An Economic Analysis of Solar PV System in Bangladesh

A thesis paper submitted to the
Department of Electrical and Electronics Engineering
In partial fulfillment of the requirement for the Degree of
Bachelor of Science in
Electrical and Electronics Engineering

By
Md. Naim Muzzammir
ID: 101-33-149

Abdullah Al Masum Foraji
ID: 101-33-165

Supervised by
Professor Dr. Shamsul Alam
Dean, Faculty of Science & Information Technology
Daffodil International University

Department of Electrical and Electronics Engineering
DAFFODIL INTERNATIONAL UNIVERSITY

JUNE 2014

APPROVAL

This thesis titled **"An economic analysis of solar PV system in Bangladesh",** submitted by Md. Naim Muzzammir and Abdullah Al Masum Foraji 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

Professor Dr. M. Shamsul Alam
Dean & Professor
Department of EEE
Faculty of Science & Information Technology
Daffodil International University

Nusrat Jahan Imu
Research Assistant
Department of EEE
Daffodil International University

Ms. Susmita Ghose
Lecturer
Department of EEE
Daffodil International University

DECLARATION

We hereby declare that, this thesis paper has been done by us under the supervision of **Professor Dr. M. Shamsul Alam,** Dean, Faculty of Science & Information Technology and **Nusrat Jahan Imu,** Research assistance and Lecturer Department of EEE on 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:

____

Professor Dr. M. Shamsul Alam,
Dean & Professor
Department of EEE
Faculty of Science & Information Technology
Daffodil International University

Nusrat Jahan Imu
Research assistant
Department of EEE
Daffodil International University

Submitted by:

____

Md. Naim Muzzammir
ID: -101-33-149
Department of EEE
Daffodil International University

____

Abdullah-Al-Masum Foraji
ID: -101-33-165
Department of EEE
Daffodil International University

ACKNOWLEDGEMENT

First we express our heartiest thanks and gratefulness to the Almighty ALLAH 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, Professor Dr. M. Shamsul Alam, Dean, Faculty of Science & Information Technology Daffodil International University (DIU), for engaging me in such an important research. He was always there to share his absolute expertise and valuable time. It was his constant guidance, helpful suggestions, constructive criticism and endless patience throughout development of this thesis.

We are also grateful to different online resources from which we have got much information. We would like to thanks, Ms. Susmita Ghose Lecturer Department of EEE and Nusrat Jahan Imu Research assistance, Department of EEE because they helped us by providing recent solar data, cost analysis and other related information. We also grateful to thanks Mr. Hamid & Mr. Kaysir because they gave all kind of help about to know solar system and solar power plant in sandwip. We also thankful to our elder brother Md. Rezaul Karim, he also done heard work with us to complete this thesis paper.

We would like to express our heartiest gratitude to the Head, Department of EEE Dr. Md. Fayzur Rahman, for his kind help to finish our project and also to other faculty members and the staff of EEE department of Daffodil International University.

We would like to thank our entire course mate in Daffodil International University, who took part in this discuss while completing the course work.

ABSTRACT

The increasing demand of electric power and shortage of present energy resources lead today engineers and scientists to think about the alternative sources of energy, the sunlight is a potential sources for generating electric power. In recent years, it is increasingly used to generated power .The use of solar energy is attractive for solar home system application also. Solar home systems are quite needing no fuel and require very little maintenance. Another advantage of PV system is: free energy, reliable power, flexibility and quick installation.

Author discussed **"An economic analysis of solar PV system in Bangladesh".** Finally, author try to analyzed solar home system per unit cost, compare diesel generator cost and solar PV cost and try to describe sandwip off grid solar power plant.

The government of Bangladesh should take necessary steps for solar energy development of rural area .The government institute is "Infrastructure development company limited" (IDCOL) established from 2003 to 2013 solar home system 20lakh and produce 100 MW electricity.

We know that 70% people lived in rural area. So, this project is not sufficient for development in rural area. Sun is the source of all energy available in the world. The initial cost of the solar energy would be much higher but the experts believe that it would be a cost effective alternative to other source.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Introduction

Presently Global warming and climate changes effect is the burning issue all over the world. Bangladesh will be the most affected country in the climate changes effect round the world. There are so many causes of global warming. Among them power generation is the most remarkable one. We cannot think about any development without power (Electricity). Finally, sources of conventional energy like Fossil fuel, Natural gas and Coal are limited. If we used them in the present rate it will be finished within the short time. So, there is no other way to think about environmental friendly renewable energy production sources. In Bangladesh context solar energy is the most effective source for renewable energy production. Even if fuel is available within the country transporting that fuel to remote, rural village can be difficult .There are no loads or supporting infrastructure in many remote villages where transportation by animals is still common. Transportation by animals limits loads capacities and some loads, diesel generators, for example may be impossible to bring to such locations. The use of renewable energy is attractive for solar energy application in many developing countries. This technology, referred to as photovoltaic (PV), converts the sun energy into electricity through electromagnetic means when PV module is exposed to sunlight .The solar radiation energy is converted into DC power and requires an inverter it into AC power. But still some problems have that make it uncomfortable to us. Its efficiency is so much low and the prices of its energy still so high. So in this paper we try to find way to make it comfortable.

1.2 Solar energy attractive in Bangladesh

1. Bangladesh is situated between 20.30 – 26.38 degrees north latitude and 88.04 – 92.44 degrees east longitude.
2. Daily average solar insulation rate is 4 to 6.5 KWh per square meter.
3, Maximum amount of radiation is available on the month of March- April (6.5h) and minimum on December- January (4h).

1.3 Important uses of solar power

The main sources of world energy generation are the fossil fuels (gas, oil, coal) and nuclear power plants. Due to the usage of fossil fuels, green house gases (CFC, CH_4, O_3, but mainly CO_2) emit into the atmosphere. From the nuclear power plant, carbon is released in a small amount (90 grams equivalent of carbon dioxide per kilowatt hour).[1] But the radioactive waste remains active over thousand years which is a potential source of environmental pollution.

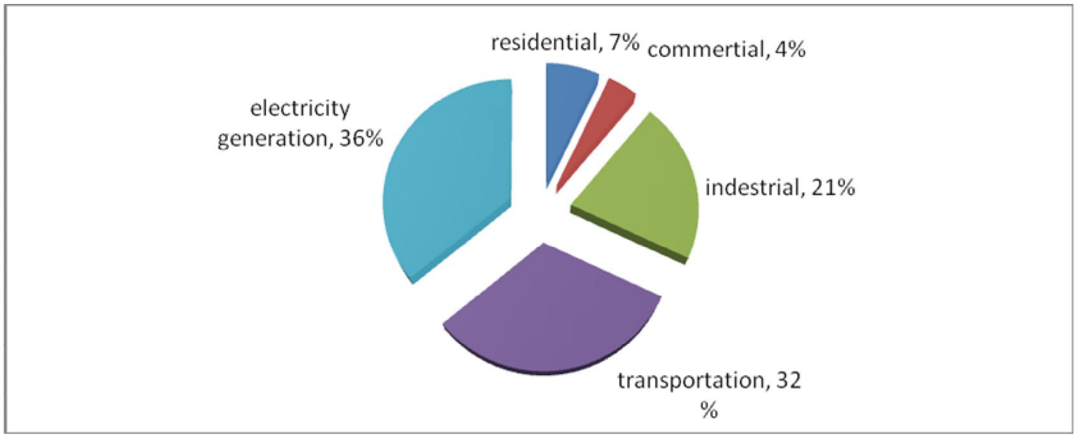


Figure1.1 Sources of carbon dioxide emissions [2]

Figure1.1 shows that electricity generation is source of the highest emission of carbon dioxide. So, production of this clean energy is actually contributing the highest towards global warming. Global warming as well as the environmental pollution is, in our times, the greatest environmental threat to human being .On the other hand, there is an alarming energy crisis world wide as fossil fuel reserves decrease and the ageing power plants are going to close in near future. From the aspect of global warming and shortage of natural gas, scientists and engineers are looking for clean, renewable energies. Solar energy is the one of the best options. Because the earth receives 3.8 YJ [1YJ = 1024 J] of energy which is 6000 times greater than the worlds consumption. [3] Bangladesh is facing an acute shortage of energy. Natural gas is the main source of electricity generation in Bangladesh. But the limited gas reserves cannot fulfill the necessities of both domestic requirements and industrial and commercial demands, especially demands for electricity generation for long. Our present power generation capacity is only around 4200 MW whereas the total power requirement is 6000 MW. [4] So, we are able to generate only 70% of our total electricity demand. Due to this shortage of electricity not only we are facing load shedding across the country but also the industrial sector is badly affected. Resulting in reduced industrial output and diminished export earnings. There is a rising demand on the energy sector for rapid industrialization, urbanization, high population growth, increasing food production, rising standard of living etc. Solar energy could be a major source of power generation in Bangladesh. Bangladesh government plans to make it mandatory to install solar panel on rooftops of every multistoried and hi-rise building. As solar energy is one of the cleanest and simplest forms of energy. Solar energy is readily available anywhere and everywhere in the earth. It can be used it to generate electricity at the point of consumption. Solar powered building is based on this concept.

As finally we can say that for use of solar energy:

1. Source of Conventional Energy is Limited.
2. Production of power from conventional Energy causes CO Emission.
3. Easy to install and use.
4. Noise free.

5. Less maintenance.

6. Source is unlimited.

7. There is no moving part, so its life is long

1.4 Potential of solar energy

There is a huge potential of solar energy. It is so huge that the total energy needs of the whole world can be fulfilled by the solar energy. The total energy consumption of the whole world in the year 2008 was 474 exajoule(1EJ=1018 J) or approximately 15TW(1.504*1013 W). [5]Almost 80%-90% of this energy came from fossil fuel. [6] From the sun earth receives 3,850,000 EJ of energy. [5]

Which is equivalent to 174 petawattas (1 PW=1015 W). The earth does not hold all the energy, a part of it reflects back. After reflection earth receives 89 PW of energy. Of this huge amount only less than 0.02% is enough to replace the fossil fuel and nuclear power supply in the whole world at present. By this we can easily understand the great potential of solar energy. Considering about green house effect environmental impact, cost, risk.

1.5 Top ten countries using solar power

Solar energy is becoming more and more popular among the grown and the growing countries. This is mainly because of government recognizing the energy problems and giving out more and more incentives for going solar, to both the general public and the corporations. The countries are starting to compete, to lead the renewable energy race in solar energy. We started wondering about which countries have the most amount of installed solar systems. So we wanted to do a top ten list of the countries which uses the most solar energy (in Mega Watts, MW) in the world. We wanted to do this in a Letterman style but we think it's better to write a short note about each country pointing out its highlights and some interesting facts. [7]

This is the (unofficial) overview of the Top10 Solar PV installed capacity across the world, we keep it updated based on latest info from various sources. . [8]

Country	Latest Installed Capacity (GWp)	PV % of electricity consumption in country	Latest capacity update date
Germany	35.65	5.3%	31 Dec 2013
China	17.7	0.1%	31 Dec 2013
Italy	18	9%	31 Dec 2013
Japan	11.86	0.8%	31 Dec 2013
USA	11.42	0.3%	31 Dec 2013
Spain	5.1	2.8%	31 Dec 2012
France	4.67	0.9%	31 Dec 2013
Australia	3.159	1.2%	31 Jan 2014

Belgium	**2.82**	**2.5%**	**31 Dec 2013**
Czech Republic	**2.0**	**3.1%**	**31 Dec 2012**
Total of Top10	**112.4**		

The following countries are catching up fast with the Top10 countries above

Country	Installed Capacity (GWp)	PV % of electricity consumption	Latest capacity update date
Greece	**2.58**	**3.5%**	**31 Dec 2013**
India	**2.123**	**0.3%**	**31 Dec 2013**
UK	**1.845**	**0.5%**	**16 Feb 2014**

1.6 Objectives of the project

1. To introduce Renewable Energy (RE) as an alternative solution for power generation.

2. Tariff calculation of solar home system.

3. Cost comparison of solar home system and diesel generator

4. Sandwip off grid solar power plant.

1.7 Project Target

1. Promote Solar Energy production and uses in Urban, Sub Urban, Rural, Agriculture & Industrial Sector.

2. Reference of uninterrupted power supply.

3. Reference of surplus power transmission directly to grid line.

4. Training to be teacher & technicians for design, Installation, repair and maintenance of solar Energy production system and equipment.

5. Formulate a sustainable & suitable policy for solar power sale.

CHAPTER TWO
Photovoltaic Technology

2.1 Solar cells:

Photovoltaic (PV) or solar cells are PN junction Semiconductor devices. It converts sun light into direct current electricity. Groups of solar cells are electrically connected into PV modules, arrays. PV modules or arrays can be used to charge batteries .This system can be used to power any number of Electrical loads. PV systems can produce alternating currents or Inverter. Compatible with any conventional appliances and operate in parallel with and interconnected to the Utility grid. Solar cells often are distinguished by their type of semiconductor junction- (A) Homojunction (n + p layer is of the same material) (B) Heterojunction (n + p layer is of different material) (d) MIS (Metal / Isolator / Semiconductor (e) SIS (Semiconductor / Isolator / Semiconductor)

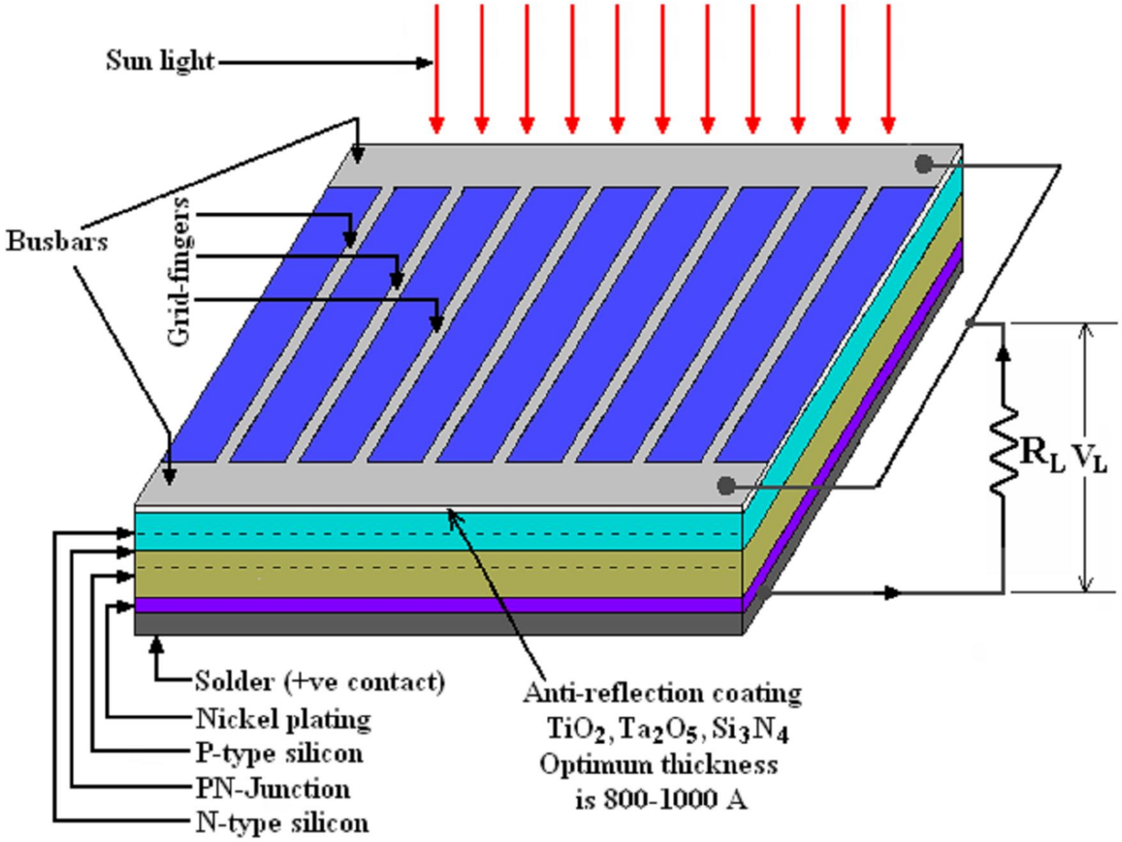


Fig 2.1: Solar cell

2.1.1 Connect cell to make modules:

- One silicon solar cell produces 0.5V to 0.6V
- Usually 36 cells are connected together to make a Module
- Such one module has enough voltage to charge 12 volt batteries and Run pumps and motors
- PV Module is basic building block of a PV power system
- Modules can be connected to produce more power

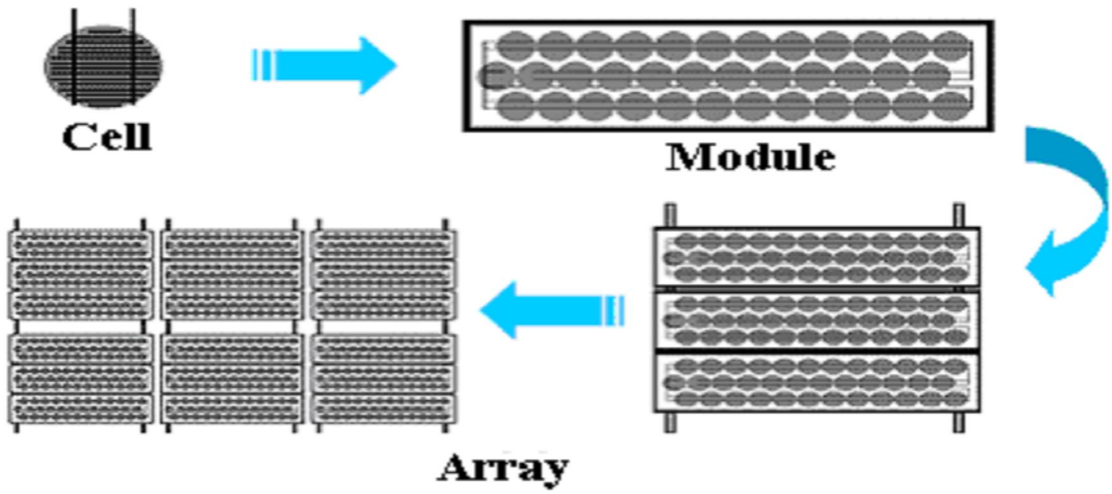


Figure2.2: Cells, Modules, Panels and Arrays

2.1.2 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
2. Multi-crystalline or polycrystalline cells and
3. Amorphous cells

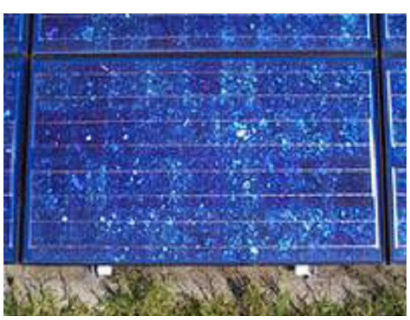


Fig 2.3: Polycrystalline solar cell

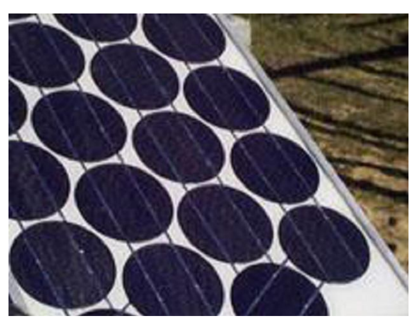


Fig2.4: Single Crystal solar cell

Fig 2.5: Amorphous solar cell

2.1.2.1. 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 production steps. These are, for instance:

a. Grinding and cleaning
b. Doping
c. Metallization
d. Antireflection coating

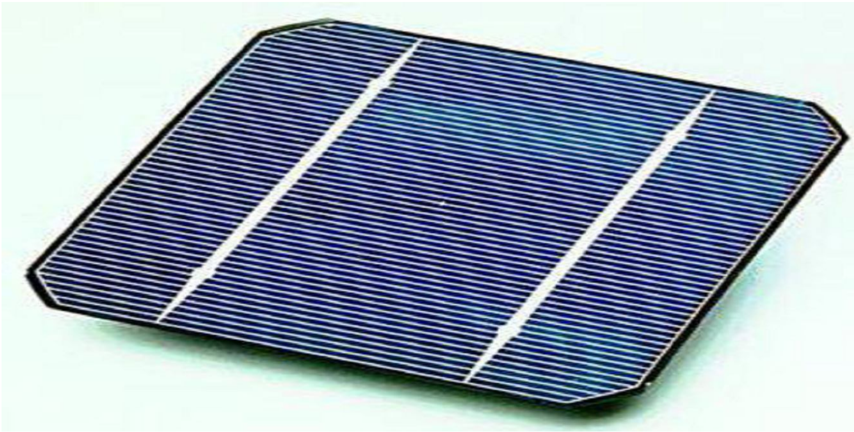


Figure2.6: Monocrystalline Cells

2.1.2.2 Polycrystalline Cells: The manufacturing process for monocrystalline silicon is highly energy-intensive and therefore very expensive. 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 and further processed, as described before. The pulling of the single-crystal can be omitted 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.

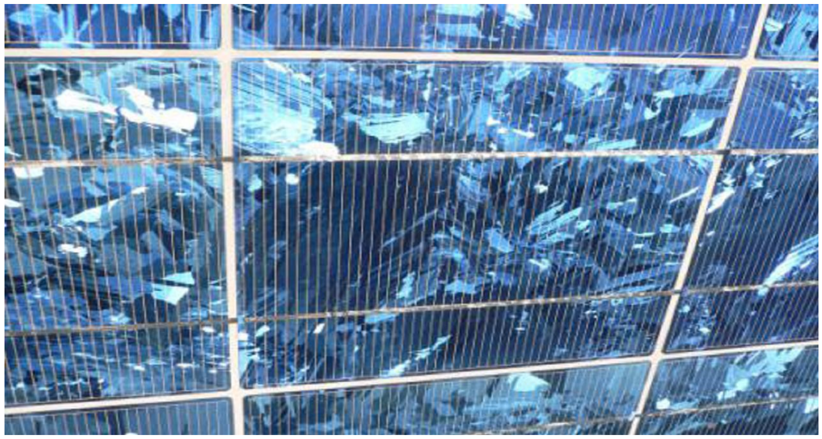


Figure2.7: Polycrystalline Cells

2.1.2.3 Amorphous Cells: In order 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 (SiH4) on a carrier material like glass and doped in a further step. The semi conducting 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 -

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

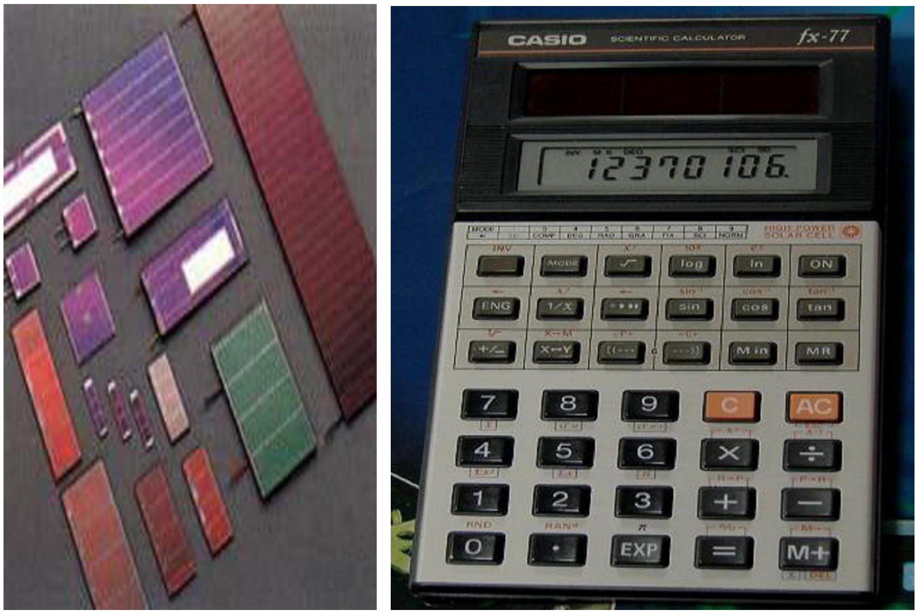


Figure2.8: Amorphous Cells

2.2 Charge Controller: Charge controller is an electronic device which is used in solar system. A solar charge controller is needed in virtually all solar power systems that utilize batteries. The job of the solar charge controller is to regulate the power going from the solar panels to the batteries. Overcharging batteries will at the least significantly reduce battery life and at worst damage the batteries to the point that they are unusable. The most basic charge controller simply monitors the battery voltage and opens the circuit, stopping the charging, when the battery voltage rises to a certain level. Older charge controllers used a mechanical relay to open or close the circuit, stopping or starting power going to the batteries.

Modern charge controllers use pulse width modulation (PWM) to slowly lower the amount of power applied to the batteries as the batteries get closer and closer to fully charged. This type of controller allows the batteries to be more fully charged with less stress on the battery, extending battery life. It can also keep batteries in a fully charged state (called ―float) indefinitely. PWM is more complex, but doesn‘t have any mechanical connections to break. The electricity produced in the solar panel is stored in the battery. The electricity stored in the battery is used at night. This whole process is monitored by the charge controller. A typical charge controller (Phocos) is shown in the figure bellow-

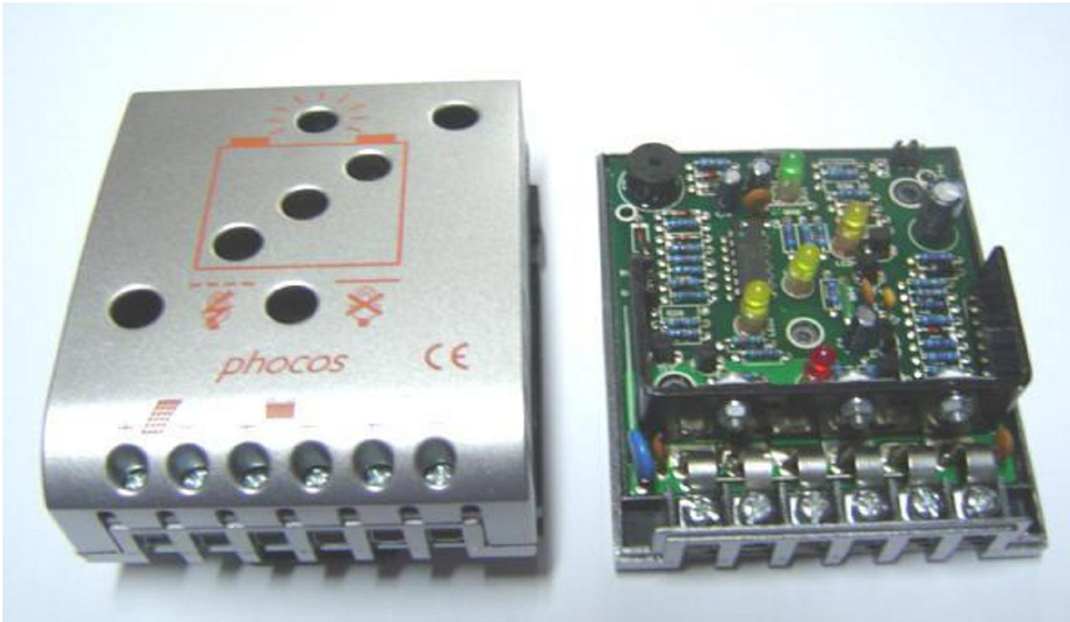


Figure2.9: Charge controller

2.2.1 Function of charge controller: The main function of a charge controller or regulator is to fully charge a battery without permitting overcharge while 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 used for co-ordination and control among the battery, load and solar panel. Charge controller stores the electricity in the battery during day time and supplies the same to the load (mainly lamp) at night. On the other hand, if battery is fully charged, then charge controller can directly supply electricity to the load (Fan, mobile charger etc) from the solar panel during day time. A charge controller or charge regulator is mainly worked as a voltage regulator. Generally it controls the voltage and current of the solar panel to save in battery. Solar panel mainly produces 16 volts to 21 volt and 14 volt to 14.4 volt is required to keep the battery in full charged state. The charge controller works as a Buck converter to minimize this voltage level. Charge controller is mainly a Chopper 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.

2.2.2 Types of Charge controller: Charge controller connection mainly two types-

1. Parallel or shunt controller
2. Series controller

2.2.3.1 Parallel Controller:

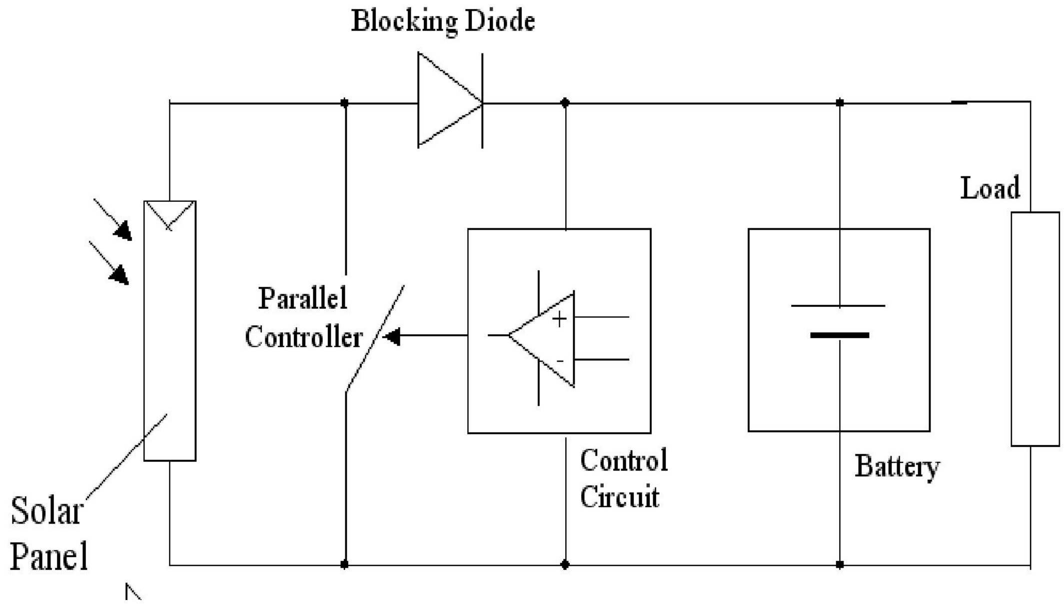


Figure2.10: Use of Shunt controller in solar home system

In this system, charge controller is in parallel with the battery and load. When the battery is fully 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 blocking diode, it gets hot.

Disadvantages of shunt controller:

- Lose of electricity
- When the panel is short circuited, huge amount of short circuit current flows through the switch (FET).
- Shunt controller gets hotter compared to series controller.
- There is a chance of hot spot on the panel.

2.2.2.2 Series Controller:

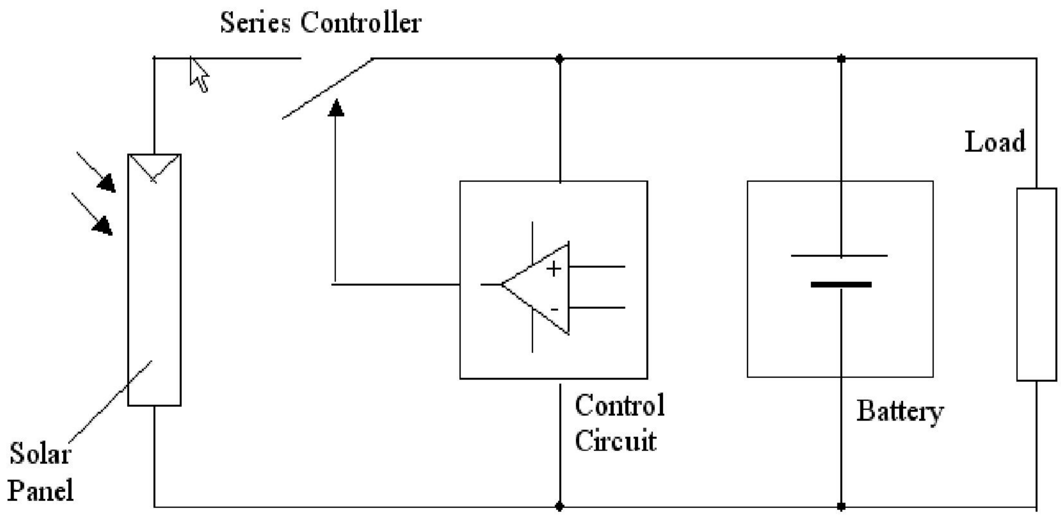


Figure2.11: Use of Shunt controller in solar home system

In this system, charge controller is connected in between with the solar panel and battery. In order to terminate the flow of electricity to the battery, the series controller must be removed from the battery. There's no need of blocking diode in this system, but in many reasons it is used to terminate the process of discharging at night. The resistance should be maintained as low as possible in order to minimize lose of the electricity.

Advantages of series controller:

- Blocking diode is not required.
- Series controller switch is handled with low voltage compared to shunt controller.
- Low switching noise.
- It is possible of precision charge and PWM of the battery.
- No chance of hot spot like the shunt controller .

2.2.3 Panel charging and characteristics of controller:

Below figure shows how different kinds of charge controller controls the voltage and current. The upper curve shows the battery voltage and the lower curve shows panel current. a,b,c,d indicates controller‘s action .

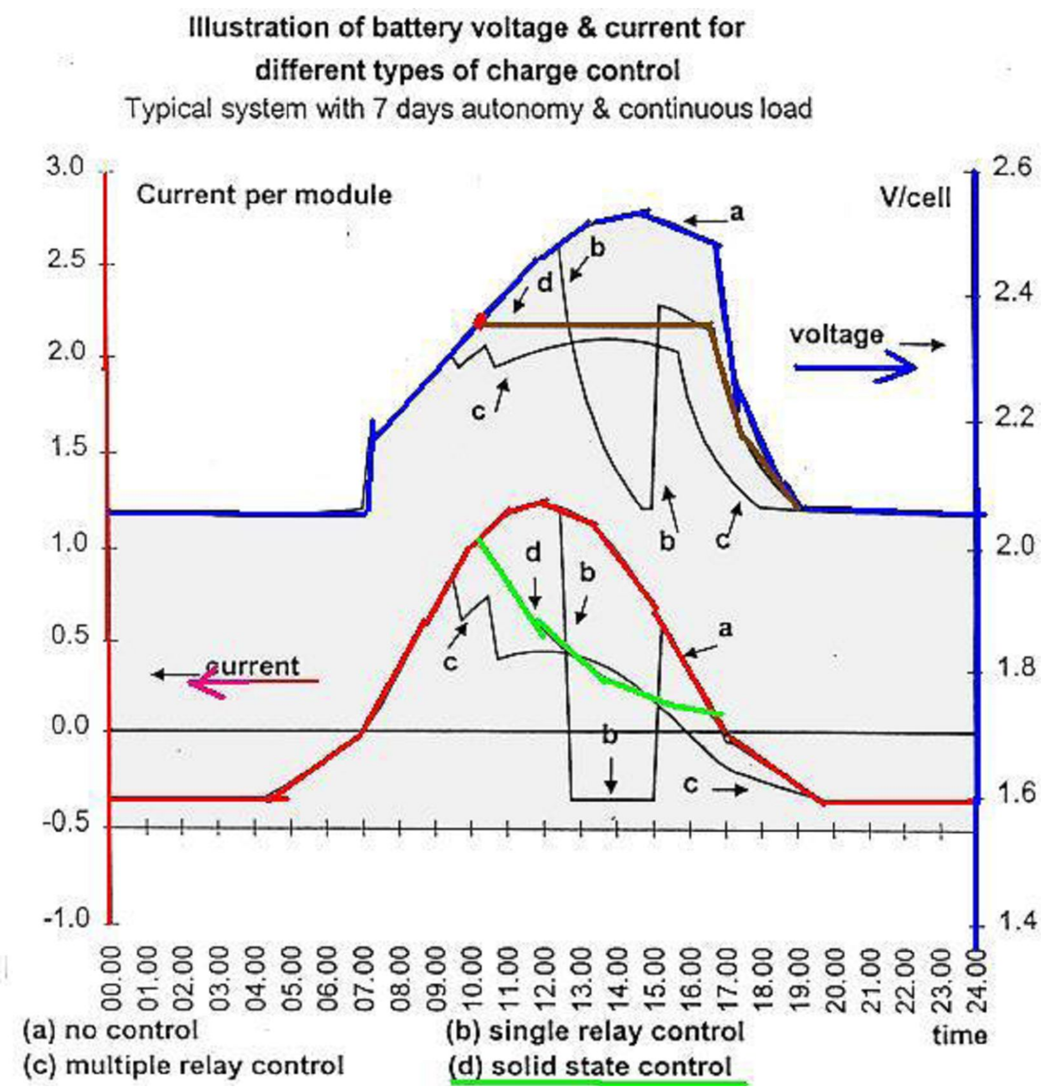


Figure2.12: Relation between different types of charge controller and battery voltage and current

2.2.4 Charge Controller Operation: Fixed Set Point:

To terminate the panel current when it reaches to the maximum voltage level and then continue it again when it reaches to the minimum voltage level is called ―Set point. The relation between charging-discharging of a battery and voltage is shown in the figure bellow-

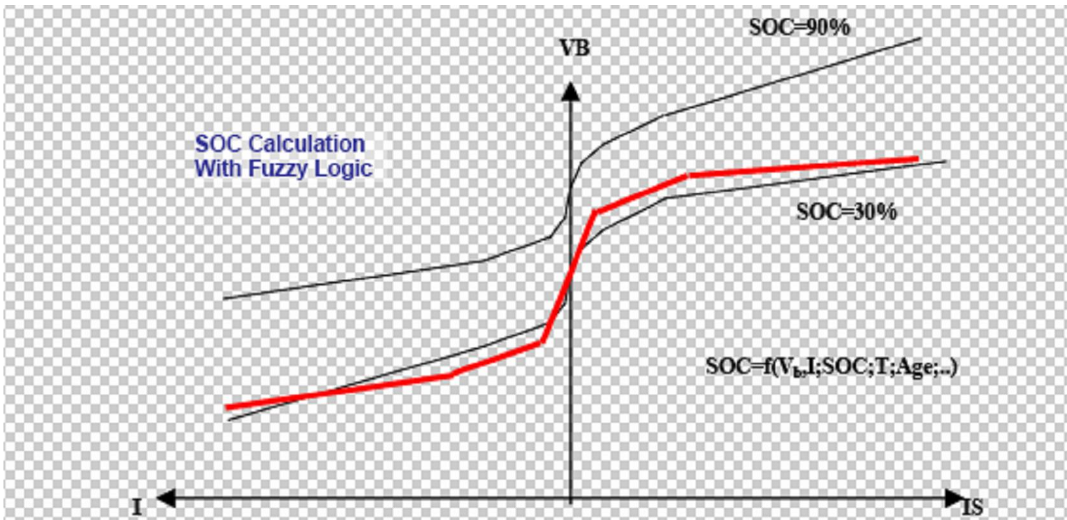


Figure2.13: Set point of controller (Micro-controller based)

There‘s a possibility of the damage of the battery (50-100%) if the voltage level is set as the red dotted line of the above figure. We can match the controller‘s voltage-current with the state of charge (SOC) by using micro-controller and Fuzz logic. This will reduce the probability of damaging the battery (10-20%).

2**.2.5 Selection of charge controller:** Solid state series controller is suitable for small system (4 ampere). Solid state shunt controller is suitable for the system of 4 to 30 ampere. A good controller must have following features-

- Low voltage disconnection
- Battery charging current indicator (LED or meter).
- Battery voltage indicator (LED or meter).
- Sense lead.
- Adjustable set point.
- Ability of Communication (for large system).
- Data logger
- Computer interface

2.2.6 Voltage setting of controller: The following factors are responsible for the voltage setting of controller-

- Types of battery
- Charging characteristics of charge controller

- Size of the battery
- Maximum panel current
- Depth of last charge

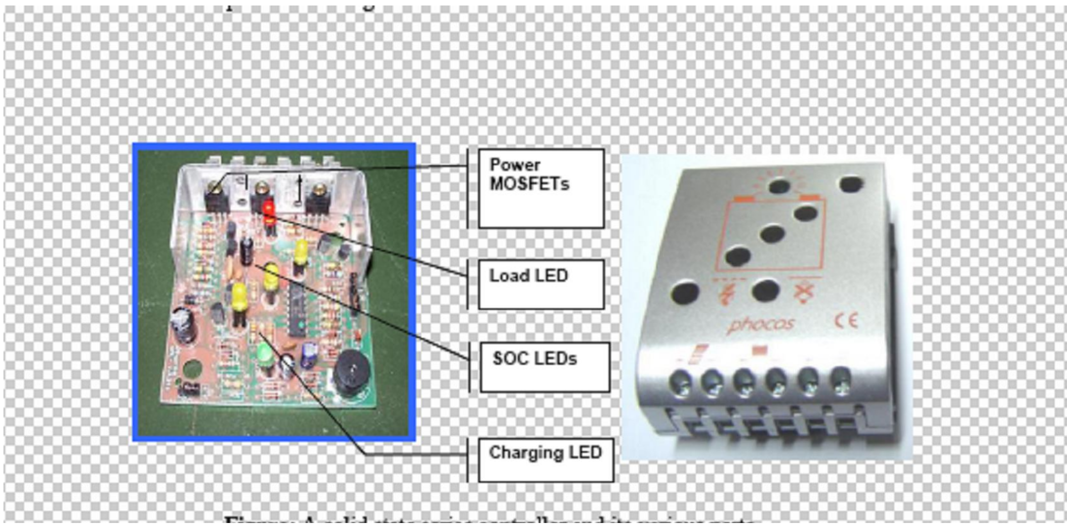


Figure2.14: A solid state series controller and its various parts

2.2.7 MPPT Charge controller:

MPPT charge controller is a maximum power point tracker which is an electronic DC to DC converter which takes the DC input from the solar panels, changes it to high frequency AC and converts it back to a different DC current to match with the batteries. This is a solely electronic tracking system and not concerned with the panel system at all.

Figure2.15: Phocos MPPT 100/20(20 amps)

2.3 Battery:

2.3.1 Battery Storage:

Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather). Other reasons batteries are used in PV systems are to operate the PV 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 protect the battery from overcharge and over discharge.

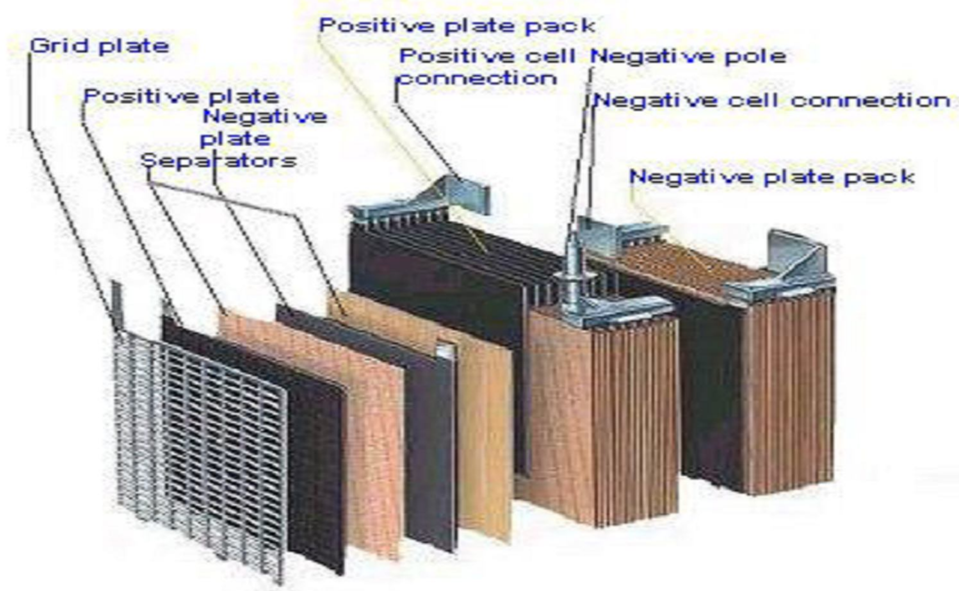


Figure2.16: Battery

2.4 Inverter:

An **inverter** is an electrical device that converts direct current (DC) to alternating current (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 supply AC power from DC sources 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 reverse, and thus was "inverted", to convert DC to AC.

Figure2.17: Inverter designed to provide 115 VAC from the 12 VDC source provided in an automobile. The unit shown provides up to 1.2 Amps of alternating current, or just enough to power two sixty watt light bulbs

2.4.1 String inverter:

Figure2.18: String inverter

- Good look
- Available in small- and medium-sized PV power station
- User-friendly Interface
- Power level 1.5KW to 6KW

Figure2.20: Power plant inverter

2.4.2 Power plant inverter:

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

`

A **grid-tie inverter** 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. The technical name for a grid-tie inverter is "grid-interactive

inverter". They may also be called synchronous inverters. Grid-interactive inverters typically cannot be used in standalone applications where utility power is not available.

Figure2.21: Inverter for grid connected PV

2.5 Solar energy system site considerations

One of the first things most home owners ask when considering a solar system is "Yeah, but will that work at my house?" This is soon followed by a litany of concerns such as to which way their house faces towards the sun, overhanging trees, too cold a climate and other factors. The good news is that both passive and active solar systems can work under a wide variety of conditions. Photovoltaic systems in particular tend to be much more site tolerant than most people suspect. Nonetheless, there are a number of site factors we should consider before deciding if solar is right for you, and if so what kind of solar system you should go with [1]. Here are a few things to consider:

2.5.1 Proximity to the Power Grid

If our home or home site is more than half a mile from the nearest power line you may want to consider going with an off-the-grid solar system using some combination of passive and active PV systems with batteries. Electric utilities can charge $50,000 or more to run a line to our home and battery systems with generators typically run far less than that.

2.5.2 Cost of Electricity

PV systems make particular sense in locations which have high electric rates. In the U.S states such as California have very high electric rates (20 to 30 cents per kilowatt hour).

2.5.3 Financial Incentives

Many states have become very eager in providing financial incentives to homeowners who wish to install PV systems. California, New York, Colorado, Florida and Illinois are among the leaders in providing incentives.

2.5.4 Shade

Shade is always a factor in the use of photovoltaic systems. If you live in a heavily wooded area you may need to determine if the trees blocking the potential site for our PV panels can be removed or cut back. In denser neighborhoods trees may not reside within our property line and this might not be an option. In such cases, consider alternative locations for our panels. Sometimes a set of panels mounted on a tracking system in the back yard can accomplish as much as a roof mounted system.

2.5.5 Roof Direction and Pitch

While it is true that south facing roofs are better for locating solar panels, most systems still can produce strong output even if they do not face south. For example, if a roof is 45 degrees off of due south it will output only 4% less electricity than if it were placing perfectly south. Roof angles are also fairly robust when it comes to placing panels. Generally a 30% angle is recommended. However a south facing roof with a strong 45% pitch will produce only 3% less electricity than one facing a perfect 30 degrees.

2.5.6 Snow and Leaves

The impact of snow and leaves, in contrast, is often an underrated factor in the performance of PV systems. PV panels work best when they are kept clear of debris or snow. Even a small amount of obstruction can significantly impair their performance. This is why regular maintenance is always recommended to keep the panels clean.

2.6 Solar Home Systems

For those homeowners who would like to achieve long-term energy independence solar photovoltaic (PV) systems using solar panels are one of the very best options. Solar energy systems for the home are relatively simple, last for decades and over the long term can save homeowners significant money, particularly in those states or countries that provide incentives for solar energy. Moreover, solar PV systems create no pollution and give off no hydrocarbon which makes them one of the best energy options from an environmental standpoint. They are definitely a home energy option I can feel good about. A key thing to remember with PV systems is that what they are harvesting is light energy, not heat or solar thermal energy. [2] That means they work as well in colder climates as they do in warmer climates. All that matters is how much light a location gets and in most of the U.S. there is more than sufficient light on average for PV systems to be very effective. If I want to learn exactly how much light your location has during the year look at our section on solar maps. These will show you exactly how many hours of sunlight per day your area gets at different times of the year.

Photovoltaic systems (PV systems for short) are any energy generation systems that make use of photovoltaic cells. A photovoltaic cell is a cell which generates electricity directly from light energy. Photovoltaic cells come in many sizes, but most are 10 cm by 10 cm and generate a little more than half a volt of electricity. PV cells are bundled together in interconnected solar panels to produce higher voltages and increased power. A 12-volt solar panel typically used in home solar energy applications has 30 to 50 PV cells and can

generate anywhere between 80 to 200 volts of electricity. In a residential application multiple solar panels are strung together into one or more modules. The number of panels we need a function of our energy use and the amount of space we have available on our southern facing roof.

2.7 Grid-Tied vs Off-the-Grid Systems

Photovoltaic systems for the home can generally be classified into those that are designed to make use of an existing electric grid(grid-tied system) or those that are designed for rural use where no electric grid is available(off-the-grid system). In a grid-tied system there is no need for a battery system to store the energy that the solar panels generate. Instead the power grid itself acts in a sense as a giant battery that uses any excess electricity that your solar panels may generate, and which you can draw from on cloudy days when there is insufficient sunlight to fully power your home. We believe that grid-tied systems offer a number of advantages over off-the-grid PV systems. Overall they are less expensive than off-the-grid systems because they do not require either batteries or battery charging controllers. Because they require less equipment they are also much simpler systems to set up and use. They take less time to install and require very little maintenance. We also think they are far more efficient and environmentally friendly than off-the-grid systems. With a grid-tied system none of the energy your PV panels generate is wasted. On sunny days when your panels are producing more electricity than you are using the energy is transferred to the grid where it can immediately be used by others. In an off-the-grid system, once your batteries are fully charged, any excess electricity being generated by your panels has to be dumped to prevent the batteries from being overcharged. This results in wasted electricity. However, in some situations, particularly in rural areas which have no grid, there may be no option other than to go with an off-the-grid system. For a home owner to pay the utility company to bring power lines into their property could cost upwards of $10,000 per quarter mile. For many owners of rural properties this makes hooking to the grid economically non-viable. Off-the-grid systems require more care and maintenance but can give a homeowner a strong sense of independence.

2.8 TRACKING SYSTEMS

Fig 2.22: Tracking system

Tracking systems are hardware devices usually used on pole mounted solar arrays to allow the positioning of the solar panels to follow the movement of the sun. This helps ensure that there is maximum exposure for the solar cells. A tracking system can increase the output of your PV system by up to 30% in the summer and 15% in the winter over non-tracked systems. Tracking systems are usually classified as being either passive or active. In a passive system the tracker follows the sun from east to west without using any type of electric motor to power the movement. Instead the system rotates from a combination of heat and gravity. Because no external source of electricity is needed such systems are ideal for remote off-the-grid scenarios or use with water pumping systems where peak the peak demand is in the summer. Tracking systems are also sometimes classified as to the number of axis they track against. Simple one axis systems rotate only left to right rather than in an arch. A two axis tracking system will track both left to right and up and down. This allows it more accurately to follow the true arch of the sun throughout the day. Passive tracking systems have some limitations. First, they are somewhat susceptible to high winds which can throw the tracker off the proper direction. They can also be somewhat sluggish in getting moving in cold temperatures because they are mechanically rather than electronically driven. Active tracking systems are powered by small electric motors and require some type of control module to direct them. They are similar in approach to the systems supporting giant TV dishes. Active systems require some electric power which can come from an external source or from the solar panels themselves depending upon the model. The big question with trackers is whether or not the additional cost, of a tracking system, both initial cost and maintenance cost, is justified by the additional electric power they generate. Tracking systems require maintenance and add a good bit of complexity to the system simply because they have moving parts.

CHAPTER THREE
Solar System Design

3.1 Solar home system design:

3.1.1 Basic Components:

1. PV module
2. Charge controller
3. Battery
4. Inverter
5. Wire

3.1.2 Load determination:

For calculation first we need to know our demand and running hour. Think our demand is 200 W and duration of running hour is 4 hour. So 200* 4=800Wh.

3.1.3 PV sizing

PV module = demand watt hours* de-rating factor /peak sun.
Hither de-rating factor is 1.3.this try to compensate losses like battery loss, pannal loss, inverter loss etc.
Suppose peak sun is 4.5 hour. So PV module =800*1.3/4.5 =231.111W
So we need three 85 Wp module which give 255W.

3.1.4 Charge controller

Capacity of charge controller= demand watt *safety factor/system voltage
= 200*1.25/12=20.83333A/12V
This result is fraction so we use 25A/12V charge controller.

3.1.5Battery sizing

Battery capacity= demand Wh* Autonomy/efficiency*DOD*System voltage.
Here DOD is depth of discharge and autonomy is number of day we use battery as a backup power. Suppose DOD is .6 and autonomy is 1 day, efficiency is 8.
So, battery capacity =800*1/.8*.6*12 =138.888Ah

3.1.6 Inverter

Inverter = demand *safety factor

=200*1.25 =250 W   220V Ac /12 V DC

3.1.7 Wire gauge

$$mm^2 = \frac{2\times Length \times A\times R}{Vd\times system\ voltage}$$

Here R is resistance of copper wire, Vd is voltage drop, A is ampere.

3.3Connecting diagram:

<u>3.2.1Connecting diagram for dc current</u>:

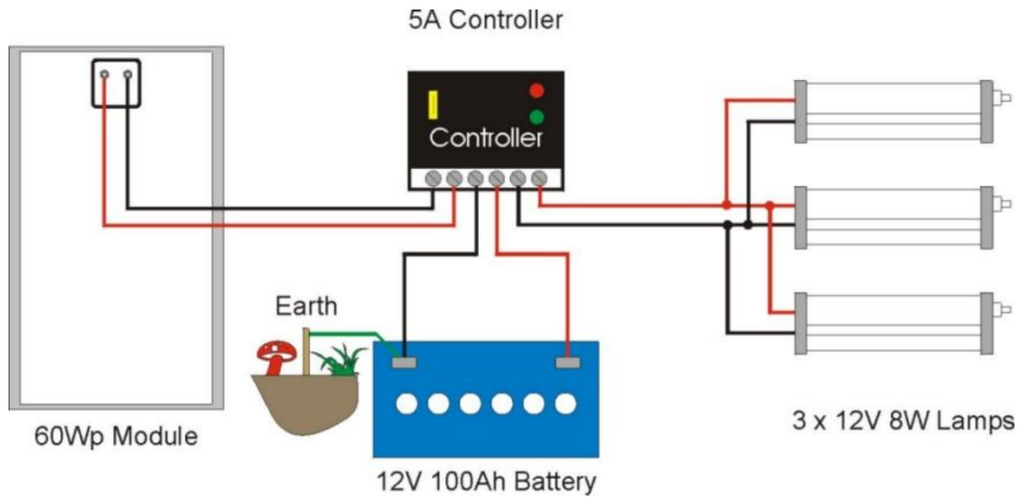


Fig 3.1: Connecting diagram for dc current

<u>3.2.2 Connecting diagram for ac :</u>

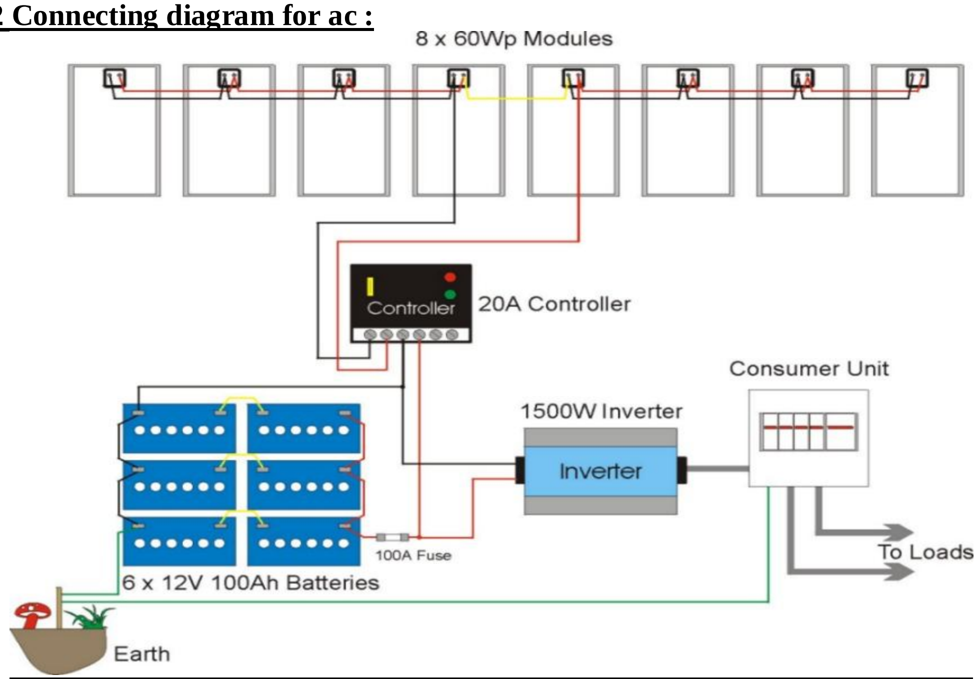


Fig3.2: connecting diagram for ac

CHAPTER FOUR
Solar Energy in Bangladesh

4.1 Physical Perspective of Renewable Energy in Bangladesh

Today our electricity installed capacity is 10312 MW. Where public sector contribution is 5962 (58%) and private is 4291 (42%) Currently only 62 percent of total population in Bangladesh has access to electricity and per capita generation being 321 kWh which is very low compared to other developing countries. our power generation is dominated by indigenous natural gas which are 90 % during FY2010.share to natural gas for power generation is 80.37% during FY2012 which is declined by 9.63%.it is estimated that share of natural gas for power generation will be reduced by 52% and 20% during 2016 and 2030 respectively. Depletion of gas reserve has forced to shift primary fuel option from natural gas to coal and liquid fuel. Bangladesh is trying to reduce its more dependence on natural gas by diversifying sources of primary fuel. At present the average cost of power generation is TK 6.3 /KWh while the cost of diesel based generation is 15.80/kwh. Yet cost of renewable is expensive compare to conventional energy but the difference is decreasing day by day.

Government has vision to provide electricity to all people by 2021 at reasonable and affordable prices. But it is fact that grid power will not available in some remote and isolated area for the next 20 years. That area, we must depend on solar energy. Renewable Energy Policy of Bangladesh sets targets for developing renewable energy resources to meet 5 percent of the total power demand by 2015 and 10 percent by 2020 [9]. Bangladesh already has achieved some remarkable successes in the implementation of renewable energy technologies (RET).

Bangladesh is situated between 20.30-20.38 degrees north latitude and 88.04-92.44 degrees east which is an ideal area for solar energy. Utilization of solar energy potential is very important for the impact analysis of SHS in our country. Daily average solar radiation varies between 4-6.5 KWh per square meter [10].We can get maximum amount of radiation on March-April and minimum from December –January. The average bright sunshine duration in Bangladesh in the dry season is about 7.6 hours a day, and that in the monsoon season is about 4.7 hours. The highest sunlight hours received is in Khulna with readings ranging from 2.86 to 9.04hours and in Barisal with readings ranging from 2.65 to 8.75 hours. These are very good statistics when compared to the 8 hours of daylight in Spain which produced 4 GW of energy covering 2.7% of national demand by the end of 2010. Moreover Germany produces 18 GW of energy which is 2% of their national demand with only half the solar Bangladesh. According to recent studies, yearly average insolation availability in Dhaka is 1.73MWh per square meter on a horizontal surface and 1.86MWh per square meter on a tilted surface. Again the annual amount of radiation is

varies from1840-1575 KWh/m2 .which is 50-100% more than the Europe. Taking an average solar radiation of 1900 KWh per square meter, total annual solar radiation in Bangladesh is equivalent to 1010*1018 J. Present total yearly consumption of energy is about 700* 1018 J. It shows that even if 0.07% of the incident radiation can be utilized, total requirement of our energy can be met [11]. At present energy utilization in Bangladesh is about 0.15 Watt/sq. meter land area, whereas the availability is above 208 Watt/sq. This shows the enormity of the potentiality of SHS in Bangladesh by using this huge solar energy. What fraction of it can be used for our use will depend on the availability of the technologies suited to local conditions.

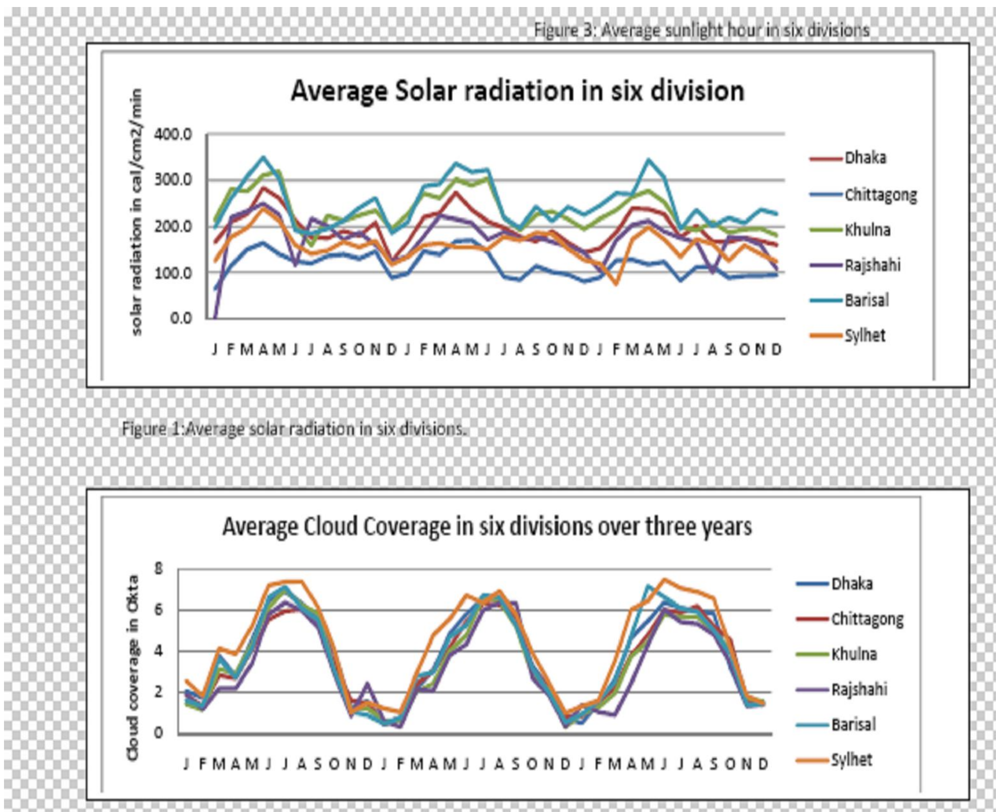


Fig:4.1:average solar radiation in six divisions and average cloud coverage in six divisions.

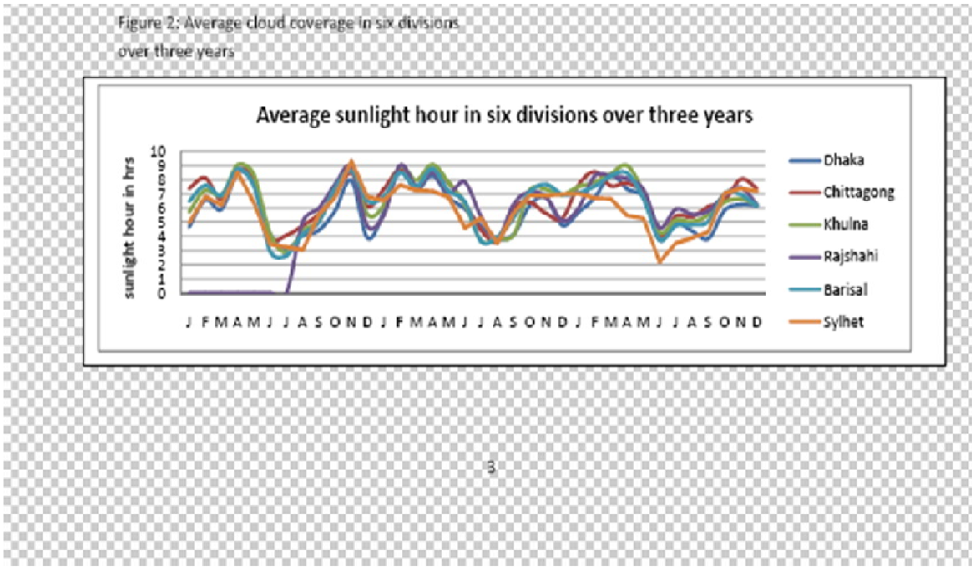


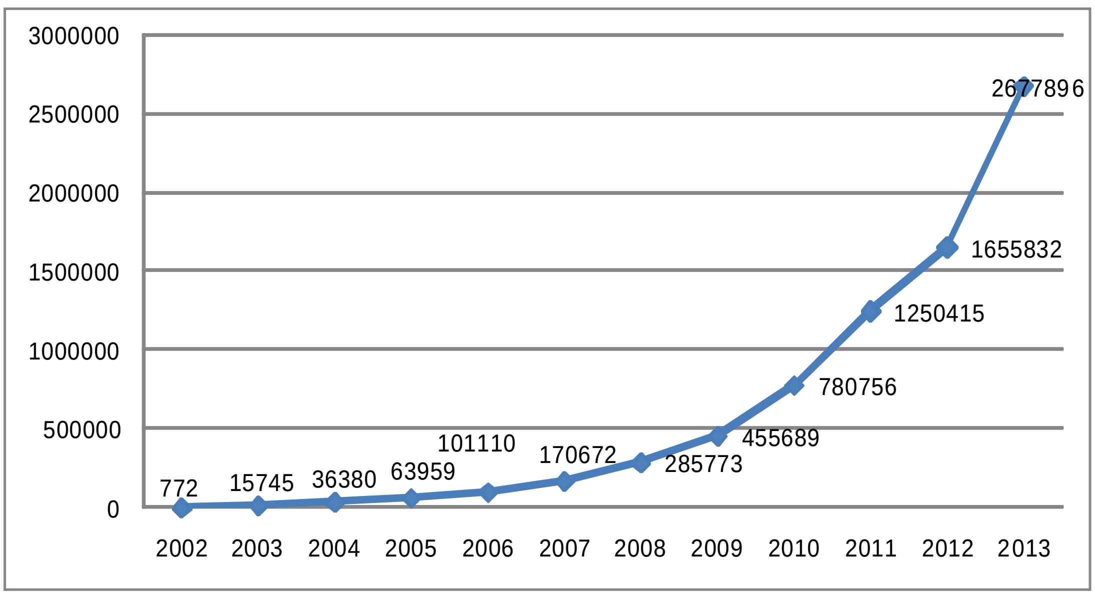
Fig average sunlight hour in six divisions. [10].

Fig 4.2: Average sunlight hour in six divisions over three years.

4.2 Present Status of Solar Energy in Bangladesh:

Bangladesh is an agricultural country in South Asia with 163 million people, where sustainable development, energy crisis and food security is of great concern. Nearly 75% of the population lives in rural areas and only about 30% of the rural households have access to grid electricity. Alternative solution is to introduce solar home systems for the rural households in off-grid areas and to introduce solar grid hybrid system for the rural grid areas. Financial initiatives as a result of policy push have major role to play in developing the market in Bangladesh. The basic applied forms of solar PV in rural Bangladesh are solar home system (SHS) and micro utility (electrification of rural markets). Feedback from the users of these system syndicates that solar energy-based electricity has been providing very satisfactory service to consumers. IDCOL, a government-owned agency equipped to develop private sector deploying private public partnership model, was selected as the implementation and monitoring agency of the solar energy program. Worthwhile to mention, IDCOL solar energy program is one of the fastest growing renewable energy programs in the world. It has brought in positive changes in the livelihood of people in remote rural areas of Bangladesh by providing access to electricity. The Chairman of the Senate Foreign Relation Committee of the United States, John Kerry in his speech at the World Bank Head office on 19 November 2009 mentioned IDCOL SHS project as a good example of literally life-altering project of the World Bank. IDCOL promotes dissemination of solar home system (SHS) in the remote rural areas of Bangladesh through its Solar Energy Program with the financial support from the World Bank, Global Environment Facility (GEF), KFW (German Development Bank), GIZ (German Technical Corporation), Asian Development Bank, USAID and Islamic Development Bank. IDCOL started the program in January 2003 and its initial target was to finance 50,000 SHSs by the end of June 2008. The target was achieved in September 2005, 3 years ahead of schedule and US $ 2.0 million below

estimated project cost. IDCOL then revised its target to install 1 million systems by 2012. This was also achieved ahead of schedule by June 2011. IDCOL celebrated installation of 2 million Solar Home Systems under its Renewable Energy Programs on 12 May 2013. Now IDCOL target to finance 4 millions SHSs by the year of 2015.Up to November 2013, a total of 2,677,896 SHSs have already been installed under the program. IDCOL is implementing this program with financial assistance from the World Bank, ADB, IDB, GEF, GIZ, CIDA,JICA and KFW. IDCOL implements through 47 partner organizations (POs) and solar PV growth market improves quality of life through access to electricity, which provides access to electricity to 200,000 people per month while adding 2.0 MW to national power generation by installing 50,000 systems, creates additional income, generates activities in the rural areas, promotes local entrepreneurs, creates jobs in rural areas for both skilled and unskilled people, promotes domestic industries, and reduces



carbon. [12].

Fig. 4.1 shows a sharp increase in the number of total SHS installations financed by IDCOL in recent years

4.3 Solar Energy source of Bangladesh:

First solar PV was disseminated by Rural Electrification Board (REB) in 1993 then Local Government Engineering Department (LGED), and then Infrastructure Development Company Limited (IDCOL) started their solar energy program (Islam & Marufa 2012). Currently, a numerous Government Organizations (GOs) and Non-Government Organizations (NGOs) are disseminating SHSs throughout the country under various renewable energy program financed by IDA, GTZ, KFW, GEF, ADB and IDB. IDCOL is the pioneer organization supporting its 47 Partner Organization (PO) to disseminate SHSs.

So far, up to November 2013, a total of 2,677,896 SHSs have already been installed under the program. A snapshot of SHSs dissemination by various GOs and NGOs in Bangladesh is shown in Table 1.

Table4. 1: Dissemination of SHSs by different organizations in Bangladesh.[14]

Organization	Number of SHSs Installed	Capacity
IDCOL's PO		
GS	1020,014 SHSs all over the country	10-130Wp each
RSF	389,583 SHSs all over the country	
BRAC	77,019 SHSs all over the country	40Wp (20%), 50Wp (60%) and 75Wp (20%)
Srizony Bangladesh	58,927 SHSs	
HFSKS	37,078 SHSs	
UBOMUS	25,234 SHSs	
BRIDGE	20,449 SHSs	
IDF	14,238 SHSs	
TMSS	13,059 SHSs	30–75Wp each
PDBF	10,672 SHSs	
SEF	21,720 SHSs	
AVA	12,817 SHSs	
DESHA	10,931 SHSs	
BGEF	50,000 SHSs	
RDF	20,027 SHSs	
COAST Trust	6,181 SHSs especially in coastal areas	
INGENI Ltd.	9,871 SHSs	
NUSRA	9,372 SHSs	
RIMSO Foundation	8,196 SHSs	
GHEL	6,138 SHSs	
SFDW	9,485 SHSs	
Other	29661 SHSs	
LGED	SHSs, centralized units, and water pump in different remote and coastal off-grid areas all over the country	53.84 kW
BPDB	1212 SHSs at off-grid Hill areas, 6 solar vaccination	374.26 kW

	refrigerators, 3 solar water pump, 30 solar street light, 4 centralized solar PV power plant at Juraichari upazilla	
REB	23,412 SHSs and Solar Power Plants	1,937.855 kW
BCSIR	82 SHSs, 1 pump, 2 solar data logging units	1.5 kW
Total		About 2 million SHSs/SHLSs with solar water pump, solar central unit of total capacity 94 MW

4.4 Cost Analysis of SHS

Normally 40~85 Wp systems are mostly used in the rural areas. The cost of a 40 Wp system was 23,000 BDT, whereas for a 85 Wp system, the cost was 37,600 BDT. Table 4.2 represents the cost of SHSs with detail equipments provided by the POs. Battery, PV panel and charge controller are the three main components of the PV system. POs also provide structure for panel and battery, lamps and ballast, switch, switch board and necessary wires during the installation period. But, the owner or user had to buy other equipments if they need, such as, adapter, DC-DC converter for radio, cassette and mobile charger, etc.

The breakdown of total cost of a 50 Wp system is shown in table 4.3. The Battery and solar panel were found to be the main reasons of the high cost of the PV system. Solar panel contributed to 28%, whereas battery cost was around 30% of the total cost though most of the batteries were produced in Bangladesh. Three years after sale service and installation cost 13.50%, overhead cost 10%, cable, switches and others 7.50% and lamp shade 5% were the significant others costs.

Except these, tube lights and steel structure for panel contributed 2% and 1% of total cost respectively. This break down of cost was also similar for 40 and 60 Wp system as price variation was not much. On the other hand, percentage of battery and panel cost was little bit higher for 80 and 85 Wp system. It was found that for 80 and 85 Wp battery and panel cost were 33% and 30% of the total cost respectively

SL. No.	System Capacity (Watt)	Loads can be used	Equipments supplied by GS	Package Price (BDT)
1	10	2 x 2.5 watt LED light	A 10 watt panel, 2 x 2.5 watt LED light, a 15AH battery, a charge controller, a frame and cables	8,100
2	15	2 x 3 watt LED light	A 15 watt panel, 2 x 3 watt LED light, a 15AH battery, a charge controller, a frame and cables	9,400

3	20	3 x 3 watt LED light	A 20 watt panel, 3 x 3 watt LED light, a 20/23 AH battery, a charge controller, a frame and cables	12,000
4	20	3 x 3 watt LED light	A 20 watt panel, 3 x 3 watt LED light, a 30AH battery, a charge controller, a frame and cables	13,000
5	30	2 x 3 watt LED light and a 15" LCD/LED TV	A 30 watt panel, 2 x 3 watt LED light, a 30AH battery, a charge controller, a frame and cables	15,500
6	40/42	3 x 3 watt LED light and a 15" LCD/LED TV	A 40/42 watt panel, 3 x 3 watt LED light, a 40/45AH battery, a charge controller, a frame and cables	22,000
7	50	4 x 3 watt LED light and a 15" LCD/LED TV	A 50 watt panel, 4 x 3 watt LED light, a 55/60AH battery, a charge controller, a frame and cables	27,100
8	60	5 x 3 watt LED light and a 15" LCD/LED TV	A 60 watt panel, 5 x 3 watt LED light, a 60AH battery, a charge controller, a frame and cables	30,600
9	63/35	5 x 3 watt LED light and a 15" LCD/LED TV	A 63/65 watt panel, 5 x 3 watt LED light, a 70/80AH battery, a charge controller, a frame and cables	31,600
10	75	6 x 3 watt LED light, a 12 watt fan and a 15" LCD/LED TV	A 75 watt panel, 6 x 3 watt LED light, a 80AH battery, a charge controller, a frame and cables	34,100
11	80	7 x 3 watt LED light, a 12 watt fan and a 15" LCD/LED TV	A 80 watt panel, 7 x 3 watt LED light, a 80AH battery, a charge controller, a frame and cables	36,600
12	83/85	7 x 3 watt LED light, a 12 watt fan and a 15" LCD/LED TV	A 83/85 watt panel, 7 x 3 watt LED light, a 100AH battery, a charge controller, a frame and cables	37,600
13	100	9 x 3 watt LED light, a 12 watt fan and a 15" LCD/LED TV	A 100 watt panel, 9 x 3 watt LED light, a 100AH battery, a charge controller, a frame and cables	41,600
14	130/135	7 x 3 watt LED light, two 12 watt fans and a 15" LCD/LED TV	A 130/135 watt panel, 7 x 3 watt LED light, a 130AH battery, a charge controller, a frame and cables	46,100

Table 4.2. Current Cost of SHSs system [15]

*The price of system is changeable

Table.4.3 Break down of cost of PV system in rural Bangladesh

Components	Price (%)
Battery	30%
Solar pannal	28%
3 years after sales service and installment collection	13.05%
Overhead cost	10%
Others(switch, cable ,etc)	7.5%
Lampshades(4 Nos)	5%
Charge controller	3%
Flurescent lamps(4 Nos)	25
Structure	1%

The types of financing scheme provide by POs to the users are as follows [15]:

 Option 1: 15 % down payment and rest of the 85% payable in 36 monthly installments with flat rate service charges of 8%

 Option 2: 25% down payment and rest of the 75% payable in 24 monthly installments with a flat rate of service charges of 6%

 Option 3: 35% down payment and rest of the 65% payable in 12 monthly installments with flat rate service charges of 5%.

 Option 4: 100% down payment and you will get 4% discount on the package price

 Option 5: 25% down payment and rest of the 75% payable in 12 monthly installments without any service charges (only for mosque/temple/church)

40~85 Wp systems are mostly used in the rural areas. The cost of a 40 Wp system was around 22,000 Bangladeshi Taka (BDT), whereas that for a 85 Wp system costs about 37,6,00 BDT. The average payback period was found to be 2 years and varied between 3

and 3.5 years. On the other hand, Net Present Values (NPV) varies between 34,500 BDT to 14800 BDT. The total primary energy requirement for a 50Wp in its total life of 20 years is 4593 MJth. This gives around 253 kg of CO2 emission. A 50 Wp SHS on the other hand supplies around 11773 MJth of Energy in 20 years. Energy payback for the same module was found to be 7.80 years and the total CO2 emission reduction compared to kerosene consumption of the users' was 11604 kg in 20 years.

4.5 Government programme

4.5.1Government planning

Government already taken 500 MW PV base solar programme. Government has set a target to generate 5% electricity by 2015 and 10% by 2020 from renewable sources which is in term of capacity of 80MW and 2000MW respectively. Government has undertaken various activities to promote renewable energy from different sources like solar, wind, biomass, bio-gas, hydro, tidal and wave to achieve the target. Among those, government has identified solar power as on of the most potential source for sustainable energy development. The strategy of the mission is to embrace 500mw solar power by 2016 as part of the policy at affordable price. To this end government will encourage privet sector involvement of this mission. The mission will be implemented in public and privet sector. Major portion of this mission which is equivalent to 340 MW will be implemented in public and privet sector. [16]

4.5.2 Types of projects under this programme

Considering project financing, implementation approach and modus operandi, projects are categorized in two type commercial project and social sector projects. Commercial project will be implemented .operate and maintained by the privet sector. While the public sector project would be implemented by the different ministries and agencies as a part of social responsibilities of the government. Share of commercial and social project are. [16]

Type of projects	Capacity addition in MW
Commercial solar power projects	340
Social sector solar power project	160
Total(MW)	500

Commercial types project are again categorized into different option on the base of initial potentiality. [16]

Type of projects		Capacity addition in MW
Solar irrigation		150
Solar mini grid		25
Solar park		135
Solar roof top	Residential and commercial building	10
	Industrial building	20
total		340

Only half of our total populations are covered by grid electricity. Rest half out of the grid yet and most of them are leaving in rural village. Considering the quality lighting need for the rural community government intended to disseminate solar power system in rural areas. [16]

Type of project	Capacity addition in MW
Solar electrification in health centers	50
Solar electrification in remote educational institution	40
Solar electrification at union e-center	7
Solar electrification at remote railway station	10
Solar electrification religious establishment	12
Solar PV system in government and semi government office	41
Total	160

4.5.3 Our Limitations

1. Construction of solar power stations requires extensive infrastructure and equipment. These require a staggering amount of fund most of which will have to be borrowed from foreign donors.

2. Most of the families in the country also will not be able to afford solar cells for their home (especially in the rural areas). Moreover Bangladesh doesn't possess the necessary technology and raw materials to manufacture the photovoltaic cells (pv), reflectors and other auxiliaries, all of which will have to be imported.

3. Maintenance and repairing will also be an issue due to the lack of experience of the technicians in this sector.

4. A solar power plant will need hundreds of hectares of area cleared for its construction which will naturally have adverse effects on the environment.

5. Security is also a concern since pv's are very expensive and is likely to be stolen at the first chance from the roof of a building, from the streetlights and from other installations which are within public reach.

6. Also during the winter season and sometimes during the monsoon season cloud cover increases drastically thereby limiting sunlight availability and thus might affect the generation scheme.

7. All our country's limitations aside, photovoltaic cells have a very low efficiency.

4.5.4 Possible remedies and concluding remarks

1. First of all social awareness should be built up by running media awareness programs like talk shows and arranging seminars, especially in colleges and universities to motivate the young generation.

2. Reduced taxes and removal of any tariffs on accessories vital to this sector could help reduce the expense to a reasonable level.

3. Training programs conducted by experts from countries notable for their advancement in solar energy sector could be arranged.

4. Government can provide financial incentives, aid packages, offer technical and legal support and even subsidize organizations dealing or wanting to set up in the solar sector.

Many countries like Denmark, Spain, and Germany have already declared national policies to generate at least 20% of their national demand through renewable sources and by 2050 become completely powered by renewable energy.

The Bangladesh government has also developed a policy to meet 5% of the country's electricity demand by 2015 and 10% by 2020.such actions are indeed commendable but even more needs to be done for Bangladesh to meet the increasing demand of electricity for economic development renewable energy policy of Bangladesh (6 November 2008) investment and fiscal incentives.

1. A renewable energy financing facility shall be established that is capable of accessing public, private, donor, carbon emission trading (CDM) and carbon funds and providing financing for renewable energy investments.

2. Power division, will formulate a detailed program for providing fiscal incentives including customs and vat exemptions for import and domestic manufacture of sustainable energy equipment.
3. In addition to commercial lending, a network of micro-credit support system will be established especially in rural and remote areas to provide financial support for purchases of renewable energy equipment.

4. Gov. will facilitate investment in renewable energy and energy efficiency projects in co-operation with local government organizations, will set up an outreach program to develop renewable energy programs.
5. SEDA (Sustainable Energy Development Agency) will consider providing subsidies to utilities for installation of solar, wind, biomass or any other renewable/clean energy projects.
6. Private sector participation including joint venture initiatives in renewable energy development will be encouraged and promoted job/seda may assist in locating the project's and also assist in acquiring land for renewable energy project's).
7. Renewable energy project investors both in public and private sectors shall be exempted from corporate income tax for a period of 15 years.
8. Renewable energy project investors both in public and private sectors shall be allowed to get the fiscal incentives provided in (i) sro.73-law/97/1700/custom, date: 19/03/1997; and (ii) sro.100-law/2000/1832/custom, date: 18/04/2000.
9. Accelerated depreciation up to 80% may be allowed in the first year.
10. An incentive tariff may be considered for electricity generated from renewable energy sources which may be 1.25 times the highest purchase price of electricity by the utility from private generators.
11. To promote solar water heaters, rates of both electricity and gas may be prefixed to discourage electricity and gas use for water heating also achieve energy security.

- To reduce carbon emissions.
- To project Bangladesh as a solar hub.
- To achieve grid parity by 2015.
- To encourage indigenous solar manufacturing facilities in the local area.
- To promote the solar energy sector and hybrid systems.
- To create skilled man power and employment in a new industry.

4.5.5 Initiatives of government

1. Import of solar modules, solar cells and equipment and machineries of solar module manufacturing/assembling lines has been made duty free;
2. Fiscal incentives i.e. tax holiday would be applicable for solar PV plants for at least 5 years;
3. Tenders for three grid connected solar power plants will be floated soon by Bangladesh power development board (BPDB);

4. A feed-in-tariff policy is being formulated by the government;
5. Solar panels have been installed in important government offices including the prime minister’s office, central bank etc;
6. The government also expressed its willingness to electrify community clinics, schools, rural information centers etc. with solar power;
7. Bangladesh bank, the central bank has created a BDT 2000 million refinancing facility for the commercial banks and financial institutions to on-lend to re projects at a concessional rate.

4.5.6 Number of funds for energy projects

Government has number of large scale funds especially for renewable energy projects:
1. USD 100 million declared as climate fund by the government for climate related initiatives.
2. USD 40 million set aside by Bangladesh bank in soft loans for all kinds of renewable energy projects.
3. USD 135 million IDCOL fund for solar installation projects (funded by World Bank and others).
4. USD 23 million IDCOL fund for biogas/biomass related projects.
5. USD 29 million IDCOL fund for other renewable energy projects.
6. USD 245 million IDCOL fund for large infrastructure, conventional energy and renewable energy projects. [17]

CHAPTER FIVE
CASE STUDY ON SHS
(Solar Home System)

5.1. Case study 1

Consumer Name: Abdur Sattar .
Address :Raniganjo,kapasia, Gazipur.
Installed by : Grameen Shakti.
Installment date: 21.08.10
Price : 24702 tk (actual price is 21400tk. But they gave 15% (3210tk) down payment first then rest 85% paid in 6% flat rate include service charge (597tk) through 36installment. So, total price is 24702 tk.

Solar Home System (40W)

Solar panel : 40Wp (warranty 20 years)

Battery : 55 Ah (warranty 5 years)

Charge controller: 10A (warranty 3 years)

Tube light : 3piece, 10W

Fan : 12V DC, 10W

TV : 12” black and white, 20W

Mobile charge : 1 piece, 15W.

Energy consumption in a day

Date: 31.03. 14
Weather situation: fully sunny day

Consumption	Morning	Afternoon	Evening	Night	Total Wh
Fan, 10W	11-12			10-012	30Wh
Tube light reading room,10W			6.30-7.00	7.00-8.30	20Wh
Tube light bed room,10W				8.30-9.00 10-10.30	10Wh
Tube light bath room,10W	At least 30 minutes				5Wh
TV,20W				9.00-10.0	20Wh
Mobile charger,15W	At least 30 minutes				7.5Wh

Total Wh= 92.5Wh

Date: 01.04. 14

Weather situation: fully sunny day

Consumption	Morning	Afternoon	Evening	Night	Total Wh
Fan, 10W	11-12			10-01	40Wh
Tube light reading room,10W				7.00-9.00	20Wh
Tube light bed room,10W				8.30-9.00 10-11.00	15Wh
Tube light bath room,10W	At least 30 minutes				5Wh
TV				9.00-10.00	20Wh
Mobile charger.15W	At least 30 minutes				7.5Wh

Total Wh= 107.5Wh

So average is =92.2+107.5=200/2=100Wh.

Here, we use this generation constant for all over year. So yearly generation is=100Wh ×365= 36500Wh =36.5 KWh.

And life time generation = 36.5×20 = 730 KWh

Tariff calculation for solar home system:

Present Formula:

This consumer takes 40W solar home system with this condition that he pay 15% of the total price as down payment. The remaining 85% of the total cost is to be repaid within 36 months with 6% (flat rate) service charges.

Total price of the 40Wp SHS is = 21400. tk

Down payment 15% = 3210 tk

Due = 18190 tk

So principal installment per month = 18190/36 = 505.27 tk

Interest installment per month = (18190 × 6%)/12 = 90.95 tk

Total installment per month = 505.27+90.95 =596.27 tk .

Month	Principal Beginning(tk)	Installment(tk)	Monthly Interest(tk)	Principal Repayment(tk)	Principal Ending(tk)	Yearly Interest(tk)	Yearly Principal(tk)
1	18190	597	91	506	17684		
2	17684	597	91	506	17178		
3	17178	597	91	506	16672		
4	16672	597	91	506	16166		
5	16166	597	91	506	15660		
6	15660	597	91	506	15154		
7	15154	597	91	506	14648		
8	14648	597	91	506	14142		
9	14142	597	91	506	13636		
10	13636	597	91	506	13130		
11	13130	597	91	506	12624		
12	12624	597	91	506	12118	1092	6072
13	12118	597	91	506	11612		
14	11612	597	91	506	11106		
15	11106	597	91	506	10600		
16	10600	597	91	506	10094		
17	10094	597	91	506	9588		
18	9588	597	91	506	9082		
19	9082	597	91	506	8576		
20	8576	597	91	506	8070		
21	8070	597	91	506	7564		
22	7564	597	91	506	7058		
23	7058	597	91	506	6552		
24	6552	597	91	506	6046	1092	6072
25	6046	597	91	506	5540		
26	5540	597	91	506	5034		
27	5034	597	91	506	4528		
28	4528	597	91	506	4022		
29	4022	597	91	506	3516		
30	3516	597	91	506	3010		
31	3010	597	91	506	2504		
32	2504	597	91	506	1998		
33	1998	597	91	506	1492		
34	1492	597	91	506	986		
35	986	597	91	506	480		
36	480	597	91	506	-26	1092	6072
		21492	3276	18216		3276	18216

So actual price of 40Wp SHS = 21492+3120 = 24702 tk

Tariff calculation:

Total price of SHS is 24702 tk.

Solar module is warranty for 20 years. So we do not need to change it.

Battery warranty is 5 years. In the first installation battery cost is included. So they need change battery for 3 times. The cost of changing the battery in 20years is =3*6000= 18000 taka (6000 for each battery).

Now, charge regulator is warranty for 3 years. In first installation Charge regulator cost is included. Approximately 6 charge regulator need for 20 years. So the cost of changing the charge regulator in 20 years is: 6*600=3600tk. (600 for each battery).

Battery need at least two time distilled water and charge in a year. This operation and maintenance cost approximately 100 tk per year. So for live time O&M cost is= 100×20=2000tk.

Total cost need to use SHS (40Wp) for 20 years is=24702+18000+3600 + 2000 =48302tk.

So per Unit cost for SHS (40Wp) is= 48302/730KWh= 66.17 tk per KWh

PVIFA Formula:

PVIFA means Present Value Interest Factor Of Annuity. Its a most popular formula to calculate monthly payment needed to repay a loan. PVIFA is used in finance theory to refer to the output of a calculation, used to determine the monthly payment needed to repay a loan. The calculation has a number of variable factors, which include the quantity borrowed **P**, the given interest rate **r**, the number of regular intervals **n** at which the loan is to be repaid and the term of the loan.

Principal = 21400 tk

Down payment = 3210 tk

Due = 18190 tk

Interest = 6%

Nominal interest **r** = .5%

Installment **n** = 36

We know,

Principal = A × PVIF (Present Value Interest Factor of Annuity)

$$18190 = A \times \left[\frac{\left\{ 1 - \frac{1}{(1+r)^n} \right\}}{r} \right]$$

$$18190 = A \times \left[\frac{\left\{ 1 - \frac{1}{(1+.005)^{36}} \right\}}{.005} \right]$$

A=553.37 tk

Month	Principal Beginning(tk)	Installment(tk)	Monthly Interest(tk)	Principal Repayment(tk)	Principal Ending(tk)	Yearly Interest(tk)	Yearly Principal(tk)
1	18,190.00	553.38	90.95	462.43	17,727.57		
2	17,727.57	553.38	88.64	464.74	17,262.84		
3	17,262.84	553.38	86.31	467.06	16,795.78		
4	16,795.78	553.38	83.98	469.40	16,326.38		
5	16,326.38	553.38	81.63	471.74	15,854.64		
6	15,854.64	553.38	79.27	474.10	15,380.54		
7	15,380.54	553.38	76.90	476.47	14,904.06		
8	14,904.06	553.38	74.52	478.85	14,425.21		
9	14,425.21	553.38	72.13	481.25	13,943.96		
10	13,943.96	553.38	69.72	483.66	13,460.30		
11	13,460.30	553.38	67.30	486.07	12,974.23		
12	12,974.23	553.38	64.87	488.50	12,485.73	936.22756	5,704.27
13	12,485.73	553.38	62.43	490.95	11,994.78		
14	11,994.78	553.38	59.97	493.40	11,501.38		
15	11,501.38	553.38	57.51	495.87	11,005.51		
16	11,005.51	553.38	55.03	498.35	10,507.16		
17	10,507.16	553.38	52.54	500.84	10,006.32		
18	10,006.32	553.38	50.03	503.34	9,502.98		
19	9,502.98	553.38	47.51	505.86	8,997.12		
20	8,997.12	553.38	44.99	508.39	8,488.73		
21	8,488.73	553.38	42.44	510.93	7,977.80		
22	7,977.80	553.38	39.89	513.49	7,464.31		
23	7,464.31	553.38	37.32	516.05	6,948.26		
24	6,948.26	553.38	34.74	518.63	6,429.63	584.40	6,056.10
25	6,429.63	553.38	32.15	521.23	5,908.40		
26	5,908.40	553.38	29.54	523.83	5,384.57		
27	5,384.57	553.38	26.92	526.45	4,858.11		
28	4,858.11	553.38	24.29	529.08	4,329.03		
29	4,329.03	553.38	21.65	531.73	3,797.30		
30	3,797.30	553.38	18.99	534.39	3,262.91		

31	3,262.91	553.38	16.31	537.06	2,725.85		
32	2,725.85	553.38	13.63	539.75	2,186.11		
33	2,186.11	553.38	10.93	542.44	1,643.66		
34	1,643.66	553.38	8.22	545.16	1,098.50		
35	1,098.50	553.38	5.49	547.88	550.62		
36	550.62	553.38	2.75	550.62	0.00	210.87	6,429.63
		19,921.50	1,731.50	18,190.00		1,731.50	18,190.00

Tariff calculation:

Unit Generation	1 st year	2 nd year	3 th year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
Inslaiied capacity(KW)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total generation(KWh)	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5

Unit Generation	11 th year	12 th year	13 th year	14th year	15th year	16th year	17th year	18th year	19th year	20th year
Inslaiied capacity(KW)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total generation(KWh)	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5

Fixed cost	1 st year	2 nd year	3 th year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
O & M (TK)	100	100	100	100	100	100	100	100	100	100
Replacement	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Installment	9274	6064	6064	0	0	0	0	0	0	0
interest on term lone	963.227	584.4	210.87	0	0	0	0	0	0	0
Total fixed cost	11417.2	7828.4	7454.87	1180	1180	1180	1180	1180	1180	1180
Tariff per year	312.801	214.477	204.243	32.329	32.329	32.3288	32.329	32.329	32.329	32.32877

Fixed cost	1 st year	2 nd year	3 th year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
O & M (TK)	100	100	100	100	100	100	100	100	100	100
Replacement	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Installment	0	0	0	0	0	0	0	0	0	0
interest on term lone	0	0	0	0	0	0	0	0	0	0
Total fixed cost	1180	1180	1180	1180	1180	1180	1180	1180	1180	1180

Tariff per year	32.329	32.329	32.329	32.329	32.329	32.3288	32.329	32.329	32.329	32.32877
Tariff	64.0555									

Comparison of two methods:

Monthly installment in Present formula is 597 tk.

But PMT formula monthly installment is 553.38 tk.

So, different is (597 – 553.38) = 43.62 tk per installment & finally different is =43.62 × 36 =1570.32 tk.

Tariff in present formula = 66.17 tk per KWh

Tariff in PVIFA formula = 64.05 tk per KWh

So different is (66.17- 64.05) = 2.12 tk per KWh.

Plant factor of Solar Home System (40W)

40W solar system daily energy use is 100 Wh.

So energy uses for one year is =100*365=36.5KWh

So plant factor = $\frac{36.5}{.04\times 24\times 365}$ = 10.41%

plant factor	10.42%	11%	12%	13%	14%	15%	16%	17%
Electricity(KWh)	730.2336	770.88	840.96	911.04	981.12	1051.2	1121.28	1191.36
Total cost(tk)	46758.5	46758.5	46758.5	46758.5	46758.5	46758.5	46758.5	46758.5
cost/KWh(tk)	64.03225	60.656	55.60134	51.32431	47.65829	44.48107	41.701	39.248

Plant factor	18%	19%	20%	21%	22%	23%	24%	25%
Electricity(KWh)	1261.44	1331.52	1401.6	1471.68	1541.76	1611.84	1681.92	1752
Total cost(tk)	46758.5	46758.5	46758.5	46758.5	46758.5	46758.5	46758.5	46758.5
Cost/KWh(tk)	37.06756	35.11663	33.3608	31.77219	30.328	29.00939	27.80067	26.68864

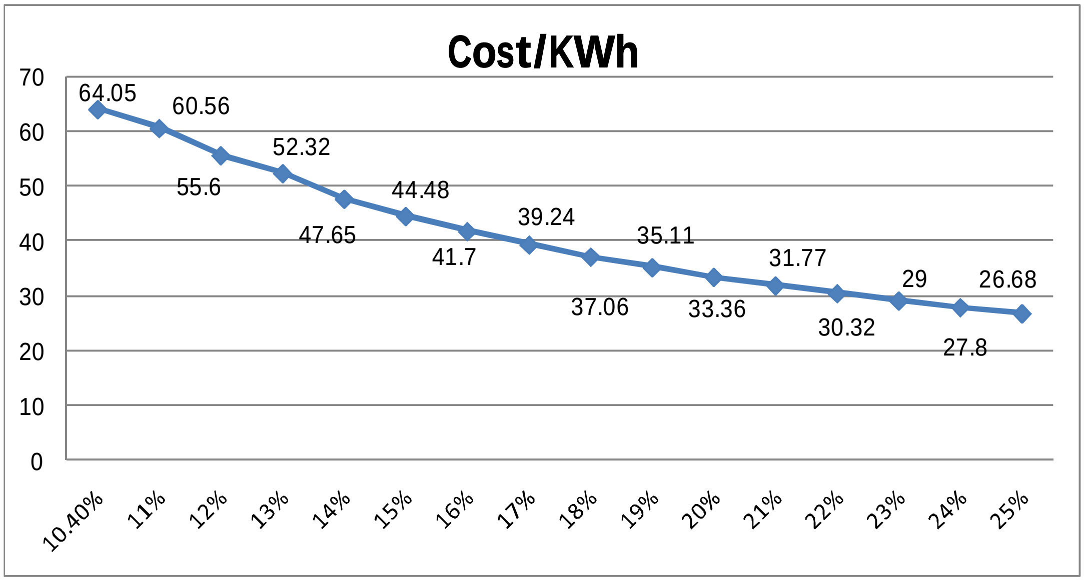


Fig 5.1 Power factor increase per unit cost decrease

5.2. Case study 2

Consumer Name: Abdur Rahman .

Address : Chilarchor , Madaripur.

Installed by : Grameen Shakti.

Installment date: 09.08.10

Price : 47052 tk (actual price is 40800tk. But they gave 15% (6120tk) down payment first then rest 85% paid in 6% flat rate include service charge (1137tk) through 36installment. So, total price is 47052 tk.

Solar home system (85W)

Solar panel : 85Wp (warranty 20 years)

Battery : 130Ah (warranty 5 years)

Charge controller: 10A (warranty 3 years)

Tube light : 8 piece, 10W

Fan : 12V DC, 10W

Mobile charge : 1 piece, 15W.

Energy consumption in a day

Date: 29.03. 14

Weather situation: fully sunny day

Consumption	Morning	Afternoon	Evening	Night	Total Wh
Fan, 10W	11.30-12.30		6.00-7.00	9.00-12	50Wh
Tube light reading room,10W			6.30-7.00	7.00-8.30	20Wh
Tube light bed room1,10W				9.00-10	10Wh
Tube light bed room2,10W				8.00-10	20Wh
Tube light Kitchen room,2piece,10 W				7.00-8.30	30Wh
Tube light Guest Room			6.00-7.00		10Wh
Tube light Bath room,10W	At least 30 minutes				5Wh
Mobile charger,15W	At least 30 minutes				7.5Wh

Total Wh=147.5Wh

Date: 30.03. 14

Weather situation: fully sunny day

Consumption	Morning	Afternoon	Evening	Night	Total Wh
Fan, 10W	11.30-12.30			9.00-12	40Wh
Tube light reading room,10W			6.00-7.00	7.00-8.30	25Wh
Tube light bed room1,10W				7.0-8.00 9.00-10	20Wh
Tube light				8.00-10	20Wh

bed room2,10W					
Tube light Kitchen room,2piece,10W				7.00-8.30	30Wh
Tube light Guest Room					
Tube light Bath room,10W	At least 30 minutes				5Wh
Mobile charger,15W	At least 1 hour				15Wh

Total Wh=155Wh

So average is =147.5+155=200/2=151.25Wh

Here we consider generation per day is 150 Wh or .15KWh. so yearly generation is =.15× 365 = 54.75 KWh. And life time generation is =54.75 × 20 =1095 KWh

Tariff calculation for solar home system:

Present Formula:

This consumer takes 85Wp solar home system with this condition that he paid 15% of the total price as down payment. The remaining 85% of the total cost is to be repaid within 36 months with 6% (flat rate) service charges.

Total price of the 40Wp SHS is = 40800. tk

Down payment 15% = 6120 tk

Due = 34680 tk

So principal installment per month =34680/36 = 963.33tk

Interest installment per month = (34680× 6%)/12 = 173.4tk

Total installment per month = 963.33+173.4=1136.73tk

Month	Principal Beginning(tk)	Installment(tk)	Monthly Interest(tk)	Principal Repayment(tk)	Principal Ending(tk)	Yearly Interest(tk)	Yearly Principal(tk)
1	34680	1137	173.4	963.33	33716.67		
2	33716.67	1137	173.4	963.33	32753.34		
3	32753.34	1137	173.4	963.33	31790.01		
4	31790.01	1137	173.4	963.33	30826.68		
5	30826.68	1137	173.4	963.33	29863.35		

6	29863.35	1137	173.4	963.33	28900.02		
7	28900.02	1137	173.4	963.33	27936.69		
8	27936.69	1137	173.4	963.33	26973.36		
9	26973.36	1137	173.4	963.33	26010.03		
10	26010.03	1137	173.4	963.33	25046.7		
11	25046.7	1137	173.4	963.33	24083.37		
12	24083.37	1137	173.4	963.33	23120.04	2080.8	11559.96
13	23120.04	1137	173.4	963.33	22156.71		
14	22156.71	1137	173.4	963.33	21193.38		
15	21193.38	1137	173.4	963.33	20230.05		
16	20230.05	1137	173.4	963.33	19266.72		
17	19266.72	1137	173.4	963.33	18303.39		
18	18303.39	1137	173.4	963.33	17340.06		
19	17340.06	1137	173.4	963.33	16376.73		
20	16376.73	1137	173.4	963.33	15413.4		
21	15413.4	1137	173.4	963.33	14450.07		
22	14450.07	1137	173.4	963.33	13486.74		
23	13486.74	1137	173.4	963.33	12523.41		
24	12523.41	1137	173.4	963.33	11560.08	2080.8	11559.96
25	11560.08	1137	173.4	963.33	10596.75		
26	10596.75	1137	173.4	963.33	9633.42		
27	9633.42	1137	173.4	963.33	8670.09		
28	8670.09	1137	173.4	963.33	7706.76		
29	7706.76	1137	173.4	963.33	6743.43		
30	6743.43	1137	173.4	963.33	5780.1		
31	5780.1	1137	173.4	963.33	4816.77		
32	4816.77	1137	173.4	963.33	3853.44		
33	3853.44	1137	173.4	963.33	2890.11		
34	2890.11	1137	173.4	963.33	1926.78		
35	1926.78	1137	173.4	963.33	963.45		
36	963.45	1137	173.4	963.33	0.12	2080.8	11559.96
		40932	6242.4	34679.88		6242.4	34679.88

.

So actual price of 85Wp SHS = 40932+6120 = 47052tk

Tariff calculation:

Total price of SHS is 47052 tk.

Solar module is warranty for 20 years. So we do not need to change it.

Battery warranty is 5years. In the first installation battery cost is included. So they need change battery for 3times. The cost of changing the battery in 20years is =3*13500= 40500 taka (13500 for each battery).

Now, charge regulator is warranty for 3 years. In first installation Charge regulator cost is included. Approximately 6 charge regulator need for 20 years. So the cost of changing the charge regulator in 20 years is: 6*600=3600tk. (600 for each battery).

Battery need at least two time distilled water and charge in a year .This operation & maintenance cost approximately 100tk per year. So for life time O&M cost is=150×20=3000 tk.

Total cost need to use SHS (40Wp) for 20 years is=47052+40500+3600+3000=94152tk.

So per Unit cost for SHS (40Wp) is= 94152/1095KWh= 85.98tk per KWh.

PVIFA Formula:

PVIFA means Present Value Interest Factor of Annuity. It's a most popular formula to calculate monthly payment needed to repay a loan. PVIFA is used in finance theory to refer to the output of a calculation, used to determine the monthly payment needed to repay a loan. The calculation has a number of variable factors, which include the quantity borrowed **P**, the given interest rate **r**, the number of regular intervals **n** at which the loan is to be repaid and the term of the loan.

85W Solar home system:

Principal = 40800 tk

Down payment = 6120 tk

Due = 34680 tk

Interest = 6%

Nominal interest **r** = .5%

Installment **n**= 36

We know,

Principal = A × PVIF (Present Value Interest Factor Of Annuity)

$$34680 = A \times \left[\frac{\left\{1-\frac{1}{(1+r)^n}\right\}}{r}\right]$$

$$34680 = A \times \left[\frac{\left\{ 1 - \frac{1}{(1+.005)^{36}} \right\}}{.005} \right]$$

A=1055.03

Month	principal Beginning(tk)	Installment(tk)	monthly Interest(tk)	principal Repayment(tk)	principal ending(tk)	yearly interest(tk)	yearly Principal(tk)
1	34,680.00	1,055.03	173.4	881.63	33,798.37		
2	33,798.37	1,055.03	168.99	886.04	32,912.33		
3	32,912.33	1,055.03	164.56	890.47	32,021.86		
4	32,021.86	1,055.03	160.11	894.92	31,126.93		
5	31,126.93	1,055.03	155.63	899.40	30,227.53		
6	30,227.53	1,055.03	151.14	903.90	29,323.64		
7	29,323.64	1,055.03	146.62	908.41	28,415.22		
8	28,415.22	1,055.03	142.08	912.96	27,502.27		
9	27,502.27	1,055.03	137.51	917.52	26,584.75		
10	26,584.75	1,055.03	132.92	922.11	25,662.64		
11	25,662.64	1,055.03	128.31	926.72	24,735.92		
12	24,735.92	1,055.03	123.68	931.35	23,804.56	1784.957209	10,875.44
13	23,804.56	1,055.03	119.02	936.01	22,868.55		
14	22,868.55	1,055.03	114.34	940.69	21,927.86		
15	21,927.86	1,055.03	109.64	945.39	20,982.47		
16	20,982.47	1,055.03	104.91	950.12	20,032.35		
17	20,032.35	1,055.03	100.16	954.87	19,077.48		
18	19,077.48	1,055.03	95.39	959.65	18,117.83		
19	18,117.83	1,055.03	90.59	964.44	17,153.39		
20	17,153.39	1,055.03	85.77	969.27	16,184.12		
21	16,184.12	1,055.03	80.92	974.11	15,210.01		
22	15,210.01	1,055.03	76.05	978.98	14,231.03		
23	14,231.03	1,055.03	71.16	983.88	13,247.15		
24	13,247.15	1,055.03	66.24	988.80	12,258.35	1,114.18	11,546.21
25	12,258.35	1,055.03	61.29	993.74	11,264.61		
26	11,264.61	1,055.03	56.32	998.71	10,265.90		
27	10,265.90	1,055.03	51.33	1,003.70	9,262.20		
28	9,262.20	1,055.03	46.31	1,008.72	8,253.48		
29	8,253.48	1,055.03	41.27	1,013.77	7,239.71		
30	7,239.71	1,055.03	36.20	1,018.83	6,220.88		
31	6,220.88	1,055.03	31.10	1,023.93	5,196.95		
32	5,196.95	1,055.03	25.98	1,029.05	4,167.90		
33	4,167.90	1,055.03	20.84	1,034.19	3,133.71		
34	3,133.71	1,055.03	15.67	1,039.36	2,094.34		
35	2,094.34	1,055.03	10.47	1,044.56	1,049.78		
36	1,049.78	1,055.03	5.25	1,049.78	0.00	402.04	12,258.35
		37,981.18	3,301.18	34,680.00		3,301.18	

Tariff calculation:

Unit Generation	1 st year	2 nd year	3 rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
Inslalled capacity(KW)	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
Total generation(KWh)	54.75	54.75	54.75	54.75	54.75	54.75	54.75	54.75	54.75	54.75

Unit Generation	10th year	11th year	12th year	13th year	14th year	15th year	16th year	17th year	18th year	19th year	20th year
Inslalled capacity(KW)	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
Total generation(KWh)	54.75	54.75	54.75	54.75	54.75	54.75	54.75	54.75	54.75	54.75	54.75

Fixed cost	1 st year	2 nd year	3 rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
O & M (TK)	150	150	150	150	150	150	150	150	150	150
Replacement (tk)	2130	2130	2130	2130	2130	2130	2130	2130	2130	2130
Installment (tk)	16995.44	11546.21	12258.35	0	0	0	0	0	0	0
interest on term lone (tk)	1784.96	1114.18	402.04	0	0	0	0	0	0	0
Total fixed cost (tk)	21060.39	14940.39	14940.39	2280	2280	2280	2280	2280	2280	2280
Tariff per year (tk)	384.6645	272.8838	272.8838	41.6438	41.6438	41.6438	41.6438	41.6438	41.6438	41.6438

Fixed cost	11th year	12th year	13th year	14th year	15th year	16th year	17th year	18th year	19th year	20th year
O & M (TK)	150	150	150	150	150	150	150	150	150	150
Replacement	2130	2130	2130	2130	2130	2130	2130	2130	2130	2130
Installment (tk)	0	0	0	0	0	0	0	0	0	0
interest on term lone (tk)	0	0	0	0	0	0	0	0	0	0
Total fixed cost (tk)	2280	2280	2280	2280	2280	2280	2280	2280	2280	2280
Tariff per year (tk)	41.6438	41.6438	41.6438	41.6438	41.6438	41.6438	41.6438	41.6438	41.6438	41.6438
Tariff (tk)	81.9189									

Comparison of two methods:

Monthly installment in present formula is 1137 tk.

But PMT formula monthly installment is 1055.03 tk .

So different is (1137 – 1055.03) = 81.97 tk per installment & finally different is =81.97×36 =2950.92 tk.

Tariff in present formula = 85.98 tk per KWh

Tariff in PVIFA formula = 81.92 tk per KWh

So different is (85.98- 81.92) = 4.06 tk per KWh

Plant factor of Solar Home System (40W)

40W solar system daily energy use is 150 Wh.

So energy uses for one year is =150*365=54.75KWh

So plant factor = $\frac{54.75}{.085\times24\times365}$ = 7.35%

Plant factor	7.35%	8%	9%	10%	11%	12%	13%
Electricity(KWh)	1094.562	1191.6	1340.28	1489.5	1638.12	1787.4	1935.96
Total Cost (tk)	89701.17	89701.17	89701.17	89701.17	89701.17	89701.17	89701.17
Cost/KWh	81.95166	75.27792	66.92719	60.22234	54.75861	50.18528	46.33421

Plant factor	14%	15%	16%	17%	18%	19%	20%
Electricity(KWh)	2085.3	2233.8	2383.2	2531.64	2681.1	2829.48	2979
Total Cost (tk)	89701.17	89701.17	89701.17	89701.17	89701.17	89701.17	89701.17
Cost/KWh	43.01595	40.15631	37.63896	35.43204	33.45685	31.70235	30.11117

Plant factor	20%	21%	22%	23%	24%	25%
Electricity(KWh)	2978.4	3127.32	3276.24	3425.16	3574.08	3723
Total Cost (tk)	89701.17	89701.17	89701.17	89701.17	89701.17	89701.17
Cost/KWh	30.11723	28.68308	27.3793	26.1889	25.0977	24.09379

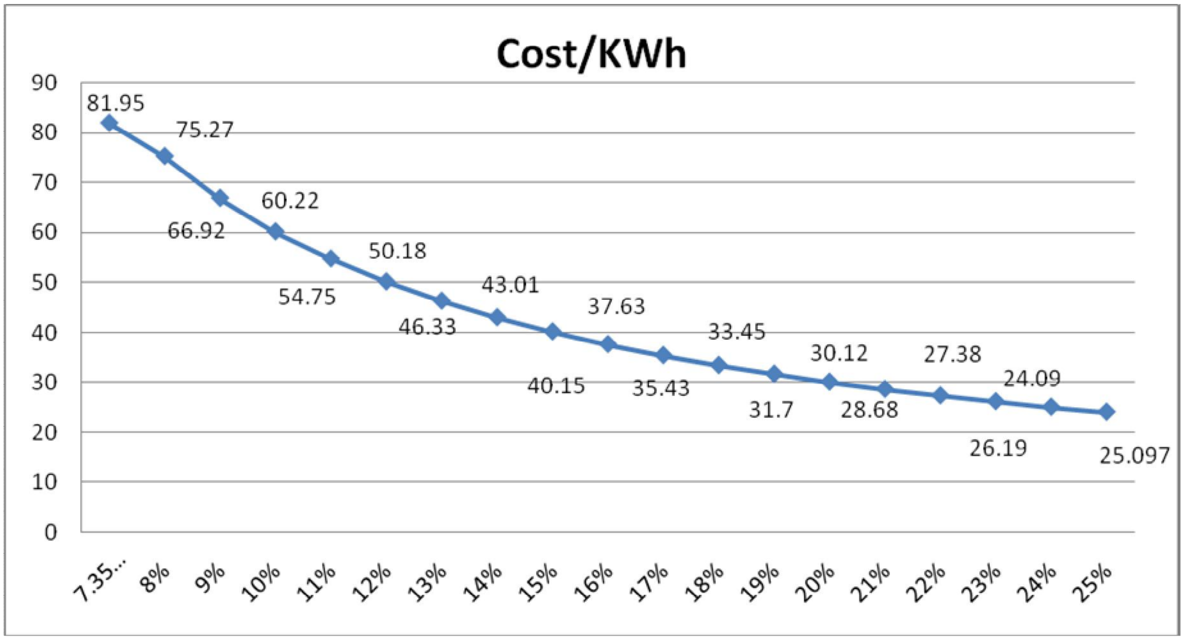


Fig: Show if plant factor increase per unit cost decrease.

5.3. SHS cost limitation:

Solar home systems price still so high in Bangladesh. Still big portion people in our country are away from grid connection. All of those people are living in village and their economical conditions are also so poor. So we should need to take policy how those poor people can use solar home system in cheaper prices.

1. Need to reduce interest rate of solar home system package.
2. Requirement change of the way of interest calculating method.
3. Our local battery price is lower than imported battery .so we can use our local standard battery in solar home system.
4. Need huge research to improve efficiency of solar panel.
5. Government need to take appropriate policy and strong monitoring this sector.

CHAPTER SIX
Cost Comparison
(Study between SHS & Diesel Generator)

6.1Background

Access to electricity is one of the major factors that impinge on socio-economic maturity of a country. At present Bangladesh is distressing from an acute electricity problem. Around 65% of people having lack access of electricity and majority of them are living in village. Among them about 44% are living below poverty line. So, energy supply in Bangladesh poses great challenges. [18].In 2013, the per capital electricity production in Bangladesh was 321KWh.But remote places and the remote island, the panorama of supplying grid electricity is near about impossible within foreseeable future. In absence of grid electricity, using of diesel generator to supply electricity is often proposed as an alternative. Actually using generators is not an effective solution. Using diesel generators has its own set of problems. Generators themselves are quite expensive. So producing electricity by generator is very costly. Even if some household can afford to buy and run this, lack of fuel supply often limit the use of generator. Biomass might be a good alternative source of energy. But it is becoming more expensive and scarce due to high demand. Electricity supply is often erratic due to inadequate power generation capacities. Under these circumstances, Solar Home System (SHS) can be an appropriate alternative to provide electricity. Providentially, Bangladesh is endowed with copious supply of solar energy due to its geographical location. Annual amount of radiation varies from 1840 to 1575 kwh/m2 which is 50-100% higher than Europe [19].

6.2 Diesel Generator Cost: 20 Years Case

Assumption:

Configuration of the model Diesel generator:

Fuel tank capacity: 15 L
Fuel option: Diesel
Weight: 170Kg
Fuel consumption: 1.25-1.5 lit/hr
Output (minimum): 4000 Watt
Maximum (maximum): 4500 Watt
Rated: Around 4000 watt
Operating time: 6 hours continuing
Voltage: 220V

Speed: 3000 rpm
Frequency: 50 Hz

Price: 50,000 Taka

1st 5 years:

Year(No) Diesel	Diesel cost (Taka	Calculation (Taka)
1	68 (Present)	(1.5×4×365×68)=148920
2	70	(1.5×4×365×70)=153300
3	72	(1.5×4×365×72)=157680
4	74	(1.5×4×365×74)=162060
5	76	(1.5×4×365×76)= 166440

Total 788400+ 90000 = 838400

2nd 5 years:

Year(No) Diesel	Diesel cost (Taka)	Calculation (Taka)
1	78	(1.5×4×365×78)=170820
2	80	(1.5×4×365×80)=175200
3	82	(1.5×4×365×82)=179580
4	84	(1.5×4×365×84)=183960
5	86	(1.5×4×365×86)=1,88340

Total 897900 + 50000 = 947900

3rd 5 years:

Year(No) Diesel	Diesel cost (Taka)	Calculation (Taka)
1	88	(1.5×4×365×88)=192720
2	90	(1.5×4×365×90)=197100
3	92	(1.5×4×365×92)=201480
4	94	(1.5×4×365×94)=205860
5	96	(1.5×4×365×96)= 210240

Total 1007400 + 50000 =1057400

4th 5 years:

Year(No) Diesel	Diesel cost (Taka)	Calculation (Taka)
1	98	(1.5×4×365×98)=214620
2	100	(1.5×4×365×100)=219000
3	102	(1.5×4×365×102)=2,23380
4	104	(1.5×4×365×104)=227760
5	106	(1.5×4×365×106)=232140

Total 1116900 + 50000 = 11,66900

Total running cost: 838400+947900+1057400+1166900 =4010600 Taka.

Now,

Maintenance cost:

1 room: 2000 taka/ month (house rent is a subject to increase in next 20 years. So we take the average one).
Calculation for 20 years: (2000×12×20) = 4, 80,000 Taka.
Again two people for maintenance = 2×4000 = 8000 per month.
Calculation for 20 years: (8000×12×20) = 1, 92, 0000 Taka.
Total: 4, 80,000 Taka+ 1, 92, 0000 Taka= 24, 00000 Taka.
Total Amount for Diesel Generator: (4010600+24, 00000) Taka = 6410600 Taka.

6.3 SHS COST: 20 YEARS CASE ASSUMTION:

Configuration of Our SHS Components

Solar module: 50 Wp
Battery: 80 Ah
Charge controller: 5or 10 Amps

For 80 house hold we need 80, 50 Wp SHS.
Each 50 Wp SHS (including Battery, Charge controller, 4,6watt
Lamp, switch, switch board, installation and other accessories) costs
32,800taka (GS) . [20]
Total installation cost for 20 years: (32,800*80) = 26, 24,000 Taka

Running cost:

Solar module is warranty for 20 years. So we do need to change it.

Battery warranty is 5 years. In the first installation battery cost is included. So the cost of changing the battery in 20 years is:

80+80+80=240 Ah

240*8000= 19, 20000 taka (80000 for each battery)

Now, charge regulator is warranty for 3 years.

In first installation Charge regulator cost is included. So the cost of changing the charge regulator in 20 years is:

Approximately 6 charge regulator for each family.

80*6= 480-80(1st installation) =400

400* 650=26000 taka

Total cost in 20 years =26, 24,000 Taka+19, 20000 taka+260000 Taka.

= 4804000Taka.

Now, for comparing with the Diesel generator if we deduced the amount for providing light, switch, switch board, installation cost(included in 1st installation) which is not included in diesel generator, the amount will:

(48, 04000-81,600) Taka= 4722400 Taka [(4*80) + (10*10) +(200*2) +200= 1020 per household]

SO, Diesel Generator will cost (6410600 Taka-4722400 Taka) = 16, 88,200 Taka more in compare with SHS!!! + Carbon credit. Here it is justified that SHS is the better alternative over Diesel generator.

CHAPTER SEVEN
Solar power plant

7.1 Feasibility of Solar Power plant in Bangladesh

In the face of tremendous social, economic and political pressure to solve power crisis in Bangladesh it has become critically important to look for energy solutions beyond the conventional sources like domestic natural gas, coals, hydroelectricity and imported fuels. The rapid depletion of natural oil and gas reserves due to the excessive consumption is leading to severe global competition and political tensions among the powerful nations to control the remaining fossil fuel reserves. Western countries have been using fossil fuels at a much larger volume than the rest of the world since World War II. Unprecedented increase of energy consumption by rapidly developing nations like China, India and Brazil is adding tremendous pressure on the demand and supply of petroleum. Extreme competition and volatility of fuel price in the global energy market is continuously hammering small players like Bangladesh. Discounted petroleum supply from friendly countries, reliance on domestic natural gas, and subsidized fuel supply to the public and private sectors are no longer politically and economically viable options for us. Global warming and the subsequent increase of the sea level and natural calamities due to excessive carbon emission from fossil fuels are causing severe environmental and ecological havoc for low-lying countries like us. The most feasible way out of this multi-dimensional crisis is to increase our reliance on renewable energy like solar power.

Today in Bangladesh about 62% area covered by grid connected electricity. Also about 38% area away from grid line. For that reason those area are rearward in every sector like education, economy, agriculture compare to grid connected area. The government in its national energy policy clarified its vision that it wants to bring the whole country under electricity supply by the year 2020. But at least 30 remote area have been identified where grid expansion is not planned for next 15-20 years. These types of area are mostly compatible for PV based solar power plant. In those area all market, hospital, educational institute, government, nongovernment offices are totally dependable on diesel generator. But diesel generator, it’s per unit cost are highly rich. Solar power plant also expensive then grid power system but not more than diesel generator. The prices of PV per unit cost less than half from diesel generator unite. Only PV power plant can be a quick solution to remove the power crisis of that remote area. This PV power plant brings electricity revolution in our country. Already several PV power plants had been established in our country. Sandwip PV power plant is pioneer all of them. This PV power plant brings revolutionary change in sandwip daily life.

7.2 Expected socio-economic benefits for Bangladesh

The usage of solar energy will not only provide us with a clean environment and risk free power production, but also present us a life where we will not have to constantly worry about the ever decreasing resources to provide us with the basic comforts of our life. In this section some of the expected socio-economic benefits of adopting solar power plant and park in Bangladesh are highlighted.

Employment: There will be two different fronts for job creation and poverty elimination related to solar power industry. First, the installation, maintenance and operation of solar plants will create many new jobs. Considering the worldwide growth potential of solar power sector, we can foresee a bright future for Bangladesh to build a solar power supporting industry to provide technical, material, manufacturing, and commercial services to this sector. For example, Bangladesh can immediately get into sub-sectors like making solar plant mounting system, battery for solar electricity storage, switches, wires, and other electrical components of solar plants. Only solar panels need to be imported. Installation and maintenance can be 100 per cent provided by local engineers and technicians.

Improved and reliable power distribution: Many countries are adopting distributed power generation scheme as opposed to centralized power generation and reliance on national grid to deliver the power to remote areas. In case of any failure in the national grid larger area or the entire country would be affected if the power generation is centralized. The distribution costs and losses will also be much higher in such scheme. Hundreds of interwoven rivers, low lands and periodic floods and cyclones make it much more difficult for Bangladesh to maintain a centralized power distribution system with only a handful of generation sites connected by a national grid. BPDB has moved towards a policy of localized power plants distributed all over the country. Local solar plants of 1 to 10 MW capacities will be a great addition to this distributed power generation scheme.

Institutional and sector productivity: Power generated by small solar plants in areas beyond the reach of the national grid will create limitless possibilities of productive and economic activities. Factories, industries, commercial organizations, health and education institutions, and many other entities can be set up all across the country. Equal distribution of facilities and opportunities across the country is a long-cherished goal for Bangladesh. Solar power industry can be a very effective vehicle to fulfill this goal. Some of the benefits that can be harvested from solar power in various sectors are illustrated below:

i) Agricultural productivity: One of our recurring problems is the interruption of power to the irrigation pumps during the cultivation seasons. Small and distributed solar plants can be the solution to this problem. Another serious problem of our agriculture sector is the manual handling, harvesting and processing of crops. People cannot afford expensive oil run machines to speed up the process. Solar plants in rural areas can open the door for many rechargeable agricultural machineries and equipments, which will dramatically increase the productivity and the efficiency of the whole cultivation, harvesting and processing chain.

ii) Fisheries industry: Except few export oriented fisheries firms, most of the fishermen across the country do not have any means to preserve their catch for extended period due to the lack of cold storage facility, particularly in the coastal and river bank areas. As a result, if the fishermen cannot sell their catch by the end of the day, they have to suffer huge financial loss. Greedy middlemen are taking unfair advantage of these poor fishermen. Most of the coastal and river bank areas are still beyond the reach of our national grid. Small and distributed solar pants in these areas can revolutionize the fisheries industry.

iii) Spreading Information Technology: The most remarkable achievements of human race in the 21st century in the wide spread use of information technology, which changed the way we live our life and the way we do things. Mankind achieved unimaginable productivity, connectivity and facilities through the use of information technology. Unfortunately, the vast majority of Bangladesh is still unable to enjoy the fruits of this sector. In this digital age spreading the information technology and related facilities across the country from urban to rural areas is an utmost necessity. Our government has very clear plans, and we have all the experts to implement this program, but materialising it requires uninterrupted electricity supply. A solar solution to this issue seems very feasible for Bangladesh.

iv) Other industries: In Bangladesh, still the major industries are concentrated in few districts mainly due to availability of electricity in these areas. For equal distribution of development and economic opportunities we need to set up industries all over the Bangladesh. This can only be done through supply of electricity.

Women empowerment: 1 to 10 MW capacity power plants can satisfy demands for vast rural territories of Bangladesh. Electricity generated by these plants would become the backbone of rural economy. The power can be used in women oriented cottage industries. This will not only solve the power crisis to a great extent, it will also open the door for economic empowerment of women and gender equality in Bangladesh.

Environmental protection and ecological balance: The sustainability of energy supply and consumption depend on the reduction of ecological and health hazards. This requires measures that increase energy efficiency of tools and machines used by human race, substitute cleaner fuels for polluting fuels, and introduce green and renewable energy technology. Protecting our nature and environment by reducing carbon foot print is one of the most important ethical and scientific goals of our time. For Bangladesh, being a low-lying coastal area, it is also a question of survival. One of the most disastrous impacts of current change in ecological balance is the increase of sea water level. Bangladesh is expected to be one of the worst sufferers of this disaster considering its geographical location and population density.

Carbon credit: International organizations, multinational corporations and industrially developed counties are expected to compete to trade carbon credits with the developing countries. By adopting solar solution to cover a significant portion of our electricity shortage Bangladesh can serve its own need, and at the same time get economic benefit by selling carbon credits to interested parties.

Sandwip 100 kW Solar Mini Grid Island

7.3 About Sandwip:

It is situated at the estuary of the Meghna River on the Bay of Bengal and separated from the Chittagong coast by Sandwip Channel. It has a population of nearly 350,000. There are as many as fifteen different wards, 62 mahallas and 34 villages on Sandwip Island. The entire island is 50 kilometers long and 5-15 kilometers wide. It is located at the north-eastern side of The Bay of Bengal, nearby the main port city of Chittagong. It is bounded by Companiganj on the north, Bay of Bengal on the south, Sitakunda and Mirsharai, and Sandwip Channel on the east, Noakhali Sadar, Hatiya and Meghna estuary on the west. About three hundred ships of salt per year were loaded for export from Sandwip's port. It also had a shipbuilding industry. The Turkish president Solaiman Demirel came to Chittagong in 1994 and imported a gun ship from Sandwip port.[22]

Fig 7.1: Sandwip Upuazila, Chittagong, Bangladesh

7.4 Description about Sandwip 100 kW Solar Mini Grid Island

The Sandwip Island, has a population of 400,000, is detached from Chittagong mainland by a channel of about 75 kilometers. Located along the south eastern coast of Bangladesh, the island is 50 kilometers long and 5.15 kilometers wide. There are 15 unions in Sandwip. Because of its position and inaccessibility there is no possibility of grid electrification service in this area in the distant future. Sandwip is an upazilla with very high literacy rate and remittance earnings from the United States and Middle Eastern countries. The island, however, has a dynamic population with various public and private service offerings providing support to the general public including educational institutions, health service centers, small and medium enterprises, etc. Despite shortage of reliable and consistent supply of electricity, use and willingness of use of various loads have been found in this region i.e. computers, printers, scanners, photocopy machine, refrigerators, color television, etc.

At present, the electricity demand of general shops in the markets of Sandwip are served by diesel micro-grid run by several diesel generator operators who provide services for about 5 to 8 hours per day. Besides, several diesel generators are used by several shop owners for captive consumption. Average tariff rate being charged to the customers by the diesel operators currently range between BDT 53 per kWh and BDT 60 per kWh.

Bangladesh Power Development Board also has diesel generator that supplies electricity to mainly government offices.

Several non-government organizations (NGOs) have been providing off-grid electrification solution in the household levels through ‘solar home system’ units in Sandwip under a program run by state-owned financial institution named Lighting Rural Bangladesh “LRB”. LRB was established by the Government of Bangladesh to catalyze the development of private sector infrastructure and renewable energy project.

Observing the demand patterns in the commercial areas, the NGOs came up with an idea of installing a 100-kW solar based power station in an optimal location from where electricity will be dispatched through a distribution line.

Construction of such a system would cost at least BDT 5 crore and the 1 kWh, kilowatt-hour, is a unit of energy equivalent to one kilowatt (1 kW) of power expended for one hour (1 h) of time. 2 Solar home system is a small power unit(ranging between 10 Wp to 130 Wp) consisting of solar PV module, battery, charge controller installed in a household for running different loads e.g. lights, DC fan, black and white TV.

Consortium of the NGOs could afford up to 20% of the project cost. The NGOs recognized that the Project would require extensive concessionary financing support and technical assistance. When shared the project idea with LRB, it expressed its interest to extend soft loan and arrange grant support for implementing the Project. As per its lending policy, LRB could extend 10 years loan with a grace period of 2 years at an interest rate of 6% per annum and only interest is required to be paid during the grace period. The construction period of the Project is expected to be only 4 months.

The NGOs formed a project company called PGL for implementing the Project with individual shareholding. It has been decided that PGL will inject the equity first and will start the construction works. The expected financial closing of in the Project has been planned on 31 December 2012 and the expected drawdown of the loan will be as shown the following table:

Customer	Total number of potential customers	Total number of targeted customers
Small shops	478	390
Health care	5	5
Schools	5	5

Currently there are about 11 diesel generator operators supplying electricity to the proposed project areas during day and night hours at prices ranging between Tk. 52.6/kWh and Tk. 73/kWh. When interviewed, the potential customers expressed a great deal of interest for availing the electricity connection immediately. 70% of the targeted customers have been expected to be acquired in the first year and the remaining 30% in the second year. Total electricity consumption among the targeted areas was studied to be 137,977 kWh of which 110,125 kWh was estimated to be sourced from solar energy source. The remaining portion of the demand will be served by diesel generator.

The Project will produce electricity through solar micro-grid. The solar PV modules are the main power generation system that is operational during daytime. The other main equipment and accessories include inverter, diesel generator, batteries. About 60 kW of the PV modules will be directly connected to 6 mini central inverters which will convert from DC3 to AC4 power at 220V and supply to the micro-grid distribution line at all times. Three phase configuration of the AC distribution line will be configured through the multi-cluster box, which is the interface for all connectors and control. The unused portion of the power in the distribution line will be stored into the batteries through 12 bidirectional inverters in 4 clusters. During daytime additional 40 kW PV power will be stored into the same battery bank through DC battery chargers. When the grid power is not available, mainly during evening hours, the plant will use power from the battery bank. During the periods of lesser solar radiation, and on cloudy days, backup power will be provided by the 40kW diesel generators. Tariff would be charged in the form of one-time connection fee and regular electricity tariff. The electricity tariff will be set at Tk. 35 per kWh. The connection fee will vary depending on the type of the customer as shown in the following table:

Customer type	**Connection Fee (BDT**
Small shop	4,000
Health centre	6,000
School	6,000

The electricity tariff is expected to be increased by 5% from the third year of operation. The full technology of the Project will be supplied by ABC Systems on a turnkey basis. As per the arrangement, ABC Systems will procure, install and commission the Project and after implementation, will hand over the Project to PGL. ABC Systems will also provide technical assistance during the first year of operation and will train the technical team of PGL. The equipment would cost about BDT 4.25 core. ABC Systems will charge a technical assistance fee of BDT 28.66 lac. The transportation costs have been assumed to be BDT 7.25 lac and other accessories will cost about BDT 33.5 lac. The O & M cost of the Project in the first year has been estimated to be 1% of the project cost excluding

technical assistance fee, which is BDT 4.76 lac. The O & M cost is expected to increase by 5% per year from the second year onwards. The annual insurance cost will be BDT 95,000. Per unit diesel requirement was identified to be BDT 0.17 liter/kWh and diesel price was BDT 45 per litre. Price of diesel has been expected to increase by 5% per year. The economic life of the Project is estimated to be 20 years. The battery bank, however, is to be replaced in 7th and 13th year at a cost of BDT 1.12 core. The technical assistance fee is to be amortized in five years. The applicable income tax rate would be 37.5%. There is, however, provision for tax holiday of 15 years for encouraging power generation in the private sector. Recognizing the economic value of the Project, LRB is looking for a minimum IRR of 9.00% and minimum NPV of BDT 2 crore.PGL, however, expects to receive an equity IRR of 20%. As a thumb rule, LRB allows minimum DSCR to be 1.2x. In this case, the DSCR could go down as low as 1.17x.With the cost of equity being 9%, the weighted average cost of capital (WACC) has been found to be 4.5%. LRB and PGL decided to use the WACC as the discount factor for calculating NPV. Consider 360 days in a calendar year.

7.5 Over view of 100 KW solar mini grid project at a glance

Name of the Projec : 100 kW Solar Mini Grid, Enamnahar , Sandwip, Chittagong

Project Area : 0.6 Acre
Project Cost : BDT 57.71 Million
Financed By : IDCOL, kfW-Germany and World Bank
Loan30% : Tk 17.31 Million
Grant50% : Tk 28.86 Million
Equity20% : Tk 11.54 Million

Proposed Electricity Supplied Area :Enamnahar Bazar, Malek Munsir Bazar, Khontar Hat & Ponditar Hat.

Proposed Length of Distribution Line: 4 kilometer

Proposed Number of Consumers : Commercial Shop- 390, Health Center- 5 & School- 5

Technical Assistance : Prokaushali Sangsad Limited (PSL), Dhaka, Bangladesh
Technology Supplied : Energy Systems (BD) Ltd, Asantys Systems (Germany)

Hardware Details: Solar Module- Kyocera, Inverter- SMA Solar Technology AG, Germany Battery- Hoppecke, Germany Introducing PGEL

Management: Asma Huque,Chairman

Johirul Alam, Managing Director
Bimal Kumar Chandra, Director
Alauddin Ahmed, Director
Didarul Alam, Director

7.6 Sandwip Solar Plant Technology in Bangladesh

The system design is based on AC-coupled bus concept. The main idea is to provide direct solar energy to the consumer via an AC bus through converters, when the converter energy (radiation) meets with the energy demand. Surplus will be charged via a so called “sunny island” charger into the batteries. The size of the solar micro-grid project under consideration is 100 kW accompanied by 40 kW Diesel. The solar micro-grid is given in Figure 1, which is a combined operation of several sub-systems.

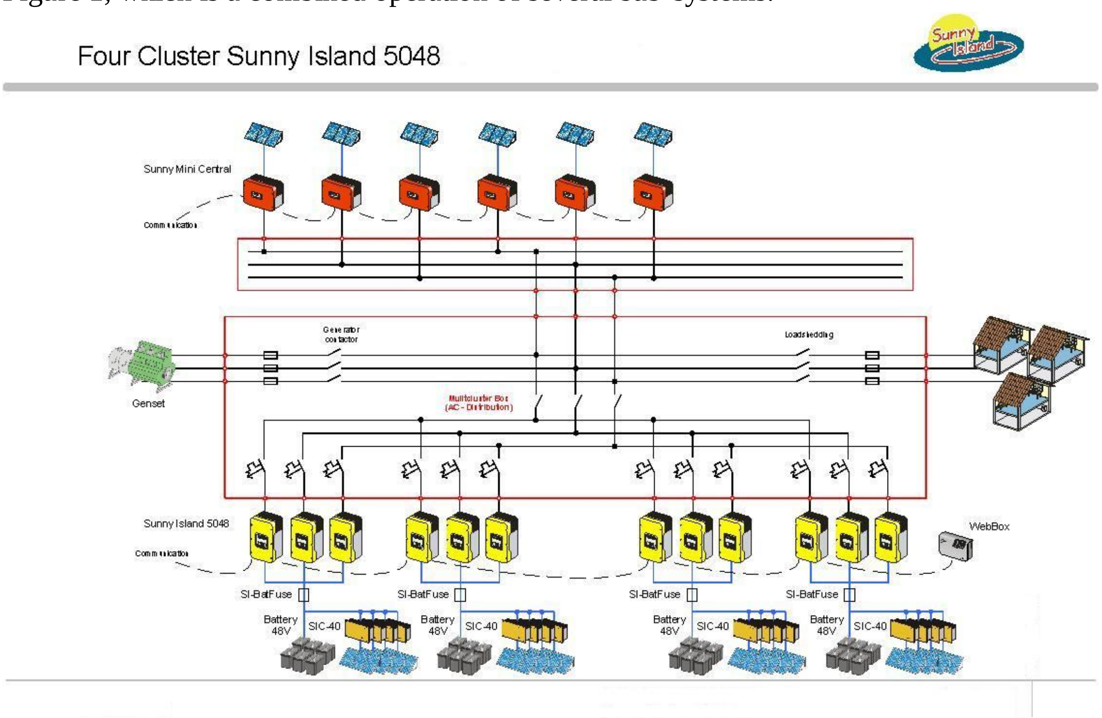


Figure 7.2 Solar Micro Grid Layout using Four Cluster Sunny Island

7.6.1 List of major Equipments

Table 7.1: Major Equipments list

Equipment	Supplier	Country of Origin
Photovoltaic Module	Kyocera	Japan (Assembled in China)
Inverter	SMA Solar Technology AG	Germany
Battery	Hoppecke	Germany
Grid Inverter	SMA Solar Technology	Germany

	AG	
Sunny Web box & Battery Fuse	SMA Solar Technology AG	Germany

7.6.2 Supplier Details

SMA solar Technology AG.SMA is world"s largest producer in this segment and has a product range with the matching inverter type for any module type and any power class. This applies for grid tied applications as well as island and backup operation. The Sunny Mini Central produced by SMA already has an efficiency of over 98%, which allows for increased electricity production. SMA"s business model is driven by technological progress. Due to its flexible and scalable production, SMA is in a position to quickly respond to customer demands and promptly implement product innovations. This allows the Company to easily keep pace with the dynamic market trends of the photovoltaic industry.

Kyocera is one of the leading PV module suppliers of the world. In IDCOL Solar Home System Program more than 80% modules are supplied by Kyocera and the performance of these modules is quite satisfactory.

Hoppecke is one of the leading battery manufacturers in Germany. This company has been developing and producing batteries since 1927.HOPPECKE is now the specialist for industrial battery systems, and at the same time the largest manufacturer in European ownership.

7.6.3 Description of Major Equipments

a) Photovoltaic (PV) Module:

The PV Module is polycrystalline and highly efficient. There will be 324 nos. of 200Wp and 240 nos. of 135 Wp PV Modules. The PV Module is expected to be procured from Kyocera.

The major features of the proposed PV module model KC200GH-2Pare as follows

Particulars	Model KC200GH-2P
Maximum Power (Pmax)	200Wp (+10%/-5%)
Maximum Power Voltage (Vmp)	26.3V
Maximum Power Current (Imp)	7.61A
Open Circuit Voltage (Voc)	32.9V
Short Circuit Current (Isc)	8.21A

b) Inverter: Inverters used in the Project will be of two types:

i) Grid inverter

ii) Inverter

i) **Grid Inverter:**

It consists of the following:

- Multi cluster box
- Bidirectional Inverter
- Battery Main Switch

c) Multi Cluster Box:
There will be 1 no. of multi cluster box. The model used is SMA MC Box-12.3 Option Code 30001 (include:3: 4 Multicluster Piggy- Back RS485 and CAN Bus).

c.1) Major Features:

- 3-phase Multicluster-Box for the easy installation of stand-alone and hybrid systems with Sunny island 5048 up to a power range of 110 kW.
- Completely wired and equipped with a main connector for PV and wind turbine systems.
- Connection for a maximum of 4 clusters consisting of three SunnyIsland 5048 devices each.
- Integrated generator and load-shedding contactor.
- The communication cables necessary for the installation are included

d) Bidirectional Inverter: There will be **12 nos. of bidirectional inverter. The model used is SMA SI 5048** Option Code 0031.

d.1) Major Feature:

- Bi-directional battery inverter for setting 3-phase stand-alone systems
- Modularly extendable
- Multicluster operation
- High efficiency
- Intelligent battery management for maximum battery lifetime
- Charge level calculation
- Excellent overload capability

- Integrated display and control panel
- Integrated protective functions, DC fuse
- Output: short-circuit proof
- Operating temperature range: -25 °C ... +50 °C
- Continuous charging current of the battery at 25 °C for 100 A battery type: lead NiCd, battery capacity 100 - 10,000Ah

i) Battery Main Switch:

There will be 4 nos of battery main switch and the model used is SMA BATFUSE-B.03 Option Code 30. The main features are as follows:

- 1-pole NH 1 battery fuse as a load disconnecting switch for up to 3 Sunny Islands
- 6 DC input ports (2 x Battery an 4 x Sunny Island Charger)
- 1 x auxiliary voltage output with 8.6 x 250
- A fuse plug with 6 additional replacement fuses for Sunny Island 5048

ii) Inverter

There will be **6 nos. of inverter. The model is SMA SMC 11000TL-11** Option Code 8000x1 **a) Main Features:**

- Inverter for the feeding-in of solar electricity into the low-voltage grid in grid-parallel operation
- Transformer-less with all current sensitive failure current monitoring unit
- Opti-Cool cooling concept - maximum output up to 40°C ambient temperature
- Integrated display; suitable for indoor/outdoor mounting
- SMA Grid Guard grid monitoring
- Electronic Solar Switch (ESS) circuit-breaker: integrated protective functions
- Input: thermally monitored varsities, ground fault monitoring, reverse polarity prevention via short-circuit diode
- Output: short-circuit proof (current regulation).

e) Charger (DC)

There will be 16 nos. of chargers of Model: SMA SIC 40-MPTOption Code 000. Main features of the charger are as follows

- MPP solar charge controller.
- Automatic regulation and single point of operation from Sunny Island

- Up to four devices can be connected in parallel, modularly extendable, active MPP tracking, efficiency > 98 %, suitable for indoor and outdoor installation due to IP65, fanless. Integrated protective functions: short-circuit / reverse polarity / overload / excessive or insufficient voltage / overheating and undercooling; operating temperature range: - 25°C … +60 °C;
- Battery type: lead; charge control IuoU process

f) Sunny Web box &Battery Fuse (Communication Kit)

There will be one communication kit of model SMA Sunny Web Box Option Code 2001. The main features are as follows:

- Multi-functional data logger and communication center for setting parameters
- System monitoring, remote diagnostics, archiving data and visualization of up to 50 inverters
- The data is automatically transferred to Sunny Portal if desired
- The Sunny Web Box is easily operated using a web interface
- The data is accessed using a SD card or the integrated FTP server

g) Deep Cycle Industrial Battery

System requirement 48V, of 12000 Ah total will be met with series and parallel connection of 2V of 96 nos. of industrial batteries. Battery banks with tubular plate industrial batteries of 48 Volt (made up of 2V units) 12000 Ah total is proposed for 100 kW PV system. Due to the tubular configuration of the positive plate, these batteries are designed to withstand deep discharge and have a longer life. The proposed batteries are manufactured in Germany, with a service warranty of 10 years. Technical Specifications of the batteries are given below.

Rated Voltage : 2V Battery
Capacity : 3000Ah@10hr
Plate Type : Positive Plate Tubular
Brand : HOPPECKE

Diesel Generator

40 kW Diesel generator will be used. The model will be selected later

h) Tariff Comparison

Table 7.2 the average tariff rate being charged by these existing operators are as given below:

Diesel generator operators	**Average tariff rate (BDT per kWh)**	**Average tariff of the diesel**	**Effective tariff of the Proposed**

		generator operators (BDT per kWh)	Project (BDT per kWh)
Operator-1 Brothers Computer	52.60	64.91	30.52
Operator-2 Ripon	66.21		
Operator-3 Bazar Committee	72.83		
Operator-4 Laik	72.83		
Operator-5 Afsar	60.09		

Table7.3 Project Debt Facilities

Facility	**Amount** (BDT million)	**Interest Rate**	**Tenor**	**Grace**	**Repayment**
Term loan	17.31	6% p.a.	10 years	2 years	Annuity; In 16 (sixteen) semi-annualinstallments

i) Operating Expenses Assumption

Expenses of the Project include the following:

- Utility
- Salary and allowances
- General and administrative expenses
- Insurance cost

Table 7.4: Depreciation and Amortization

Depreciation	**No of years**	**Rate**
Plant, Machinery & Equipment	20	5%
Building and Civil Construction	20	5%
Battery	7	14%
Amortization		
Technical assistance	5	20%

7.7 Total project cost

Total cost of the proposed Project has been estimated to be BDT 57.71 million.

Table 7.8 Budgeted Project Cost in Sandwip

Particulars	Project costs in TK
Land and Land Development	1258078
Civil Construction	2400736
Equipment	
Solar Modules (100 kW)	
grid tie ,SI inverter	
Backup diesel generator 40 KW	
Accessories	
Batteries 40V, 18000Ah	
	38348295
Transportation	727146
Distribution and other	
Distribution line (5Km)	
AC household meter	
Control room structure and others	
	2850874
Important duty and clearance cost	7404193
Technical assistance	3133653
Contingency(3%of capital cost)	1587025
TOTAL PROJECT COST	**57710000**

7.8 Result and Discussion

7.8.1 2012 daily diesel use in liter in sandwip and per unit cost:

The Sandwip Island, has a population of 400,000, is detached from Chittagong mainland by a channel of about 75 kilometers. Located along the south eastern coast of Bangladesh, the island is 50 kilometers long and 5.15 kilometers wide. There are 15 unions in Sandwip. Because of its position and inaccessibility there is no possibility of grid electrification service in this area in the distant future. Sandwip is an upazilla with very high literacy rate and remittance earnings from the United States and Middle Eastern countries. We are calculated 2012 diesel per unit cost and solar individual cost .At last we are get total Sandwip total cost and per unit cost from this project.

Total Diesel Use in May Month= 256.5 Liter, Running hours=256.5/9=28.5 hours Energy Produce=28.5*32=912 KWh, Per liter 70 Tk , So 256.5 Liter=256.5*70=17955 Tk Per Unit Cost =17955/912 =19.68 Tk

Total Diesel Use in June Month= 252 Liter, Running hours=252/9=28 hours Energy Produce=28*32=896 KWh, Per liter70 Tk , So 252 Liter=252*70=17640 TK Per Unit Cost =17640/896 =19.68 Tk

Total Diesel Use in July Month= 287.6 Liter, Running hours=287.6 /9= 32 hours Energy Produce=32*32=1024 KWh, Per liter 70 Tk , So Liter=387.6 *70= 20130 TK Per Unit Cost =20130 /1024 =19.66 Tk

Total Diesel Use in August Month= 283.5 Liter, Running hours=283.5/9=31.5 hours Energy Produce=31.5*32=1007.8 KWh, Per liter 70 Tk , So Liter=283.5 *70= 19842Tk Per Unit Cost =19842/1007.8=19.68Tk

Total Diesel Use in Sep Month= 285.6 Liter, Running hours=285.6 /9=31.7 hours Energy Produce=31.7*32=1015.8 KWh, Per liter 70 Tk , So Liter=285.6 *70=19991 Tk Per Unit Cost =19991 /1015.8=19.68 Tk

Total Diesel Use in Oct Month= 475.3 Liter, Running hours=475.3 /9=52.8 hours Energy Produce=52.8 *32=1690.1 KWh, Per liter 70 Tk , So Liter=475.3*70=33274 Tk Per Unit Cost =33274 /1690.1 =19.68 Tk

Total Diesel Use in Nov Month= 193.6 Liter, Running hours=193.6 /9=21.5 hours Energy Produce=21.5 *32=688.5 KWh, Per liter 70 Tk , So Liter=193.6*70=13555 Tk Per Unit Cost =13555 /688.5 =19.68 Tk

Total Diesel Use in Dec Month= 28.8 Liter, Running hours=28.8 /9=3.2 hours Energy Produce=3.2 *32=102.4 KWh, Per liter 70 Tk , So Liter=28.8*70=2016 Tk Per Unit Cost =2016 /102.4 =19.68 Tk

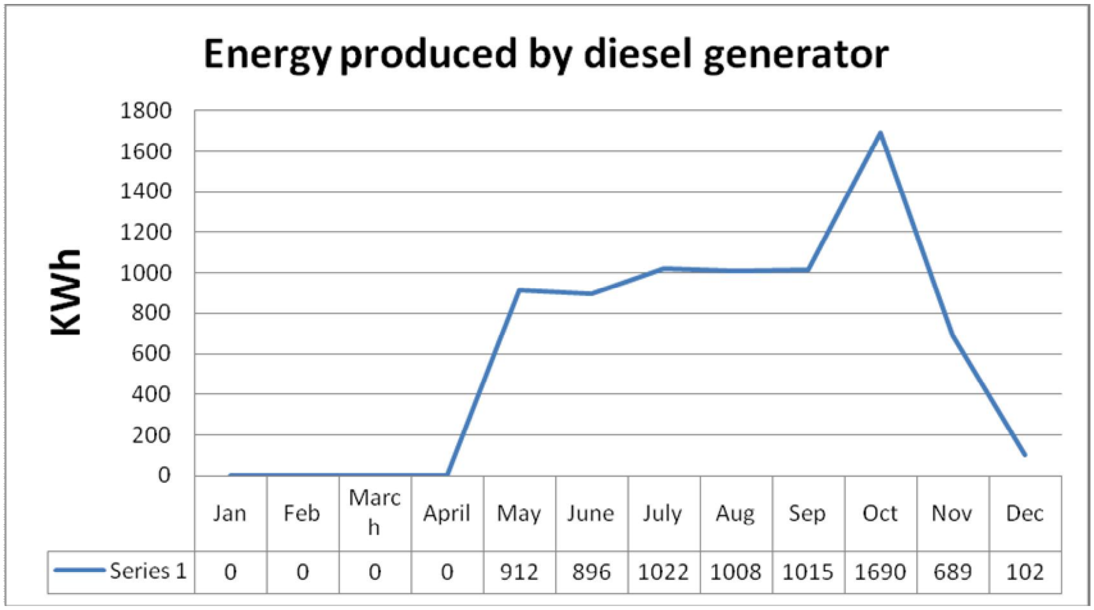


Fig 7.3 :Energy produced by diesel generator

Table 7.9 fuel cost

Month	May	June	July	Aug	sep	Oct	Nov	Dec
Use fuel in liter	256.5	252	287.6	283.5	285.6	475.3	193.6	28.8
Energy produce in KWh	912	896	1022.5	1007.8	1015.4	1690.1	688.5	102.4
Fuel cost ,TK/KWh	19.68	19.68	19.66	19.68	19.68	19.68	19.68	19.68
Fixed cost	144403							

7.8.2 Plant factor calculation 2013 and 2024

2013:

Jan= 9732.48 KWh, Feb =8946.25KWh, Mar= 12121.22KWh , Apr= 12957.19 KWh , May= 9894.19 KWh, Jun=12085.69 KWh July= 12895.55 KWh, Aug= 11070.25KWh, Sep=11453.08KWh, Oct=10003.44KWh,Nov=8835.58KWh, Dec=9350.96KWh

2014:

Jan =8521.38 KWh, Feb= 7581.65KWh

Plant factor for 2013:

So, Plant factor for month of Jan=(total KWh/100*total month of day*24)*100
=(9732.48 /100*31*24)*100
=13.08%

Plant factor for month of Feb=(total KWh/100*total month of day*24)*100
=(8946.25/100*28*24)*100
=13.31%

Plant factor for month of March =(total KWh/100*total month of day*24)*100
=(12121.22/100*31*24)*100
=16.29%

Plant factor for month of Apr=(total KWh/100*total month of day*24)*100
=(12957.19 /100*30*24)*100
=18.00%

Plant factor for month of May =(total KWh/100*total month of day*24)*100
=(9894.19/100*31*24)*100
=13.29%

Plant factor for month of Jun=(total KWh/100*total month of day*24)*100
=(12085.69 /100*30*24)*100
=16.78%

Plant factor for month of July =(total KWh/100*total month of day*24)*100
=(12895.55 /100*31*24)*100
=17.33%

Plant factor for month of Aug =(total KWh/100*total month of day*24)*100
=(11070.25/100*31*24)*100
=14.87%

Plant factor for month of Sep=(total KWh/100*total month of day*24)*100
=(11453.08 /100*30*24)*100
=15.90%

Plant factor for month of Oct =(total KWh/100*total month of day*24)*100
=(10003.44/100*31*24)*100
=13.44%

Plant factor for month of Nov=(total KWh/100*total month of day*24)*100
=(8835.58/100*30*24)*100

=12.27%

Plant factor for month of Dec =(total KWh/100*total month of day*24)*100
=(9350.96/100*31*24)*100
=12.56%

Plant factor for 2014:

So, Plant factor for month of Jan=(total KWh/100*total month of day*24)*100
=(8521.38 /100*31*24)*100
=11.45%

Plant factor for month of Feb=(total KWh/100*total month of day*24)*100
=(7581.65/100*28*24)*100
=11.28%

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
PF% (2013)	13.08	13.31	13.29	18	13.29	16.78	17.33	14.87	15.9	13.44	12.27	12.56
PF% (2014)	11.45	11.28										

7.8.3 Per unit Sandwip solar plant calculation:

100 KW Solar Plant in Sandwip
Total Cost = 57710000 TK
Total Generation =100KW*365D*25yr*5.5h*0.8
=4015000 KWh,

Per unit Generation cost =57710000/4015000
= 14.37TK

Plant Capacity =Solar +diesel (back up)
=100KW+40KW
=140KW
Max Demand =0.1
Average Load =Max Demand*Plant Capacity
=0.1*140 =14KW

Energy produce Per Year
=14*8760
=122640 KWh

Total project Cost =5771000 TK

Interest and Depreciation

=6.7%

=6.7/100*57710000

=3866570

Tk Energy cost per KWh =3866570/122640

=31.53 Tk

7.9 Generation curve

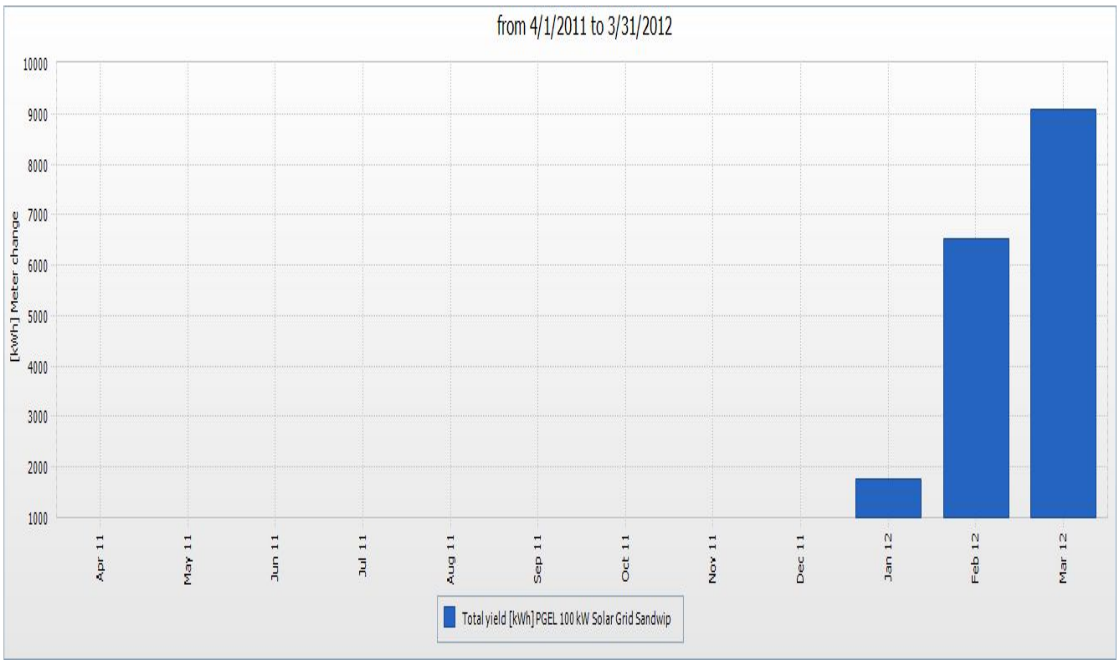


Fig 7.2: 2012 Monthly energy yield (kWh) with curve

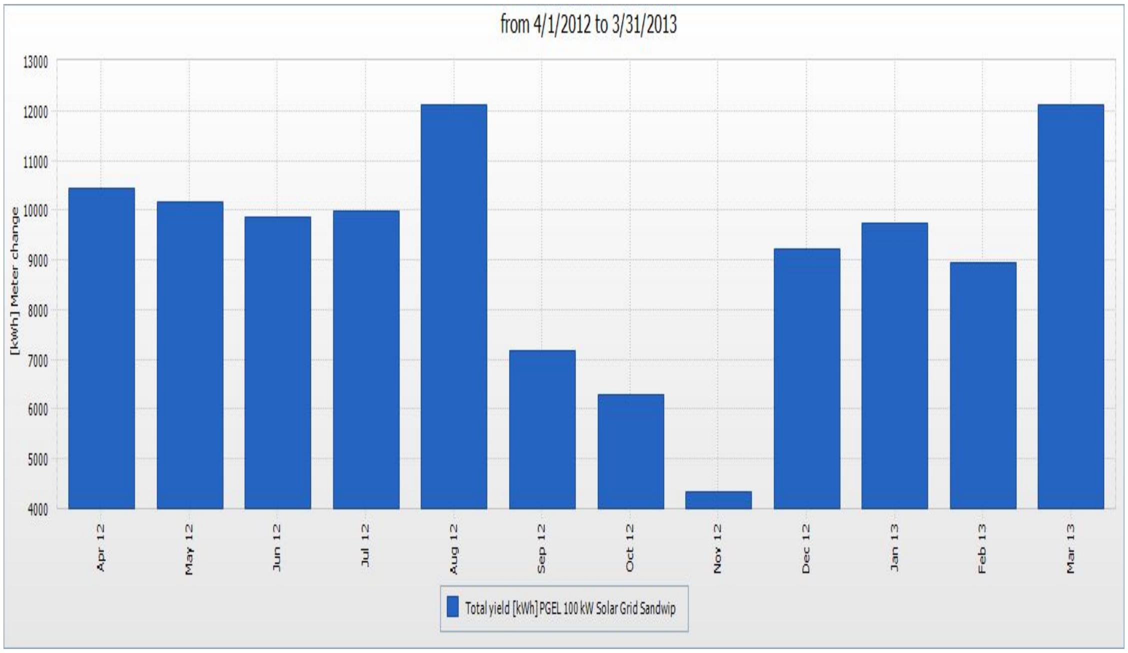


Fig 7.2 : 2012 -13 Monthly energy yield (kWh) with curve

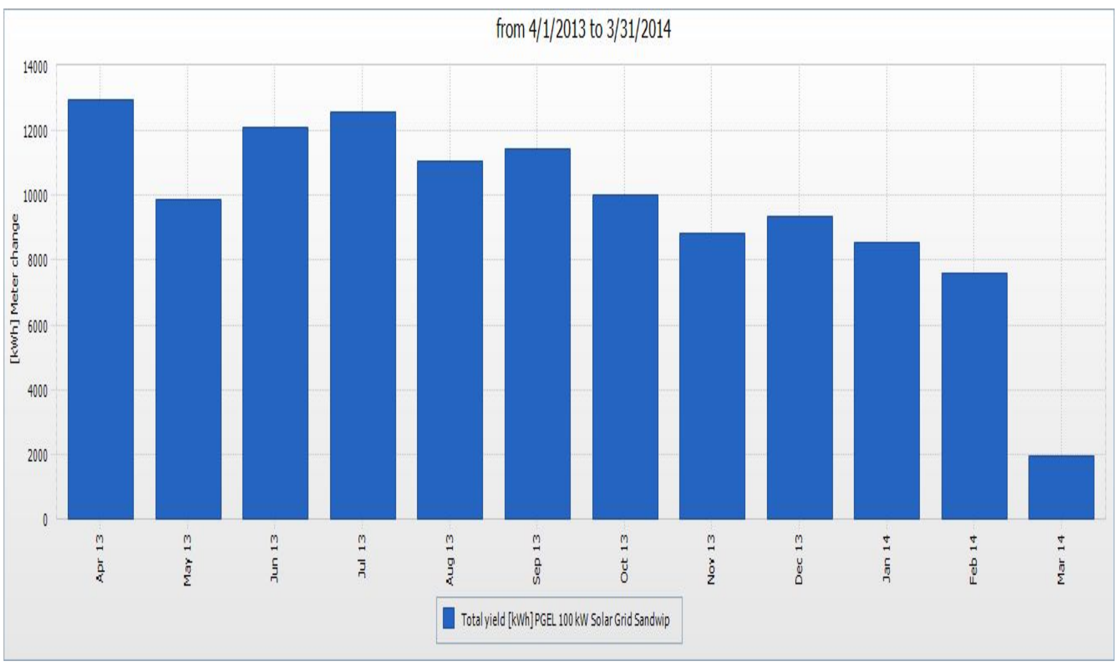
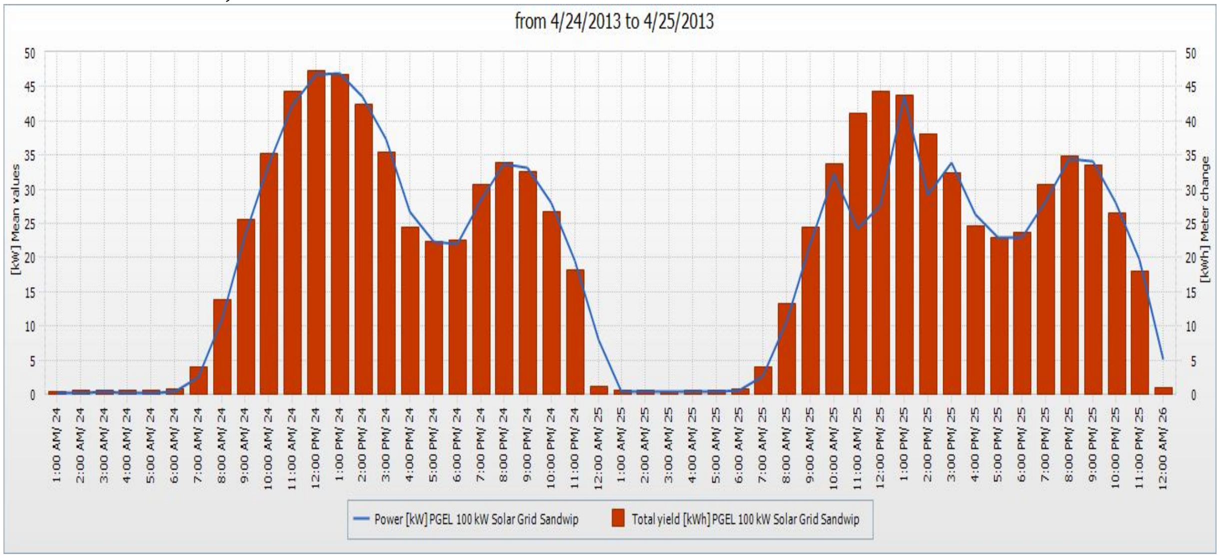


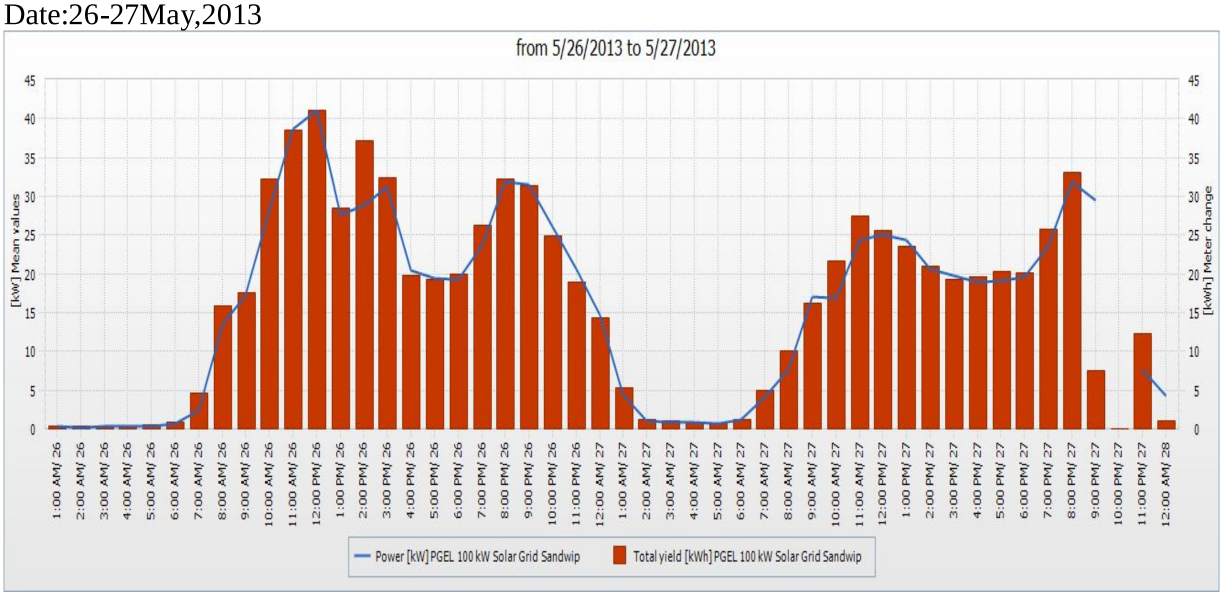
Fig 7.3 :2013-14 Monthly energy yield (kWh) with curve

Hourly generation curve in summer season:

Date: 24-25March,2013

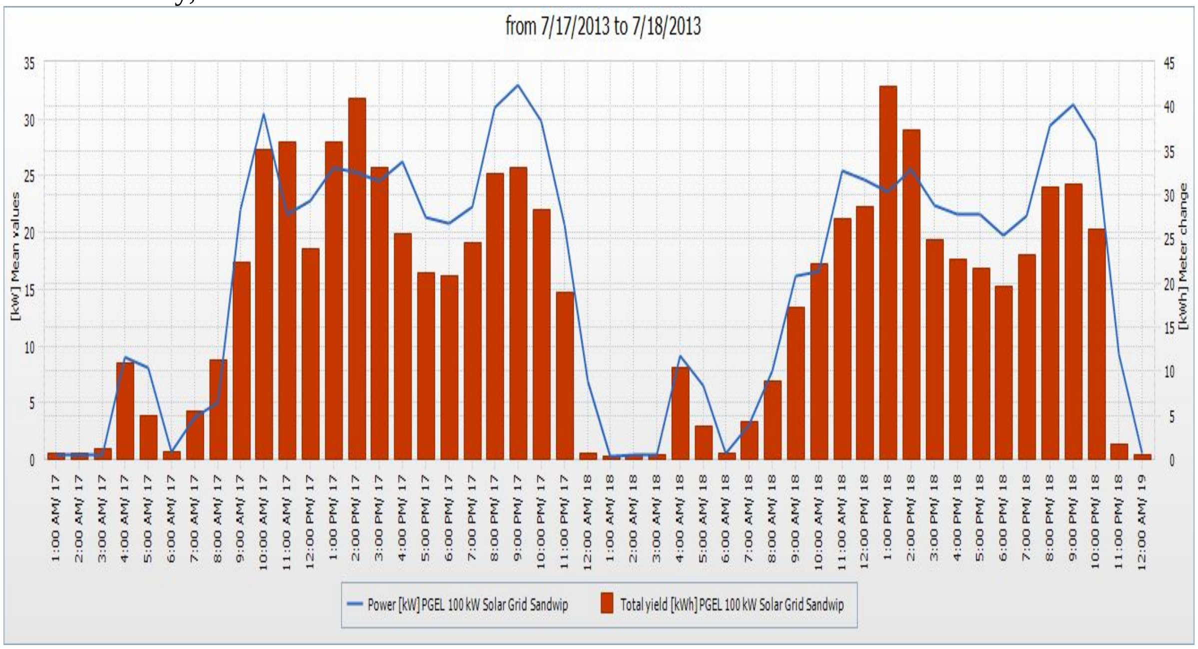


Date:26-27May,2013

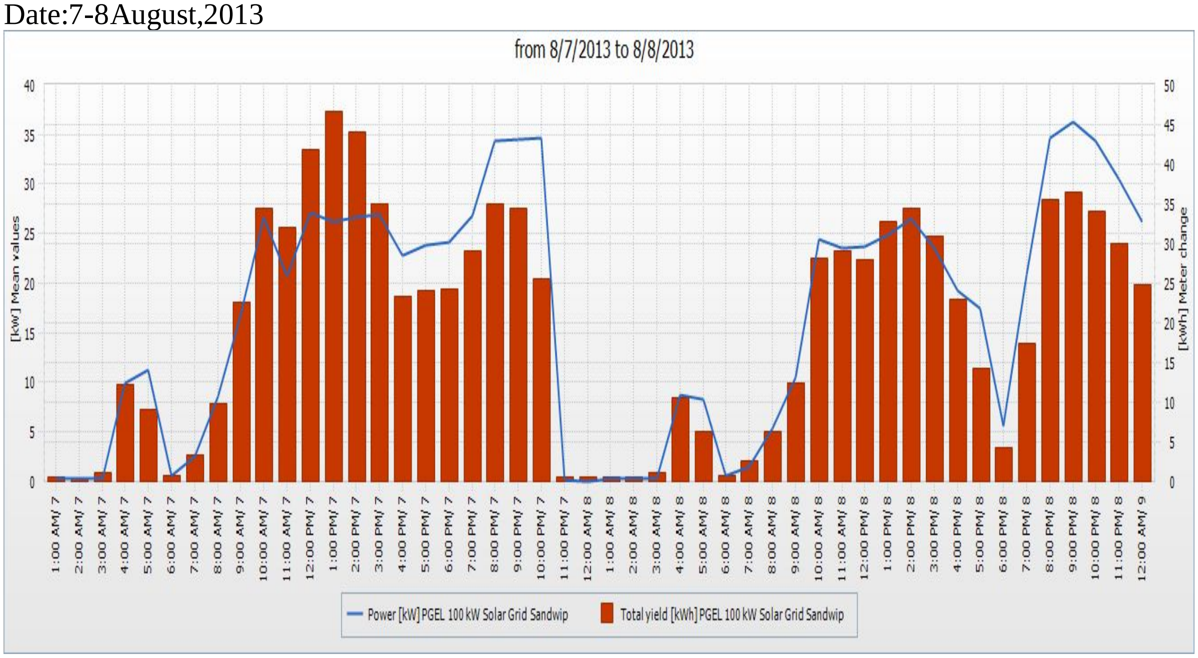


Hourly generation curve in rainy season:

Date:17-18July,2013

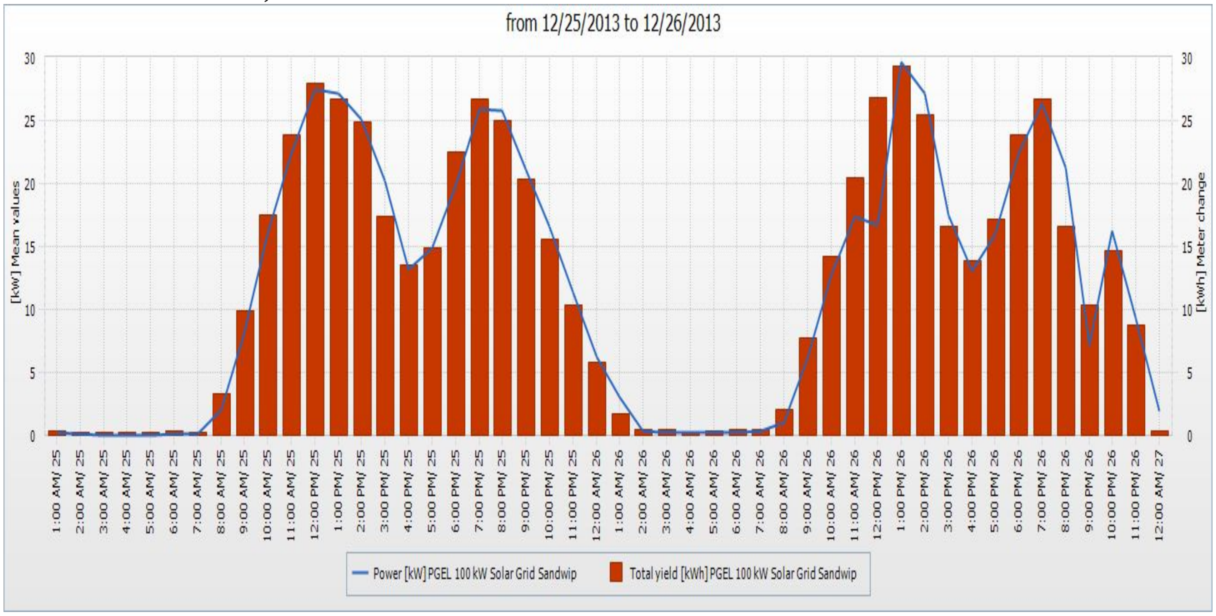


Date:7-8August,2013

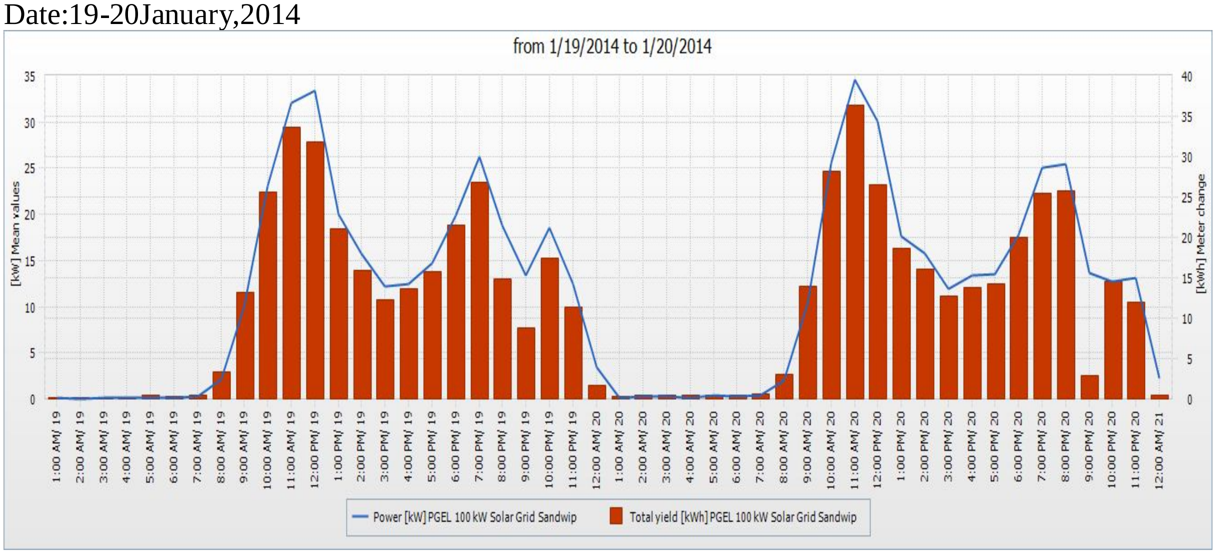


Hourly generation curve in rainy season:

Date:25-26December,2013



Date:19-20January,2014



7.9 Discussion

Environmental friendly Solar Energy will become the most important and cost-efficient energy source, if we are able to-

- Formulate a suitable & sustainable policy to sale surplus renewable energy to govt./ grid.
- Converted our lights from conventional to low consumption LED lamps.
- Capacity build-up among the Technicians who are able to Calculate, design, install, repair and maintain the solar system.
- Govt. subsidy or long term low interest loan for solar system installation.

- Stable grid line & calculate actual shortage of power that we can generate from solar

On September 29, 2010 the power plant came into operation and the first consumer is a local cooperative bank followed by the local police station, hotels and commercial shops. High quality and reliable grid power supply is being used for computers, lights, fans and other appliances instead of polluting Diesel generators. The most interesting part of this solar power plant is that 60 percent of the total 100 kW can be directly fed into the three phase line through grid tied inverters during daytime. This will serve local offices, schools and households and other user during daytime. Excess energy from this power supply will go to the battery bank. In addition, remaining 40 percent of the energy will be stored in high quality battery bank for the night, when the market is in peak demand Barriers for Sustainability of Alternative Energy Technologies:

- High initial cost
- Dependence on the weather
- lack of awareness
- Lack of established high-volume supplier-dealer chains.
- High prices of the components.

CHAPTER EIGHT
Conclusion and Future Work

Conclusion

The summary of this paper exhibits that, there is a considerable opportunity of Bangladesh to meet its future power demand and thus economic growth through renewable resources. Solar energy sources discussed above can help Bangladesh to produce more power in order to reduce Load-shedding problem. Time has come to look forward and work with these renewable energy fields to produce electricity rather than depending wholly on conventional method. Already SHS (Solar home system) established in our country. This paper showed the tariff difference between present formula and PVIFA formula. Which is 2.12 tk/KWh for 40Wp and 4.06tk/KWh for 85Wp. Here author also try to prove solar PV most cheaply then diesel generator. Authors also include this paper Sandwip solar power plant which is established by a private organization. They sell their electricity to the rural consumer where grid connection will not extend within 30 years. And they give electricity to the consumer cheaply compeer then diesel generator electricity distributor. Solar PV based power plant can be a big solution to fill our lacking on power sector. So government and privet sector should focus this point. It also reduces the solar PV electricity unit cost compare then SHS. Here also consumer can be use conventional ac load. This paper will help solving current power crisis and at the same time will have a positive impact over social and economic status of rural society using green energy technology. If we go ahead as planned, it will be possible for all citizens to have access to power within 2021. In addition, a six year plan up to 2016 has been adopted to improve power scarcity and provide excess power for future. Vision of increasing economic growth to 8 percent by 2014 and 10 percent by 2017 through industrialization will be a reality with the implementation of this plan. Other countries with similar socio-economic status can utilize the same policy to develop their electricity sector. With the help of these resources Bangladesh can generate electricity & may be able to meet the required demand in the future. Therefore, the Government and the Private sector should work hand to hand to emphasize more on renewable energy sources to produce electricity to solve our power crisis problem.

Future work

This paper we try to clarify that how rapidly we need to rely to produce electricity by our natural renewable resources and reveal our present situation and position on solar energy sector with respect to other world. We also try to light discussion about SHS (solar home system) situation in our country and Sandwip off grid solar power plant. Our theses paper is finished in here but still now some path also have where research will be continue. Some of those are briefly discuss in below.

In Bangladesh still about 38% area away from grid connection .they are gradually dependent on SHS .SHS become no of the fasted growing renewable energy program in the world. But still many problems have in this sector.

*) Highly Price is the main problem in this sector. So should find way how it will become acceptable in price for our rural people.
*) Another question is its low efficiency, should to need more research to improve their efficiency.
*) About 30 areas have in Bangladesh, where grid will be not extended within 30 years. To establish solar PV base power plant in those area will need some survey, like their yearly irradiation, total load demand, placement area of power plant, capacity of power plant.
*) At present some off grid solar power plant are transmitted and distributed by single phase. Some advantage and disadvantage show this scheme. So need some research to know how much it appropriate for our rural off grid solar power plant.
*) Government want national grid will feed 135MW electricity by solar energy. So need research for find suitable places where it will be establish and determine its capacity for feed grid.
*) Grid connected solar park per unit prices is much higher expensive than other. So we need to research how should we be reducing this price.
*) Concentrated solar power plant is also possible to establish in our country. Need widely research in this topic.

REFERENCE

References

[1]http://wiki.answers.com/q/do_nuclear_power_plants_cause_any_type_of_pollution
[2] Environmental protection agency
[3] http://en.wikipedia.org/wiki/world_energy_resources_and_consumption
[4] http://www.energybangla.com
[5] http://en.wikipedia.org/wiki/world_energy_resources_and_consumption
[6] http://en.wikipedia.org/wiki/solar_energy]
[7] http://en.wikipedia.org/wiki/solar_power_by_country
[8] http://www.solarika.org/blog/-/blogs/top10-solar-pv-countries-world-overview
[9]http://www.powercell.gov.bd/
[10] Cyber journals: multidisciplinary journals in science and technology, journal of selected areas in renewable and sustainable energy (jrse), June edition, 2012
[11] International journal of renewable energy research S.M. Najmul Hoque et al., vol.3, no.2, 2013
[12] Sadeque, Zubair km. implementation status & results: Bangladesh- rural electrification and renewable energy development (p071794), sequence 22 (English), the World Bank (page- 2), June 2012.
[13] IDCOL solar home system program in Bangladesh. Nazmul Haque director & head of investment infrastructure development company limited (IDCOL), Bangladesh.
[14] Progress scenario of solar home systems (shss) in Bangladesh
p. k. halder1*, n. paul2, t. ghosh2, imran khan1 and p. mondal3.
[15] gs solar home system program, grameen shakti, bangladesh. www.gshakti.org, 2012. accesssed on 26th may 2012.
[16]http://www.powerdivision.gov.bd/user/brec/50/91
[17] http://www.science today.com
[18] [22] Md. m. hasan and md. f. khan, "a comparative study on installation of solar pv system for grid and non grid rural areas of Bangladesh," international conference on the developments in renewable energy technology, january2012, Dhaka, Bangladesh.
[19] m. Eusuf, prospect and problem of solar energy in Bangladesh: implementation stage of solar system, Bangladesh center for advance studies, Dhanmondi, Dhaka1209, Bangladesh 1997.
[20]http://www.gshakti.org/index.php?option=com_content&view=article&id=58&itemid=62
[21] a. keyhani, "energy and civilization," in *design of smart power grid renewable energy systems*, new jersey: john wiley and sons, 2011, pp. 1-12
[22] http://en.wikipedia.org/wiki/sandwip.
[23] http://www.bpdb.gov.bd
[24] Secondary, documents provided by grameen shakti
[25] **source:** secondary, mondal (2005)
[26] Bangladesh's solar energy by gordon feller, urban age institute, january 18
[27] Khan et al. (2005), p. 98
[28] Power failure; weekly publications of daily star, april 17,2009

[29] www.reein .org.mht [30] our solar solution?; weekly publications of daily star, may 15,2009. [31] www.psldhaka.net [32] sma solar technology