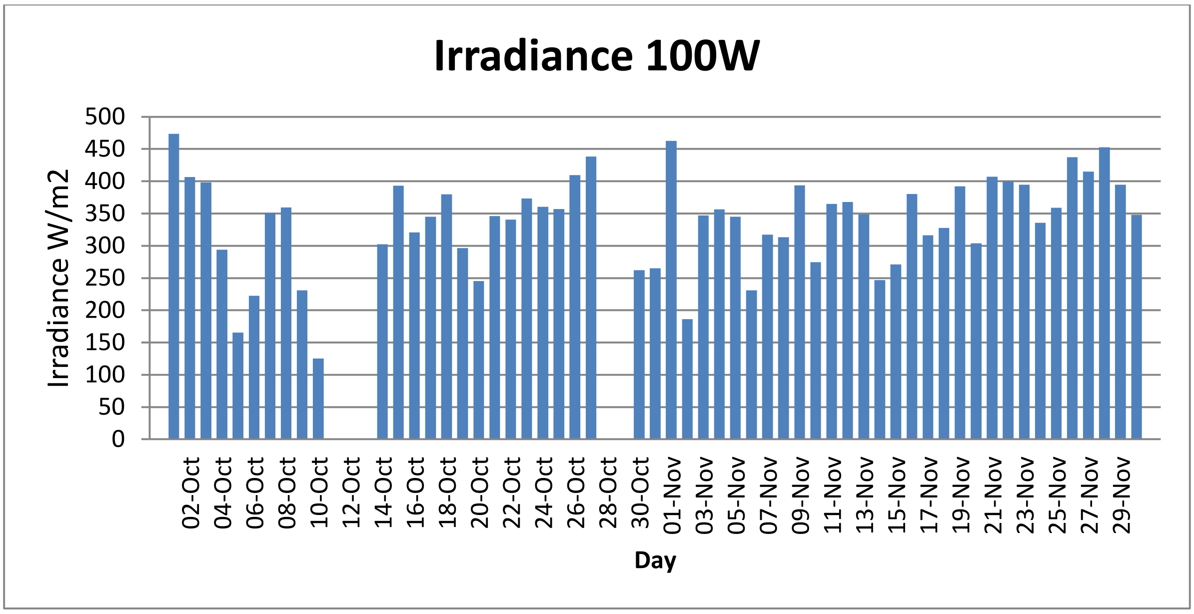


Fig. 4.10 Sunny Day Irradiance 100W

Figure-4.10 and 4.11 show the data regarding the irradiance of a sunny day in October and November 2018: During a sunny day, we get the highest irradiance 519.52 W/m^2 for the 60W panel and 473.69 W/m^2 for the 100W panel. In a sunny day, we measured our data every hour.

4.2.9 Shows the data of Sunny day Power in October & November 2018

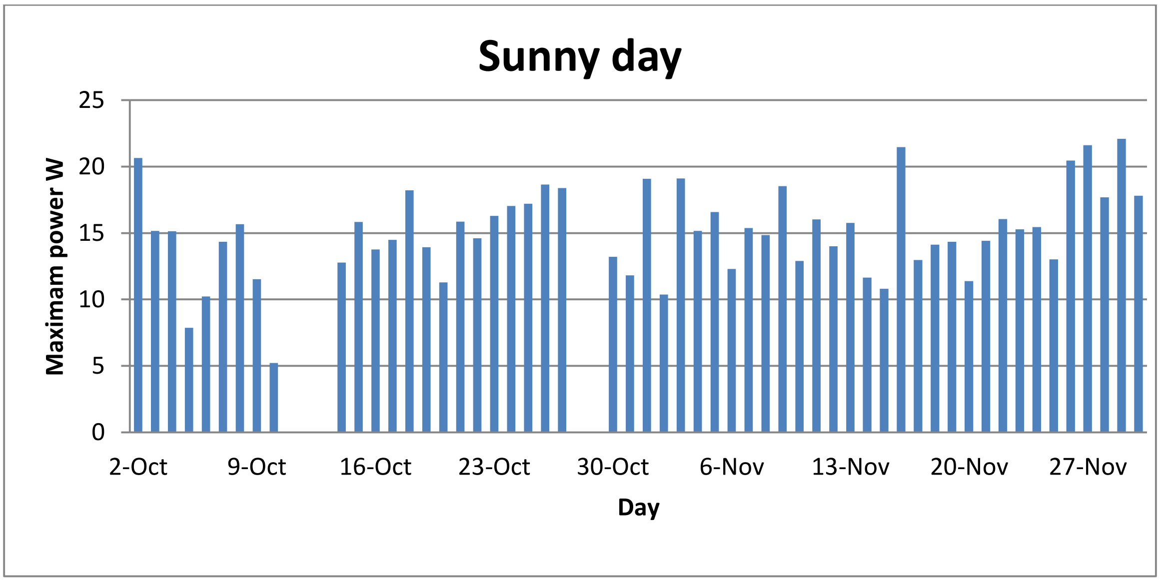


Fig. 4.11 Only Sunny Day Maximum Power (60W).

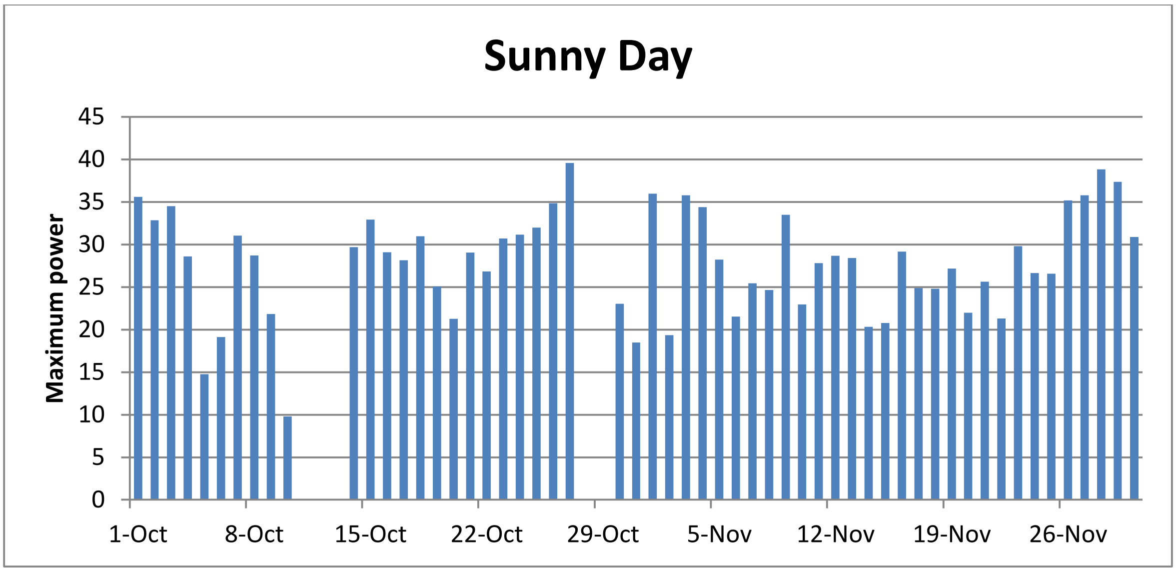


Fig. 4.12 Only Sunny Day Maximum Power 100W.

Figure 4.12 shows the data regarding the generated power on a sunny day October and November 2018 from the 60W solar panel and Figure-4.13 shows the data regarding the maximum power of sunny day in October and November 2018: During a sunny day, we get the highest power 22.1W for the 60W panel and 39.57W for the 100W panel. In a sunny day, we measured our data every hour.

4.2.10 Shows the data of Rainy day Irradiance in October 2018

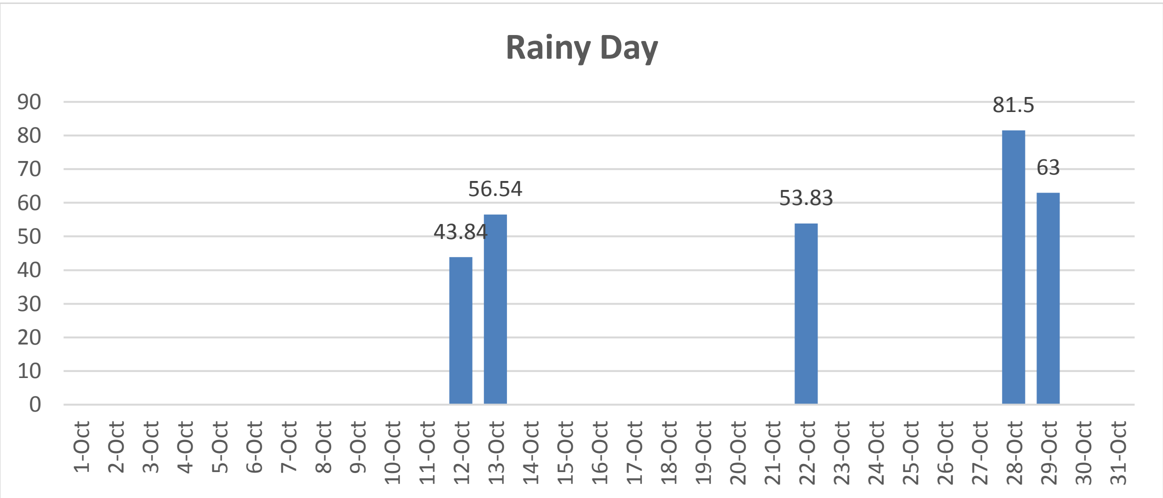


Fig. 4.13 Only Rainy-Day Irradiance 60W, October 2018

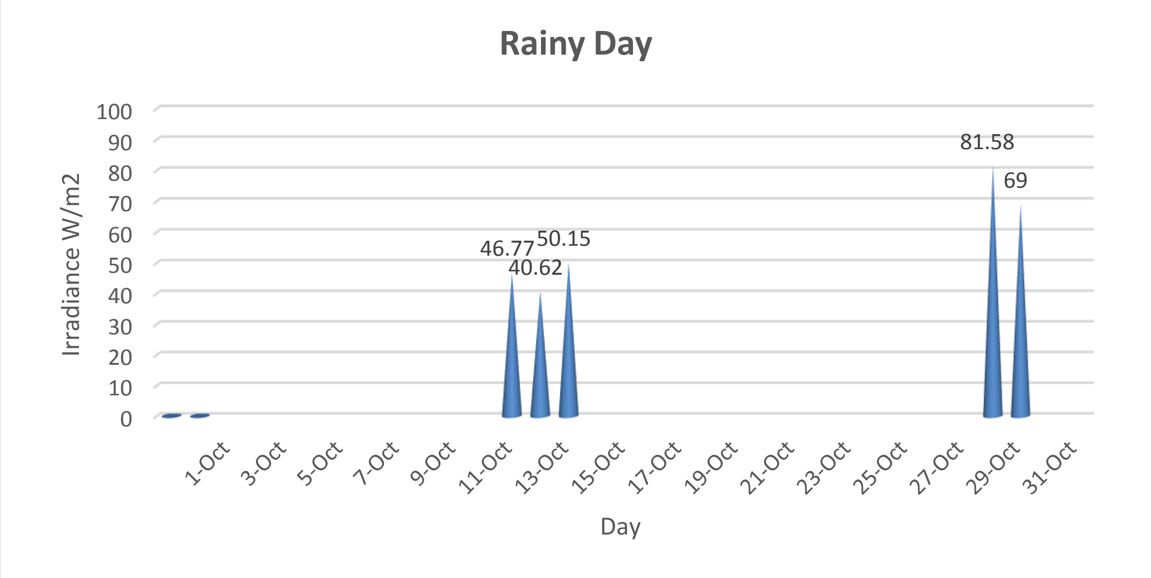


Fig. 4.14 Only Rainy-Day Irradiance 100W, October 2018

Figure-4.14 and 4.15 show the data regarding the irradiance of a rainy day in October for 60w and 100w. On the other hand, November 2018 has no rainy day. During a rainy day, we get the highest irradiance 81.50 W/m^2 for the 60W panel and 81.58 W/m^2 for the 100W panel. In a rainy day, we can not measure our data properly.

4.2.11 Shows the data of Rainy day Power in October 2018

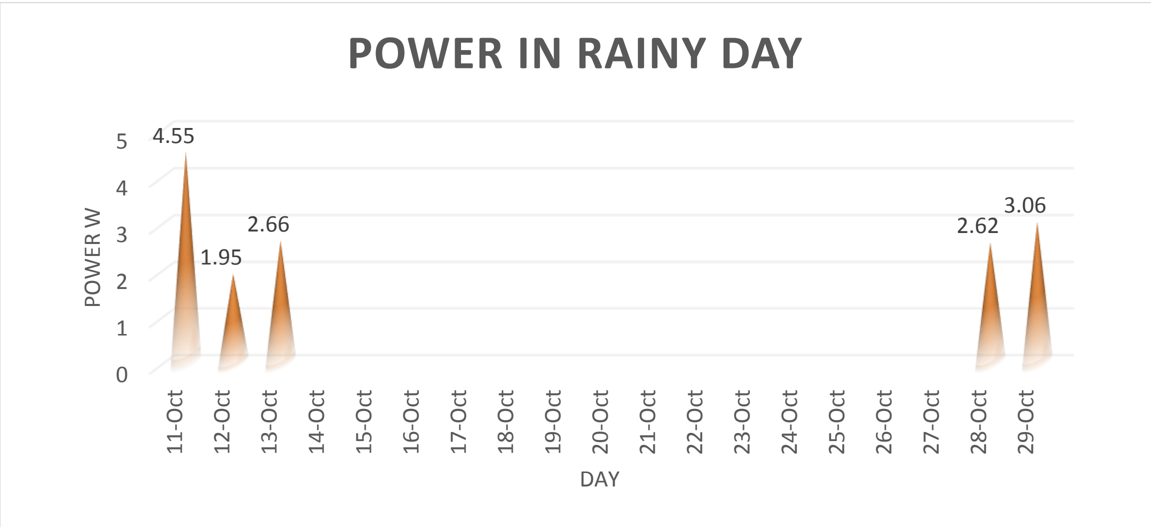


Fig. 4.15 Only Rainy-Day Maximum Power 60W, October 2018

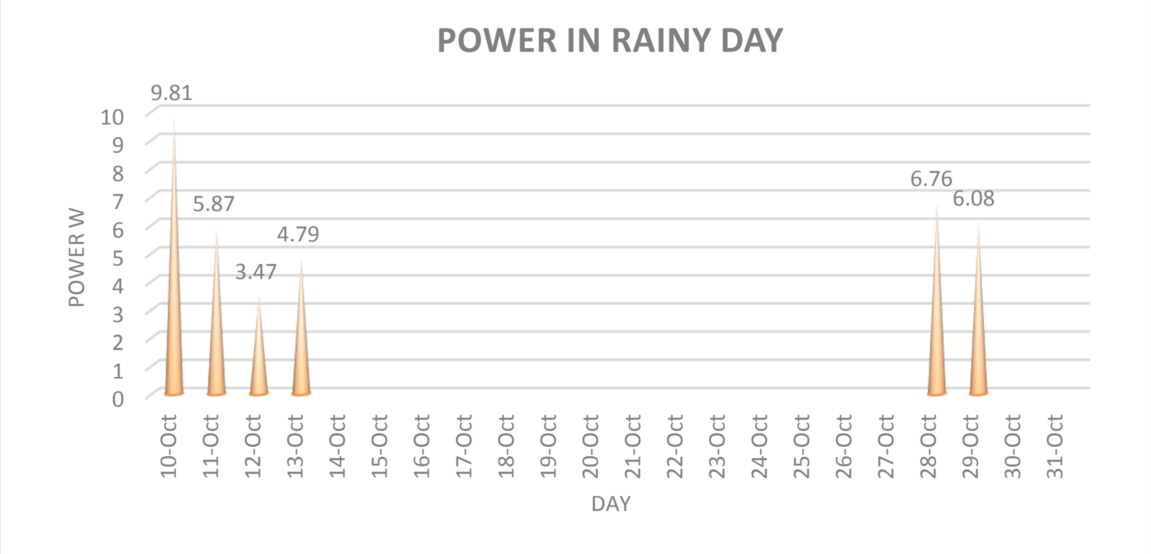


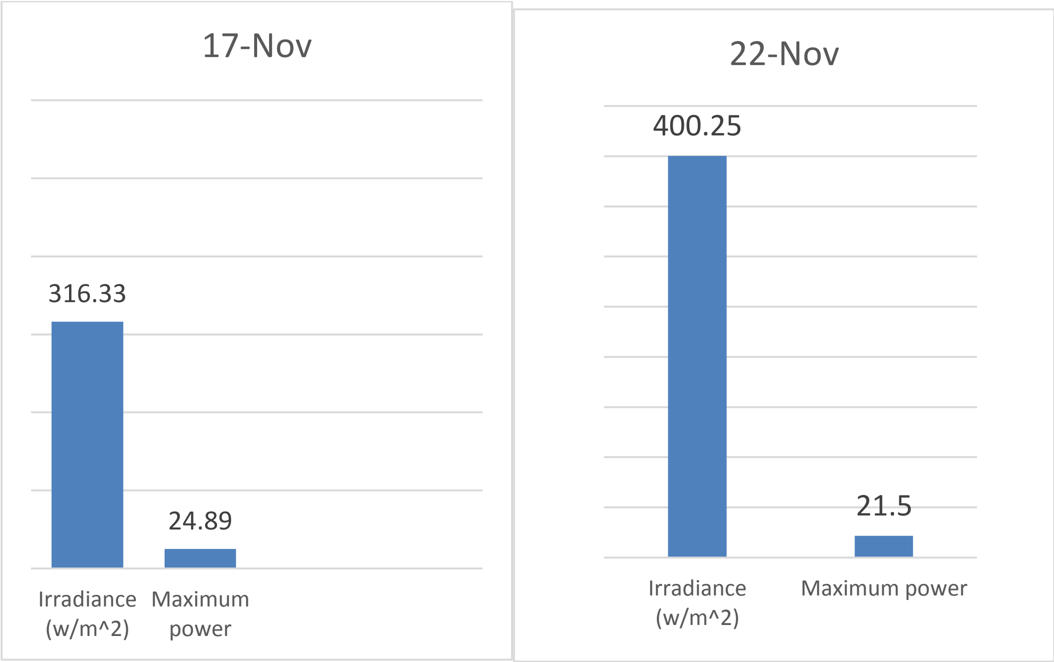
Fig. 4.16 Only Rainy-Day Maximum Power 100W, October 2018

Figure 4.16 shows the data regarding the generated power on Rainy-day October and November 2018 from the 60W solar panel and Figure-4.17 shows the data regarding the maximum power of Rainy-day in October and November 2018 from the 100W solar panel. During Rainy-day, we get the lowest power 1.95 for the 60W panel and 3.47 for the 100W panel. In Rainy-day we cannot measure our data every hour because of rain.

4.3 Variation of Generated Power with Respect to Irradiance

On 17 November 2018, the measured irradiance was 316.33 W/m^2 and the corresponding power produced by that panel was 24.89 W. However, the matter of concern that, on 22 November 2018, the measured irradiance was 400.25 W/m^2 but the power produced by the panel was 21.5 W which was comparatively lower than the previous one. This is another finding of this research. Generally, we can see that the power is proportional to the irradiation of the sun. But in this case, the situation is not similar because we get more power in less irradiation and get less power in higher irradiation. Here in this research, we find this main reason behind this problem. This happens because the irradiation measurement tool does not measure the power production of the panel at that moment. We get the total produced power from the solar panel and irradiation from the other toolbox.

As we know sun irradiation is not the same in all places. So, when we measured the less power at that moment the fallen irradiation of the sun on that panel was less than the irradiation measured toolbox. So, we get less power in more irradiation.



(a) (b)

Fig. 4.17 Irradiance & Generated Power, October & November 2018

4.4 Comparison between 60W and 100W Solar Radiation Data

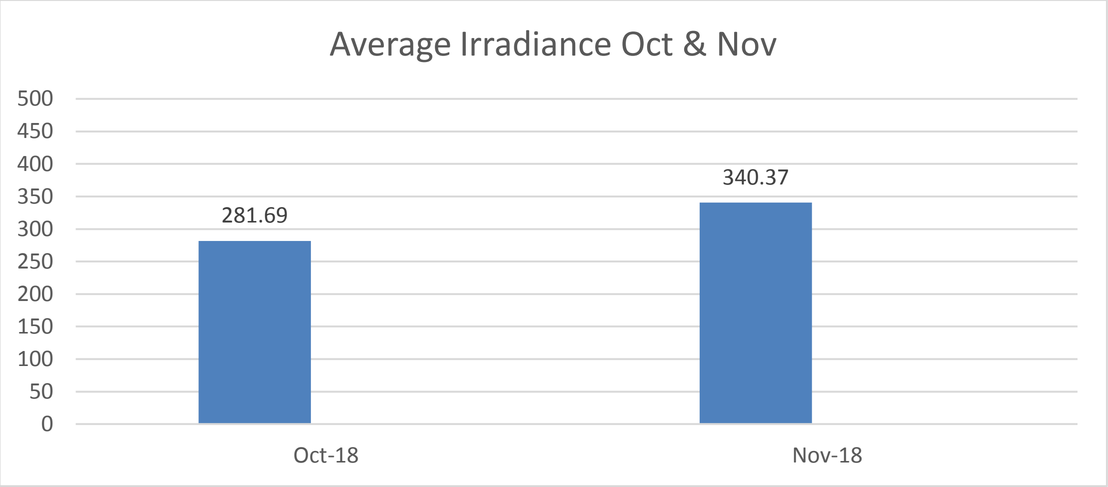


Fig 4.18 Comparison of Irradiance 60W (Oct-Nov,2018)

Fig 4.19 shows the comparison of irradiance. This was our main goal for this paper, we are comparing the irradiance data of 60W solar panel on this segment. In October 2018 from the 60W solar panel we get average irradiance of 281.69 W/m^2- but in November 2018 from the 60W solar panel, we get average irradiance of 340.37 W/m^2, which was greater than October's average irradiance.

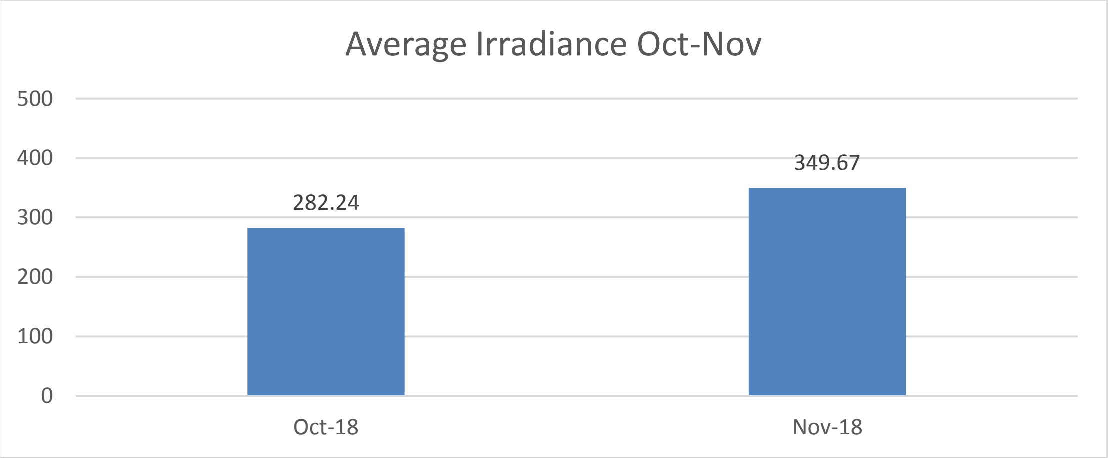


Fig 4.19 Comparison of Irradiance 100W (Oct-Nov,2018)

Fig 4.20 shows the comparison of irradiance for the 100W solar panel. In October 2018 from the 100W solar panel we get average irradiance of 282.24 W/m2 but in November 2018 from the 60W solar panel, we get average irradiance of 349.67 W/m2, which was greater than October's average irradiance. From this data chart, we can see the difference between those two months of solar radiation.

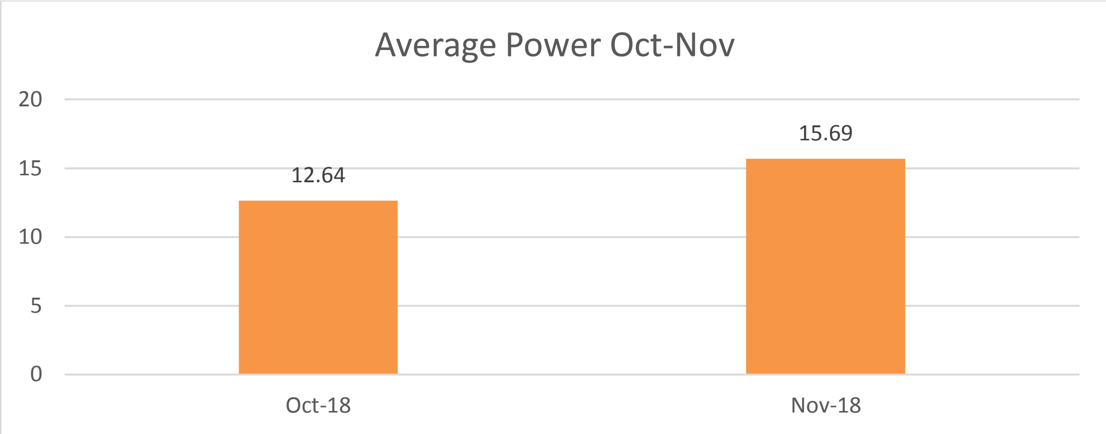


Fig 4.20 Comparison of Maximum Power 60W (Oct-Nov,2018)

Fig 4.21 shows the comparison of Power generation of the 60W solar panel. In October 2018 from the 60W solar panel we get average generated power of 12.64W but in November 2018 from the 60W solar panel we get average generated power of 15.69W, which was greater than October's average generated power.

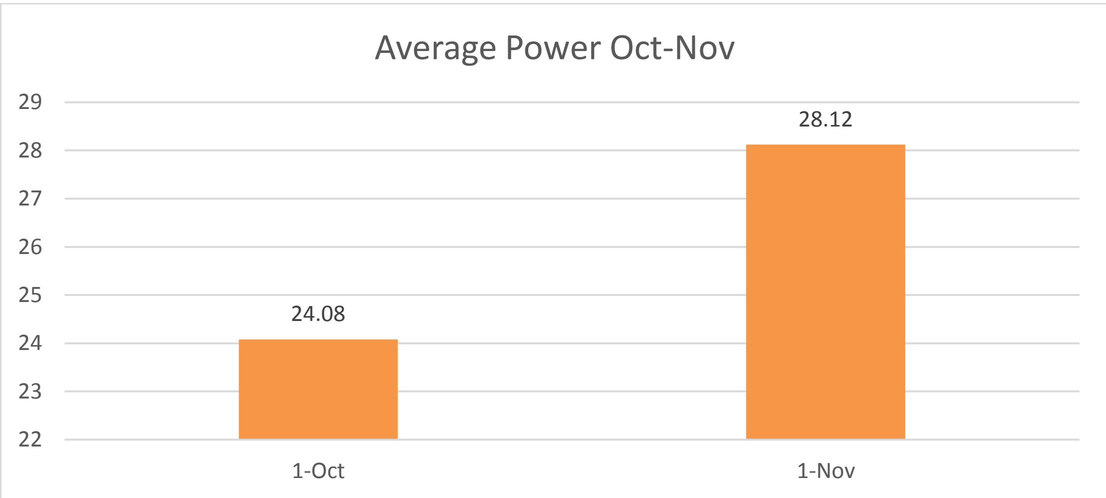


Fig 4.21 Comparison of Maximum Power 100W (Oct-Nov,2018)

Fig 4.22 shows the comparison of average generated power for the 100W solar panel. In October 2018 from the 100W solar panel we get average generated power of 24.08W but in November 2018 from the 100W solar panel, we get average generated power of 28.12W, which was also greater than October's average generated power. From this data chart, we can see the difference between those two months average generated power by the solar panel.

4.5 Comparison of Solar Radiation Data among Different Years

Table-9: Data of Monthly Average Solar Irradiance in 2008,2009 & 2010 [42].

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 between 2009 and 2010 because, in 2010, only 4.50 $kWh/m^2/day$ irradiation was measured as shown in Table- 9.

Solar radiation data were collected from Renewable Energy Research Center (Dhaka University), National Renewable Energy Laboratory and Development and Research are given in Table-7. Most of these solar radiation data were collected from DU for Dhaka with different cities in Bangladesh.

Table-10: Collected Solar Irradiance Data of Bangladesh from 1985-2006 were Presented Below [43]

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-11: 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	October	3.96
	November	4.7
1987-89	October	4.5
	November	4.61
1992	October	5.38
	November	4.93
2000-2003	October	3.76
	November	4.19
2003-2005	October	3.78
	November	3.57
2008	October	4.55
	November	4.31
2009	October	4.00
	November	4.53
2010	October	3.97
	November	4.20
2018	October	8.91
	November	7.62

4.6 Summary

In this chapter, we are trying to present the data of October and November 2018. In this part, we try to present irradiance, maximum output power, the situation of generation in a rainy day and sunny day, the difference of data in October and November, the average efficiency of all data, previous year's data analysis.

CHAPTER 5

CONCLUSION

In this research, we attempt to clear up that how much power can be delivered in the long stretch of October and November 2018 from a solar framework. We have worked just for two months yet in future we can quantify power and irradiation during the time alongside the investigation of panel proficiency. The synopsis of this paper displays that, there is a significant chance to take care of things to come power demand of Bangladesh by SHS innovation. Bangladesh is arranged between 20.30 - 26.38 degrees north scope and 88.04 - 92.44 degrees east scope which is a decent area for solar energy usage. Every day normal solar irradiation changes between 4 to 6.5 kWh per square meter. Most extreme measure of radiation is accessible in the period of April-May and least in December-January.

For using the solar power all the more viable, it is critical to gauge the irradiation of that nation time to time in light of the fact that solar radiation is changed after some time. In this postulation, our fundamental point was to discover the irradiation of sun in Dhaka city in the period of October and November so the power generation by the solar panel can be assessed and by utilizing this data we can without much of a stretch comprehend the electricity creation by SHS and make a standard type of power generation of SHS in 2018. Here we find that the normal irradiation of October 8.91 kWh/m2/day and November was 7.62 kWh/m2/day. Corresponding power delivered by 60W and the 100W solar panel was 12.084W and 12.44 W.

Solar energy sources talked about above can assist Bangladesh with producing more power to diminish Load-shedding issue. Time has come to look forward and work with these renewable energy fields to create electricity instead of depending entirely on ordinary technique. As of now, SHS built up in our nation. Presently a-days the force, elements and manageability of a human progress rely upon energy. Henceforth, a nation can be considered as acculturated one in the event that it has enough access to energy as required for the mechanical, horticultural and monetary development. There are heaps of parts to utilize solar electricity in the country region of Bangladesh

Future Scope:

In this research, we endeavor to elucidate that how much power can be created in the long stretch of October and November 2018 from a solar framework. We have worked just for two months yet in future we can gauge power and irradiation during the time alongside the examination of panel effectiveness.

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