

# **DESIGN AND SIMULATION OF A SOLAR PV SYSTEM FOR BRAC UNIVERSITY**

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# Table of Contents

<b>Declaration.....</b>	<b>5</b>
<b>Acknowledgement .....</b>	<b>6</b>
<b>1.0 Objective.....</b>	<b>7</b>
<b>2.0 Overview.....</b>	<b>7</b>
<b>2.1 Why use solar power.....</b>	<b>7</b>
<b>2.2 Works on Solar Technologies Around the World.....</b>	<b>8</b>
<b>2.3 Potential of solar energy .....</b>	<b>10</b>
<b>2.4 Solar Panel.....</b>	<b>10</b>
<b>2.5 Types of Solar System Design .....</b>	<b>11</b>
<b>3.0 Solar PV Technologies .....</b>	<b>11</b>
<b>4.0 Components of Solar PV System .....</b>	<b>12</b>
<b>4.1 Charge Controller .....</b>	<b>12</b>
<b>4.2 Battery .....</b>	<b>12</b>
<b>4.3 Inverter .....</b>	<b>13</b>
<b>5.0 Load Survey of BRAC University .....</b>	<b>13</b>
<b>5.1 BRAC University’s electrical Energy Consumption .....</b>	<b>13</b>

5.1.1 BRAC University's Monthly Electricity Consumption ...	13
5.2 Site Survey.....	16
5.2.1 Dimensional Measurement of BRAC University .....	16
5.2.2 Irradiance and Insolation .....	21
6.0 BRAC University Solar PV System Design .....	22
6.1 System Configuration .....	22
6.2 PV Module Selection .....	24
6.3 Inverter Selection .....	25
6.4 Combiner Box Selection .....	26
6.5 Mounting .....	27
6.6 System Sizing .....	29
6.6.1 Number of Module Selection .....	29
6.6.2 PV Array Designing .....	30
6.6.3 Number of Inverter Calculation .....	31
6.6.4 Number of Combiner Box .....	31
6.6.5 Wiring .....	31
6.6.6 Proposed Mounting for BRAC university... ..	32
6.6.7 Energy Supplied By the Proposed PV Solar System.....	32
7.0 Design Simulation .....	33
7.1 Simulation Results. ....	36

7.2 System Capacity .....	41
7.3 Comparison of Results .....	42
8.0 Cost Calculation .....	42
9.0 Per Unit Energy Cost.. .....	43
10. Conclusion .....	44
11. Further Works .....	44

## **DECLARATION**

We hereby declare that the thesis titled “**DESIGN and Simulation of a Solar PV System for BRAC University**” submitted to the Department of Electrical and Electronics, Dhaka , in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering, is our original work and was not submitted elsewhere for the award of any other Degree or Diploma or any other Publication.

Dhaka, Date: 8th December 2010

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## Acknowledgement

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## 1.0 Objective

The objective of our work is to design a grid connected solar PV system for the BRAC University campus.

## 2.0 Overview

### 2.1 Why use solar power

The main sources of world's 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<sub>4</sub>, O<sub>3</sub>, but mainly CO<sub>2</sub>) 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.

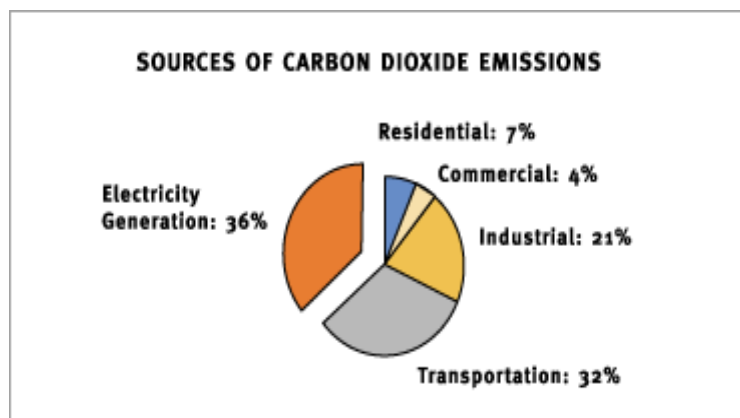


Figure1. Sources of carbon dioxide emissions [2]

Figure1 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 [ $1\text{YJ} = 10^{24}\text{J}$ ] 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, we can hope to find.

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.

Considering the above aspects, solar power option for the BRAC University campus is being studied in this work.

## **2.2 Works on solar technologies around the world**

There are huge works, research, thesis, implementation, design consideration and Improvement on solar technologies is going on around the world as well as in our country. That is why we have more than 35 [5] company doing business, implementation and research on solar technologies.

University students around the globe working with solar system. Like A group of students of Ahsanullah University of science and technology designed a solar system for their university .

A group of students of the Pennsylvania State University has designed and simulated a Distributed photovoltaic system for their university as their thesis. Again Rajamangala University ofTecnology Thanyaburi of Thailand installed pv system for their university to promote solar energy project.

Scientist working on developing the solar panels, like scientist of korea and California has develop a new way of boosting the efficiency of plastic solar panels [6]. By this they make it more competitive to traditional solar panels. Commercial buidings, houses, offices, companies are installing solar system for green energy. Such as the largest solar



powered building in Dezhou, Shangdong Province in northwest China [7].



Figure 2. The largest solar power building in northwest china

The above picture is the largest solar powered building and it will be the venue of the 4<sup>th</sup> world solar city congress.

We can also see 100% solar powered buildings. Like the stadium for the world game 2009 in Taiwan was 100% solar powered.



Figure 3: 100% solar powered stadium in Taiwan.

The fig 3 shows that the 100% solar powered building in Taiwan. It has 8,840 solar panels in the roof and can produce 1.14 million kWh/year. By this it can prevent 660 tons of carbon dioxide to release in the environment [8].

Many works like research, improvement etc on solar technologies is going on around the world and in our country as well. Solar energy is mainly site based with some key factors.

**Site and load based:** The solar power is site or location based. Solar power is designed and supplied from a particular location to a particular consumer/s. Such as- a house or apartment can use its rooftop, lawn, garden etc to implement their solar system to get the desired power. Beside a solar power plant is designed for a particular amount of load, such as-Sarnia Photovoltaic Power Plant of Canada can deliver 80 MW of power [9], Olmedilla Photovoltaic Park of Spain can deliver 60 MW of power [10].

## 2.3 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( $1\text{EJ}=10^{18}\text{ J}$ ) or approximately  $15\text{TW}(1.504*10^{13}\text{ W})$ . [11] Almost 80%-90% of this energy came from fossil fuel. [12]

From the sun earth receives 3,850,000 EJ of energy. [11] Which is equivalent to 174 petawatts ( $1\text{PW}=10^{15}\text{ W}$ ). 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 green house effect, other environmental impact, cost, risk and availability solar energy has the greatest potential among all the energy sources.

## 2.4 Solar panel

Solar panels produce electricity from sunlight. The first solar panel-powered satellite was launched in 1958 by Hoffman Electronics.

A solar panel consists of number of photovoltaic (PV) solar cells connected in series and parallel. These cells are made up of at least two layers of semiconductor material (usually pure silicon infused with boron and phosphorous). One layer has a positive charge; the other has a negative charge. When sunlight strikes the solar panel, photons from the light are absorbed by the semiconductor atoms, which then release electrons. The electrons, flowing from the negative layer (n-type) of semiconductor, flow to the positive layer (p-type), producing an electrical current. Since the electric current flows in one direction (like a battery), the electricity generated is DC.

## 2.5 Types of solar system design:

There can be various types of solar system design. But there are three basic design consideration, they are-

1. Grid tie
2. Off-grid
3. Stand alone

## 3.0 Solar PV technologies

With the growing demand of solar power new technologies are being introduced and existing technologies are developing. There are four types of solar PV cells:

- Single crystalline or mono crystalline
- Multi- or poly-crystalline
- Thin film
- Amorphous silicon

**Single-crystalline or mono crystalline:** It is widely available and the most efficient cells materials among all. They produce the most power per square foot of module. Each cell is cut from a single crystal. The wafers then further cut into the shape of rectangular cells to maximize the number of cells in the solar panel.

**Polycrystalline cells:** They are made from similar silicon material except that instead of being grown into a single crystal, they are melted and poured into a mold. This forms a square block that can be cut into square wafers with less waste of space or material than round single-crystal wafers.

**Thin film panels:** It is the newest technology introduced to solar cell technology. Copper indium diselenide, cadmium telluride, and gallium arsenide are all thin film materials. They are directly deposited on glass, stainless steel, or other compatible substrate materials. Some of them perform slightly better than crystalline modules under low light conditions. A thin film is very thin-a few micrometer or less.

**Amorphous Silicon:** Amorphous silicon is newest in the thin film technology. In this technology amorphous silicon vapor is deposited on a couple of micro meter thick amorphous films on stainless steel rolls. [13] Compared to the crystalline silicon, this technology uses only 1% of the material.

Table 1 below shows the efficiency of different types of solar cells.

Table1. Efficiency of different types of solar cells

Cell type	Efficiency, %
Mono crystalline	12 – 18
Polycrystalline	12 – 18
Thin film	8 – 10
Amorphous Silicon	6 – 8

## 4.0 Components of a solar PV system

A typical solar PV system consists of solar panel, charge controller, batteries, inverter and the load. Figure 2 shows the block diagram of such a system.

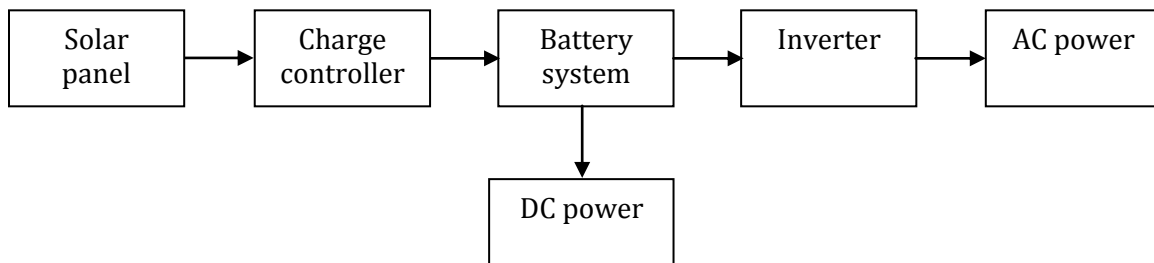


Figure 4. Block diagram of a typical solar PV system

### 4.1 Charge controller

When battery is included in a system, the necessity of charge controller comes forward. A charge controller controls the uncertain voltage build up. In a bright sunny day the solar cells produce more voltage that can lead to battery damage. A charge controller helps to maintain the balance in charging the battery. [14]

### 4.2 Batteries

To store charges batteries are used. There are many types of batteries available in the market. But all of them are not suitable for solar PV technologies. Mostly used batteries are nickel/cadmium batteries. There are some other types of high energy density batteries such as- sodium/sulphur, zinc/bromine flow batteries. But for the medium term batteries nickel/metal hydride battery has the best cycling performance. For the long term option iron/chromium redox and zinc/manganese batteries are best. Absorbed Glass Mat (AGM) batteries are also one of the best available options for solar PV use. [15]

### **4.3 Inverter**

Solar panel generates dc electricity but most of the household and industrial appliances need ac current. Inverter converts the dc current of panel or battery to the ac current. We can divide the inverter into two categories. [16] They are-

- Stand alone and
- Line-tied or utility-interactive

## **5.0 Load survey of BRAC University**

Finding out and understanding the total energy consumption of BRAC University is the first step through designing an Energy Program for BRAC University. In this part we observed the data of energy consumption figures and facts of BRAC University. We collected the peak and off peak data. We analyzed the monthly load from October 2009 to September 2010.

### **5.1 BRAC University electrical energy consumption**

Annual electrical energy consumption of BRAC University is 28,62,880 kWh. The total off peak energy consumption is 22,80,400 kWh and the peak energy consumption is 5,82,480 kWh. Average energy monthly consumption including off peak and peak is 2,38,573 kWh. [17]

#### **5.1.1 BRAC University monthly energy consumption**

By using the data of monthly electricity bill of BRAC University we can determine the monthly, yearly and average energy consumption by BRAC University. Beside we can show the peak and off-peak energy consumption.

Peak-hour: peak hour is from 6pm to 11pm

Off-peak hour: off-peak hour is from 12am to 5pm

The data of monthly, monthly average and peak off-peak energy consumption BRAC University is given bellow in table no 2

Table 2. Monthly electricity bill, BRAC University

Month	Off peak consumption (kWh)	Peak consumption (kWh)
October,2009	200000	90 000
November,2009	191520	82080
December,2009	118560	60800
January,2010	148960	42560
February,2010	152000	30400
March,2010	191520	39520
April,2010	182400	39520
May,2010	207760	42560
June,2010	234080	39520
July,2010	212800	36480
August,2010	218880	39520
September,2010	221920	39520
Average	190033.33	48540

The energy consumption by BRAC University is given by the bellow bar chart

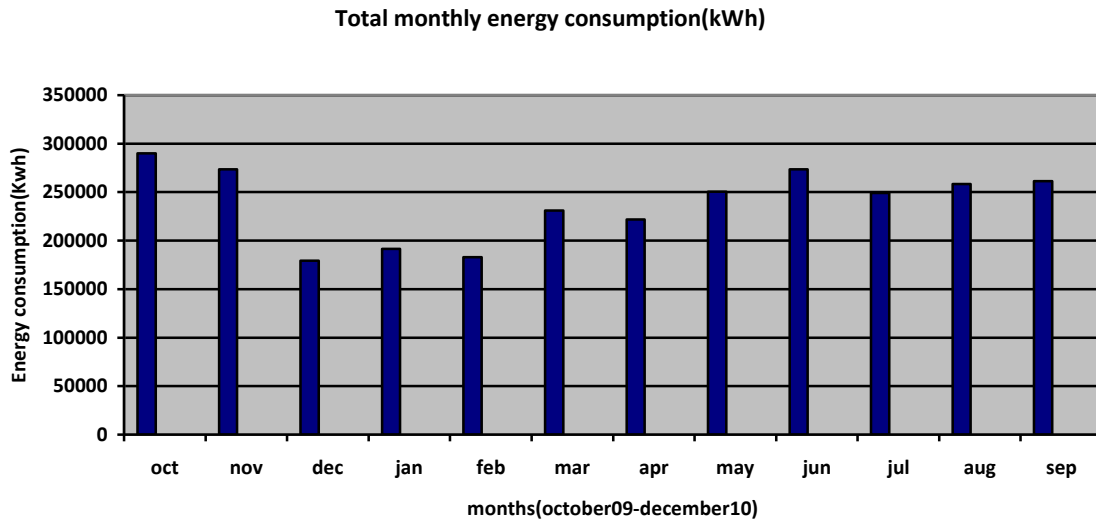


Figure 5. Monthly energy consumption from October 2009 to September 2010

From the above fig 5 we can see the variation of monthly energy consumption of BRAC University. From the above figure we can see that the highest energy consumption in October 2009 and the lowest in December 2009.

The chart of peak and off-peak consumption is given below:

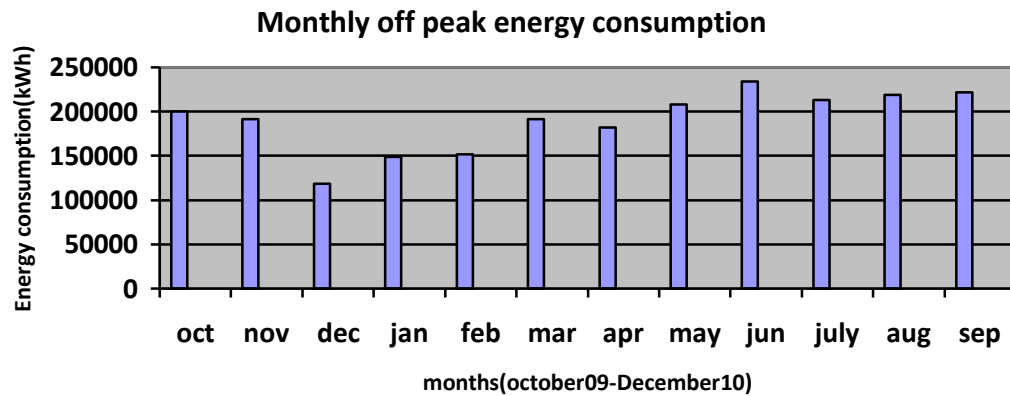


Figure 6. Monthly off-peak consumption of BRAC university

From the figure 6 we can see that the month of June has the most off –peak energy consumption

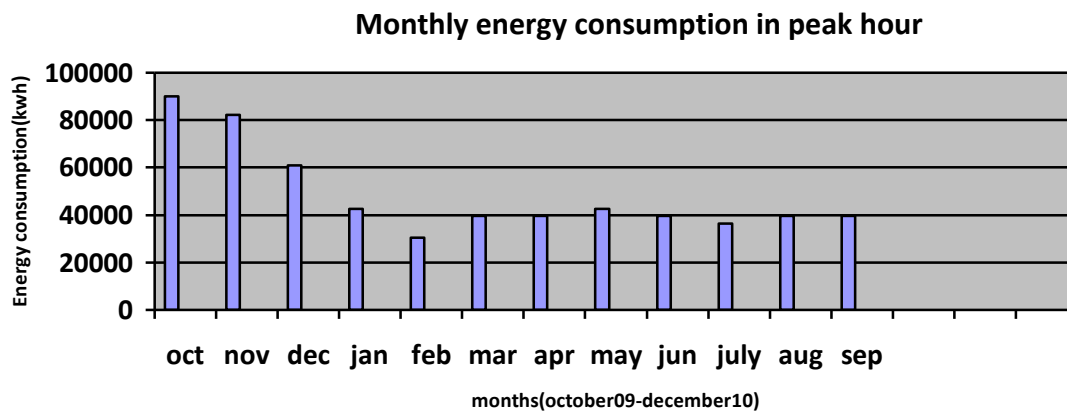


Figure 7. Monthly peak energy consumption of BRAC University

From the figure 7 we can see that the month of October has the most energy consumption.



## 5.2 Site survey

### 5.2.1 Dimensional measurement of BRAC University building

BRAC University [BRACU] is situated at Mohakhali in Dhaka city. It is a 20 storied building with a roof area of 5500 sq-feet. The height of this building is approximately 226 feet. The latitude and longitude of BRAC university building is  $23.78^{\circ}$  and  $90.41^{\circ}$  respectively. [18] The building is north facing and makes an angle of 20 degrees with the North. Figure 4 shows the roof top and 3D rendering of the BRAC University building.

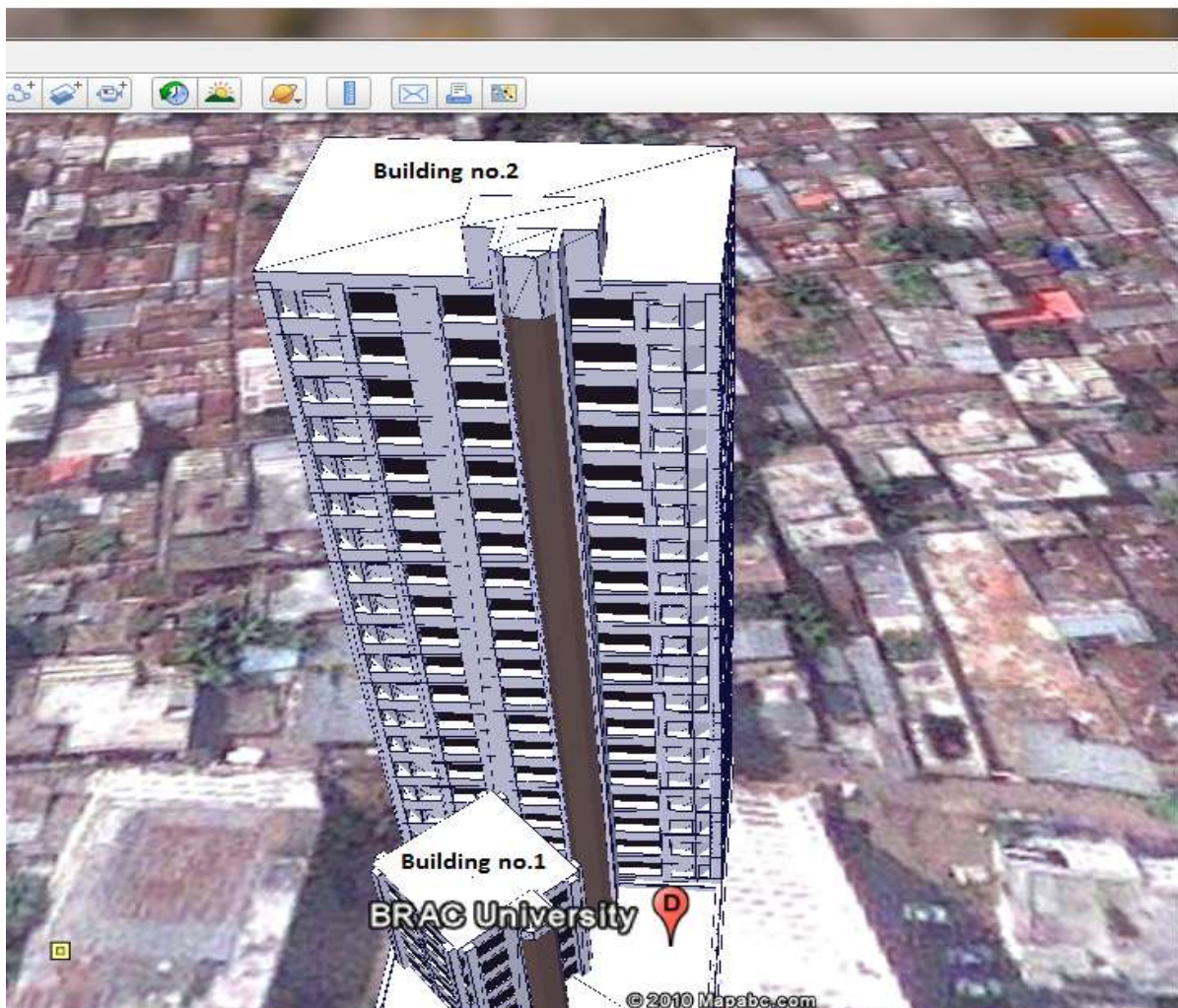


Figure 8. Front look of BRAC University showing building1 and building 2



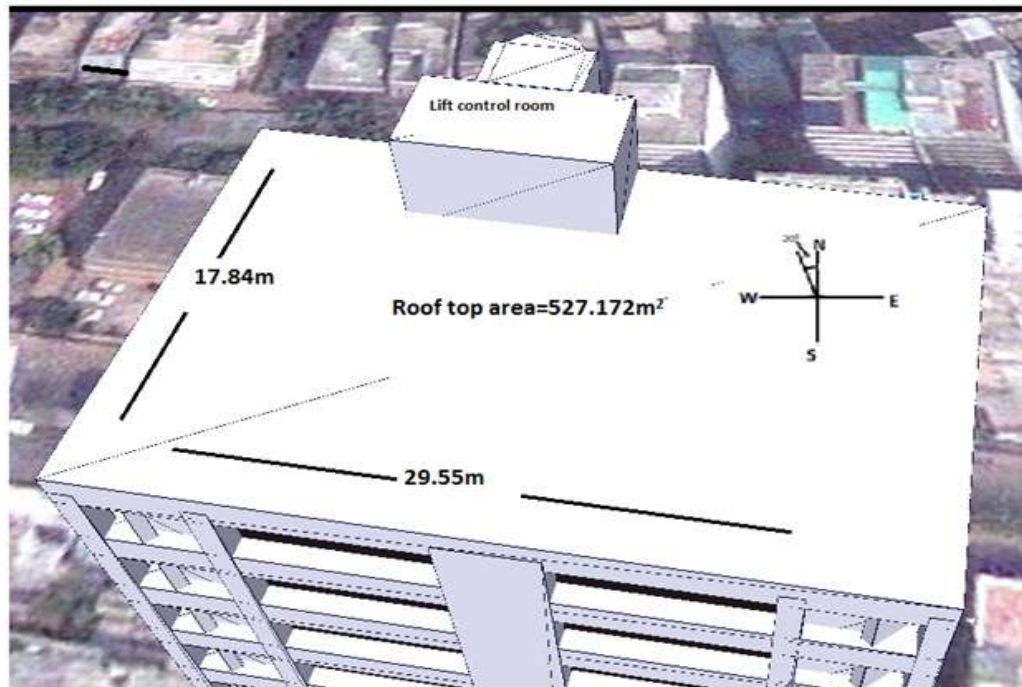


Figure 9. Showing the orientation ( $20^{\circ}$  N ) and total roof top area (from satellite over view



Figure 10. Actual view of the roof top of BRAC University

Figure 8 we see building 1(University Building) and building 2(Aarong House) of BRAC University. In our site Survey we have seen that building 1 is not suitable for installing solar panel. Because it is a 5 storied building and building 2 which is a 20 storied building standing behind this. So the shadow of building 2 is covering the whole roof of building 1 all day long. Considering this facts we selected building 2 to use to implement the solar panels.

Figure 9 is showing the 3-D picture of the roof top of building 2 taking from satellite.[18]. The figure is showing the building orientation which is  $20^{\circ}$  with north. The length of the roof top is 29.55m and the width is 17.84m. So the total area is  $527.127 \text{ m}^2$ . We considered 20% of this area for lift control room and towers etc. So, finally excluding those 20% area we get  $421.70 \text{ m}^2$ .

Figure 10 is showing the actual view of BRAC University roof top. The area of the actual roof top is  $510.96 \text{ m}^2$ . Now there is 3 lift Control room in the roof, some towers are covering the whole roof. The lift control rooms, one of them is in the left side ,one in the right side and another is in the middle of the roof. So, it is not possible to implement solar panel on this roof. To solve this situation we thought to go for mounting. Excluding the 20% of total area, actually we have  $408 \text{ m}^2$  to use for installation of solar panel.

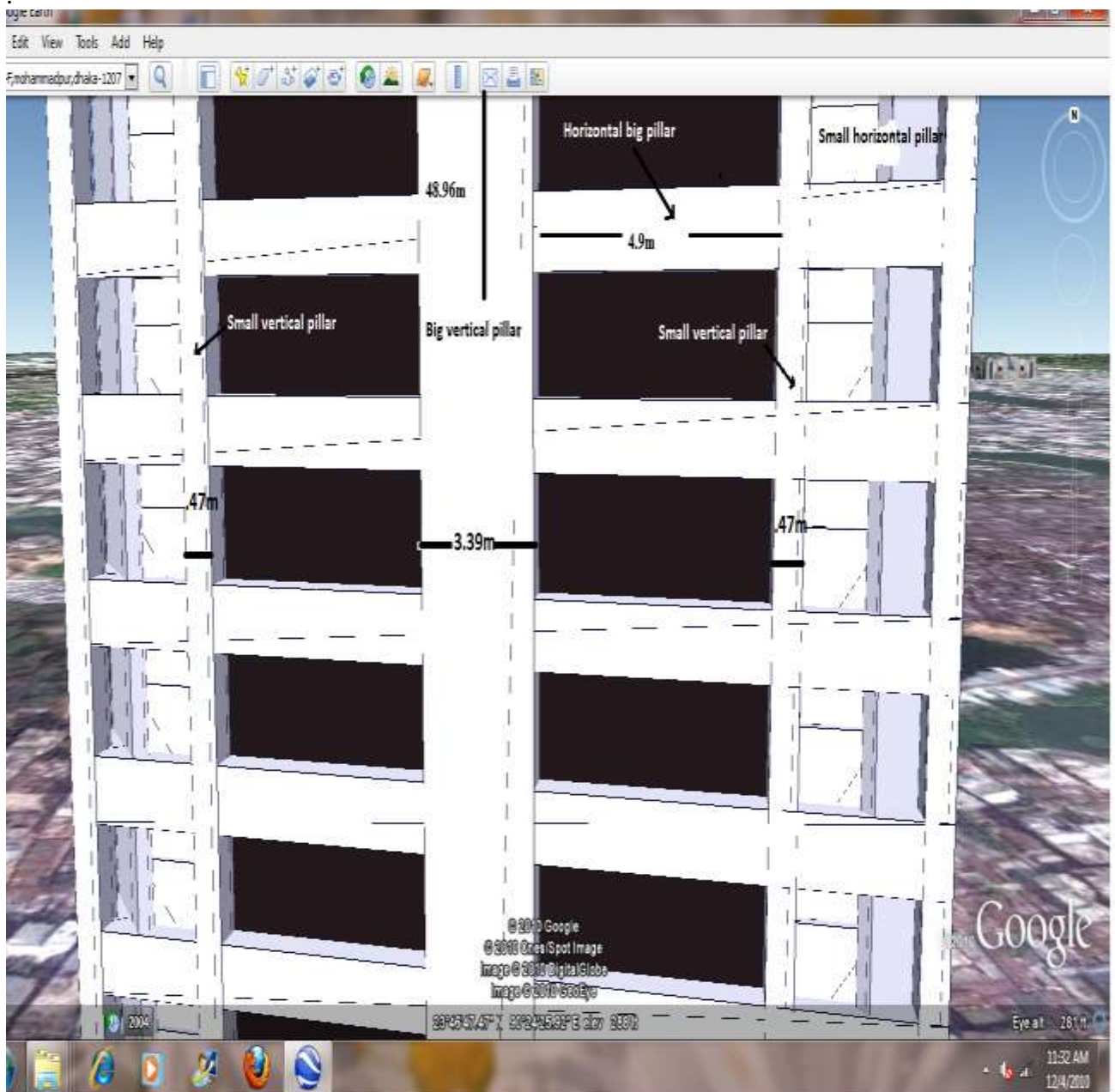


Figure 11. The Southern (back side) side showing 3D picture of the horizontal and vertical pillar from satellite

Fig. 11. is showing the 3-D picture of the building 2. Here indicating the horizontal and vertical pillars. From this calculation we see one big vertical pillar, 4 small vertical pillars. There are 28 horizontal pillars also. The length of big pillar is 48.96 m. (from 6 story to 20 story) and the width is 3.39m. The width of small vertical pillar is .47m and length is 48.96m. Horizontal pillar's length is 4.9m and width is .86 m. So, the total area we are getting is  $376.012\text{m}^2$ .



Figure 12. Photograph of the back side of the building (south face) showing the horizontal and vertical pillars.

Figure 12. is showing the actual view of horizontal and vertical pillar. It is showing one big vertical pillar and six small vertical pillars. But we are taking four pillars under our consideration. Because other two pillars are not usable. There are 28 horizontal pillars between the big and small pillars. The actual length of the vertical pillar is 48.76m and the width is 3.165m. The length of small vertical pillar is 48.76m and width is .589m. The length of horizontal pillar is 4.648m and width is .85 m.

Now the total area of roof top and facade can be presented in a table:

Table 3. Theoretical and Practical measurement of usable area

Names of places	Area calculated by Google earth (m <sup>2</sup> )	Actual area(m <sup>2</sup> )
Big pillar	165.97	154.53
Small pillar	92.04	114.932
Horizontal pillar	117.96	110.622
Roof top	421.70	408
Total	797.67	788.5

So, the total usable area 788.5 sq. meters.

### 5.2.2 Irradiance and insolation

**Insolation:** Insolation is the amount of solar energy that strikes a given area over a specific time and varies with latitude or the seasons [19].

**Irradiation:** Irradiance means the amount of electromagnetic energy incident on the surface per unit time per unit area. so the total solar irradiation is defined as the amount of radiant energy emitted by the sun over all wavelengths that falls each second on  $1\text{m}^2$  ( $11\text{ft}^2$ ) outside earth's atmosphere [19]

Irradiance of a site is given by the following relation:

$$\text{Irradiance} = \frac{\text{Average Insolation}}{\text{Average daily bright sunshine hours}}, \text{ kWh / m}^2$$

It is very important to know the irradiation and insolation of a site when anyone is going to design a solar PV system for that site. Depending on the sun shine, irradiance and insolation varies with place to place.

The irradiance of the Dhaka city can be calculated from Tables 3 and 4.

Table 4. Monthly global solar insolation in Dhaka city

Month	Solar Insolation $\text{kWh/m}^2$
January	5.47
February	5.91
March	6.00
April	5.85
May	5.23
June	4.55
July	4.18
August	4.60
September	4.94
October	5.44
November	5.34
December	5.38
Average	5.24

Table 5. Daily average bright sunshine hours in Dhaka city

Month	Daily Mean	Minimum	Maximum
January	8.7	7.5	9.9
February	9.1	7.7	10.7
March	8.8	7.5	10.1
April	8.9	7.8	10.2
May	8.2	5.7	9.7
June	4.9	3.8	7.3
July	5.1	2.6	6.7
August	5.8	4.1	7.1
September	6.0	4.8	8.5
October	7.6	6.5	9.2
November	8.6	7.0	9.9
December	8.9	7.4	10.2
Average	7.55	6.03	9.13

The daily average bright sunshine hours in Dhaka city is 7.55 hours and the average solar insolation is  $5.24 \text{ kWh/ m}^2$

From formula, we get the irradiance of Dhaka city is  $694.04 \text{ watt/m}^2$ . This value will be used for BRACU solar PV system design.

## 6.0 BRAC University solar PV system design

### 6.1 System configurations

There are many possible configurations of solar PV system. Each of these configurations has its own advantages and disadvantages. Depending on the system requirements appropriate system configurations has to be chosen. In our work, at first we considered two possible configurations for BRACU campus. The first one is grid connected solar PV system without battery (Figure 13 (a)) and the second one is stand alone solar PV system with battery (Figure 13 (b)).

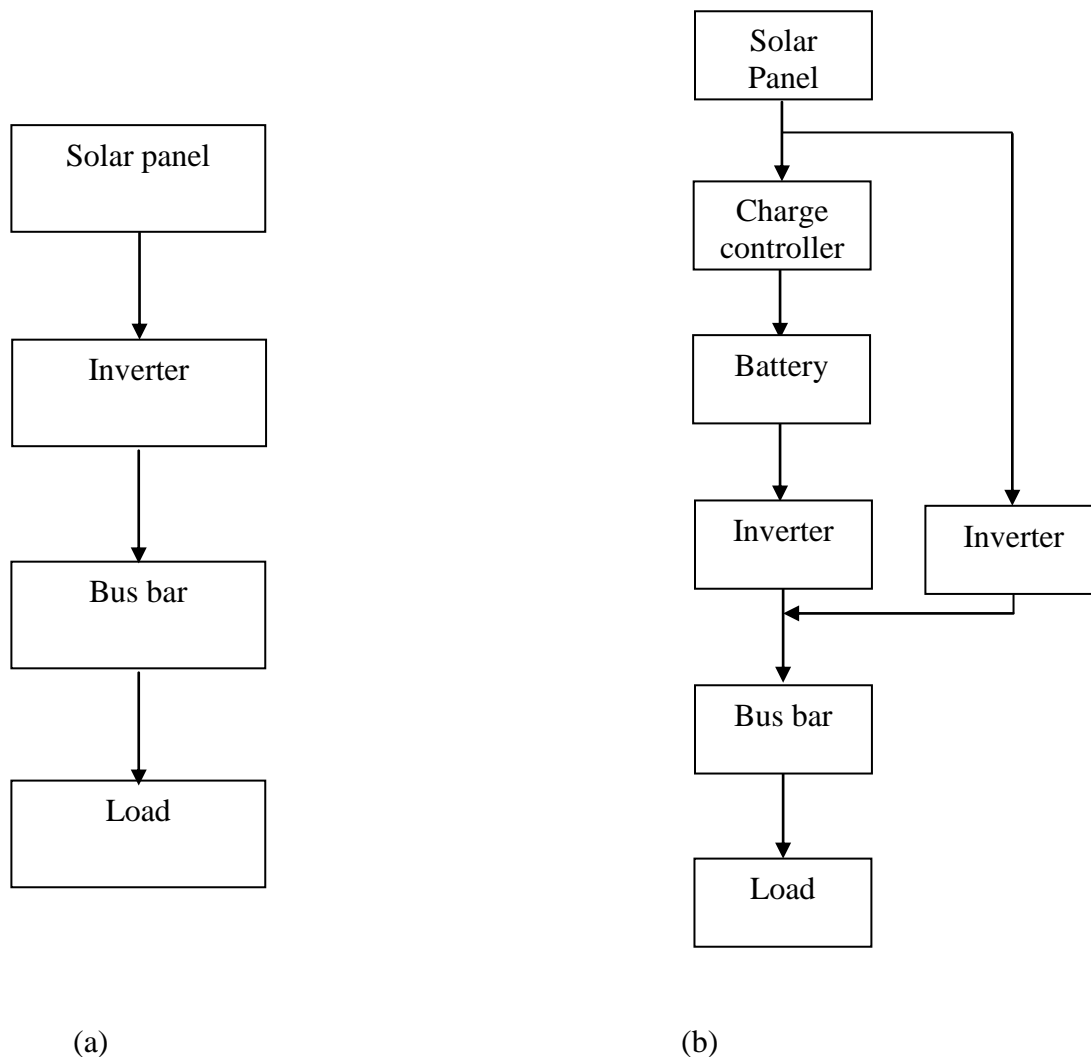


Figure 13. (a) and (b) possible configurations of solar PV system for BRAC University

**Figure (a):** The block diagram (a) shows the design configuration where the solar panels will be connected to inverters, then the from the inverter current will be supplied to the university's bus bar then to the load.

**Figure (b):** The block diagram (b) shows a design configuration that can both supply and store energy. When the demand is high the then the system will deliver energy same as the block diagram (a) as described. But when the demand is low or in a off day the battery can store energy by solar panel through charge controller. This stored energy can be used as backup for gloomy day or at night.

But we need huge amount of energy to run the University. Monthly average energy consumption of BRAC University is 238,573.33 kWh and we can theoretically produce 19335.607 kWh per month.

At  $694.04 \text{ W/m}^2$  insolation the selected PV module can produce = 173.51 W  
Daily average bright sunshine hour = 7.55  
Total no. of modules = 492

So, the monthly energy generation =  $173.51 * 7.55 * 492 * 30$   
= 19335.607 kwh/month

As this is a huge difference with the University's monthly energy consumption we can not store extra energy.

Therefore, we choose the block diagram (a) for our proposed system.

## 6.2 Selecting the PV module

As we need huge power supply and we do not have huge area. So, we selected mono crystalline silicon module. Our module selection depends on cost and efficiency.

The capital investment of solar PV panel is very high. Approximately, 60% of the total system installation cost is the price of module cost. We should consider the cost in order to get the best output of the money spent. Cost varies on efficiency of panel and the material has been used to make the PV panel. The cost of silicon solar cell is very high. In our design we used mono crystalline silicon cell.

Efficiency of solar cell depends on the technology used. Silicon solar cell has the highest efficiency. Thin film has low efficiency, but they can be ideal for some applications. Another important consideration is temperature. Module efficiency decreases as the module temperature increases. When modules operating on roof, it heats up substantially. Cell inner temperature reaches to 50-70 degree Celsius. In high temperature areas, it is better to choose a panel with low temperature co-efficient.

Considering the above factors, we have selected a module of Samsung brand.





Figure 14. Samsung LPC250S solar module

Fig. 14 shows the Samsung solar module and the model is LPC250S. Its maximum output power is 250 watt. If irradiance is 1000 watts per meter square then the module's nominal power output is 200 watt if irradiance is 800 watts per meter square. The irradiance of Dhaka City is 694.04 watts per meter square. So we will get power less than 200 watts, approximately 173.51 watts. 25 years power output warranty is 80%. The panel efficiency is 15.62%. Short circuit current of the panel is 8.66A at standard test condition and 6.90A at nominal condition. [20]

### 6.3 Inverter selection



Figure 15. ZONZEN ZZ-ZB 10kW grid tie inverter

We selected a PV grid tied inverter. The model is ZZ-ZB10kW. It is a product of ZONZEN of China [21].

- The MPPT voltage range: 100-150 V
- Output power: 10kW
- Connection: 50Hz grid frequency and 3 phase 4 wire connection
- The efficiency of this inverter: 97%.
- AC voltage: 230 Volt.

#### 6.4 Combiner box selection

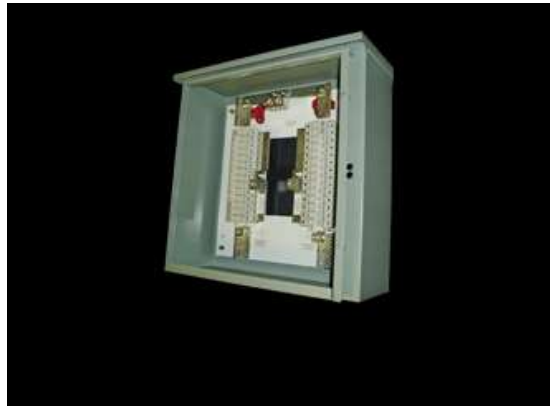


Figure 16. The SMA SCCB-10 combiner box

The model of selected combiner box is SMA SCCB-10 [22]

- The no of input circuit: 12
- Maximum input fuse rating: 20 A, 600V DC

- Maximum output current: 240 A DC

## **6.5 Mounting**

There are various types of mounting of solar panel can be done. Depending on the location and system several types of mounting is done. They are described bellow

### **Pole mounting**

There are 3 types of pole mounting [23]

1. Top of pole: In this type of mounting with a pole and metal rack the pv module is installed. The base of the pole is generally concrete
2. Side of pole: Generally small PV modules are placed be side of electricity or telephone pole
3. Tracking pole mounting: it is special type of mounting. This is done to maximize the output of the PV module by tracking with the sun path.

### **Ground mounting**

Solar modules can also be mounting in the ground. In case of more power needs or insufficient space at the roof PV panels can be mount in the ground.

### **Building Integrated Photovoltaic (BIPV)**

This is a unique kind of mounting system; the PV modules are placed on the building surface, vertical walls and also atriums. There are huge advantage of it [24], they are-

- Mounting can be done in such a way that blend with the architecture to make the building more beautiful
- It is unique and versatile
- Many benefits like shedding, protection, cooling etc.

### **Roof mounting**

Roof mounting is two type pitched roof mount and flat roof mount

#### **Pitched-roof mounting**

Roof mounting is difficult because depending in the orientation and angle, proper mounting has to done. Need to fix the tilt angle for the optimum output.

We can not hope all these categories a roof can match. That is why there are 3 types of roof mounting. They are-

**1. Flush mount:**



Figure17. Flush Mounting on roof

Those roof which faces south are best for this mounting. Any slope is suitable but a steeply slope is best. Fig17 shows a flush mount PV system.

**2. Angle mount:**



Figure18. Angle Mounting on roof

For the roof which has lower pitch-this system is best suited. Fig18 shows a angle mount pv system.

**3. Fin Mount:**



Figure19. Fin mounting on roof

Flat roof mounting: In this category there are three steps of mounting, they are-

1. Attached: This category need penetration and connection to the franing
2. Ballasted: In this category it does not need penetration, without this it can withstand 90 mph of wind [25].

Hybrid: It is combination of ballasted and structural system. The concept of hybrid system is less penetration and more ballast or vice versa.

## 6.6 System sizing

In this section we will select the number of PV module can be installed in the selected area. The no. of inverter, combiner box and other equipments is needed to complete the whole designing .we will also find that.

### 6.6.1 Number of module selection

The no of module can be accomodate on both roof top and facade can be calculated by the following formula,

No. of module accommodation =Total usable area/area of a selected PV module

By using this formula we get

Table 5. Possible number of modules using rooftop and façade area

Panel installation location	Usable area(m <sup>2</sup> )	No. of modules
Roof top	408	252
Facade	380.50	240
Total	788.50	492

### 6.6.2 PV array designing

To design the array there are some parameter to check. The most important thing to choose proper inverter and combiner box. So that, they can withstand the PV modules' voltage and current.

ZONZEN ZZ-ZB 10kW inverter's MPPT voltage range = 100-500 V

SAMSUNG LPC250S module's open circuit voltage = 37.6 V

$$\begin{aligned} 12 \text{ module in series} &= 37.6 * 12 \\ &= 451.2 \text{ V} \end{aligned}$$

This is within the inverter's MPPT voltage range. We didn't put more module due to safety.

Module's maximum power voltage = 30.9 V

Inverter MPPT voltage range : 100-500V.

$$(100-500\text{V})/12 = 8.33-41.66 \text{ (module maximum power voltage} = 30.9)$$

So, power maximum power voltage is in the inverter's voltage range.

ZONZEN ZZ-ZB 10kW inverter's current rating:

Inverter's rated voltage = 360 V

$$\text{Maximum current : } (10000/360) = 27.77 \text{ A}$$

At 694.04 W/m<sup>2</sup> maximum short circuit current = 6.01 A

$$\begin{aligned} \text{If we put 3 parallel string (1 string consist of 12 series module)} &= 3 * 6.01 \\ &= 18.03 \text{ A} \end{aligned}$$

We can not put more string, because if there rise a weather condition with low temperature and high insolation excessive current can flow.

For safety considering 35% excessive current = 24.34 A

This is also in inverter's capacity

SMA SCCB-10 combiner box maximum input fuse rating = 600 V , 20A

This is also can withstand 3 parallel string each consist of 12 series modules

Therefore, our chosen PV array design is 3 parallel string each consist of 12 series modules for 1 combiner box and 1 inverter.

As we need to arrange 492 modules we need such 14 configuration

### **6.6.3 Number of inverter calculation**

No of inverter = Total no of module / (no. of module in series in a string \* no. of parallel string)

$$\begin{aligned} &= 492 / (12 * 3) \\ &= 13.66 \\ &= 14 \end{aligned}$$

### **6.6.4 Number of combiner box**

We will need combiner box is equal to the number of inverter. So, we will need 14 combiner boxes.

### **6.6.5 Wiring**

Rated short circuit current is 8.66 A from the PV module. If there is a effect of higher insolation and lower temperature access current can flow. To prevent these to happen the safety factor is considered. Average insolation at Dhaka city is  $694.04 \text{ W/m}^2$ .

Therefore maximum short circuit current will be = 6.01 A

For 3 parallel string =  $3 * 6.01$

$$= 18.03 \text{ A}$$

Considering 35% safety factor Maximum current rating is 25 A.

So, we have chosen 25A rating wiring.

### 6.6.6 Proposed mounting for BRAC University

There are three lift room at top of the building 2. So we have to mount our solar panel above those three rooms. So we have to made a false roof and then have to hybrid mount it.

Our mounting will be BIPV. Because we will use both the surface and vertical column of southern side of BRAC university.

We have to construct a false roof for setting up our modules. From local market we are going to purchase the materials for mounting to reduce cost.

### 6.6.7 Energy supplied by the proposed PV solar system

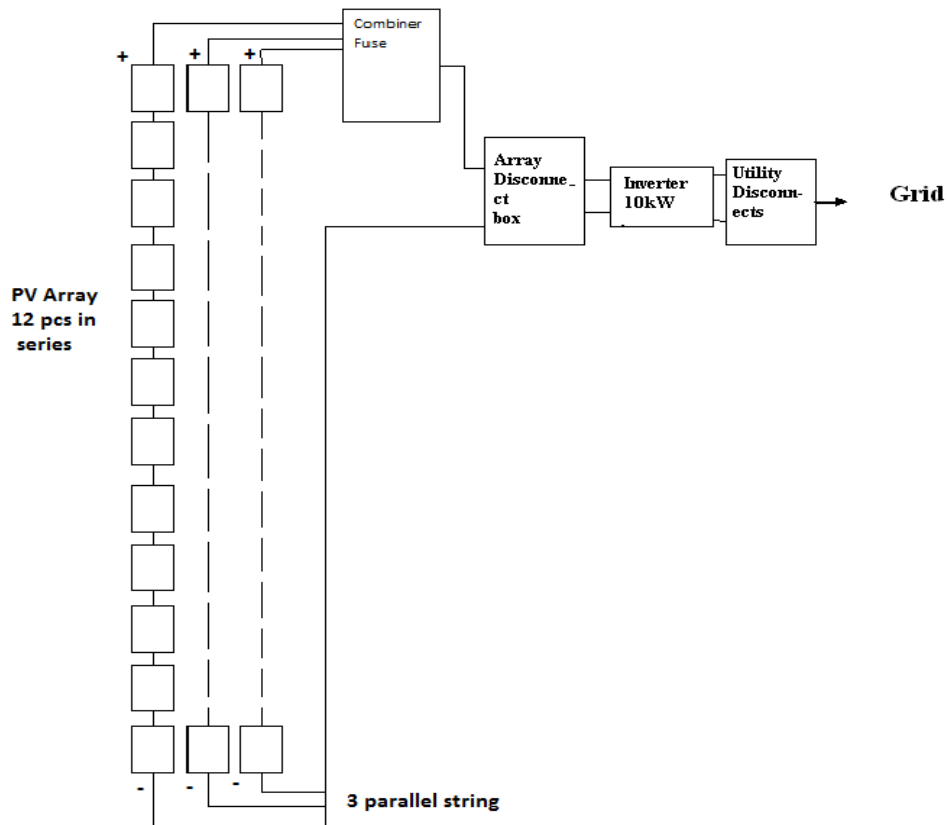


Figure 20. Designed Solar PV system



The figure 20 shows the designed solar system of BRAC University. This configuration showing that there is one combiner connected with 36 PV module. 12 PV modules in series in a string and there are 3 strings in parallel. For our system there would such 14 configuration.

The solar irradiance in Dhaka is 694.04 watt/day [ 5.2.2]. The energy supplied by the solar PV system in a year can be found by the following formula.

$$\begin{aligned}\text{Total energy supply} &= \text{Maximum Power at defined irradiance of a solar panel} * \\ &\quad \text{Average bright sunshine hour} * 365 \text{ days} * \text{total no. of solar} \\ &\quad \text{panels} \\ &= 173.51 * 7.55 * 365 * 492 \\ &= 235.249 \text{ MWh/year}\end{aligned}$$

Considering 80% of panel's output efficiency the total energy supply = 188.39 MWh/year

The daily output energy is 515.62 kWh/day

## 7.0 Design simulation

For the PV system designed for BRAC University campus, we have chosen for simulation is PVSYST software. PVSYST has several built-in mathematical models for component such as photovoltaic module, inverter and other tools.

PVSYST gives two types of designing options as preliminary design and project design. Using these options there are various kinds of system can be developed.

### **For preliminary design:**

Grid connected system, stand alone and pumping – these three types of system can be designed. Actually this is used to get a primary idea for users. There are three steps to design a system like have to define location and system sizing (select PV module type, technology, ventilation and mounting disposition). Then PVSYST will show users a result for that system.

### **For project design:**

This is more elaborate than preliminary design. There are many options to define parameters for designing a project of different types of systems like grid connected /stand alone /dc grid connected/pumping.

To design such types of systems, this section has different steps such as location, horizon and system sizing. To construct a system, there are many components like module, battery and inverter choosing, sizing array which show a number of module connected in series and parallel etc. PVSYST makes the users to interconnect this component to develop a virtual PV system and simulates that. After simulation, users get the simulation result. By using the PVSYST software, we have developed one.

### **Simulation for BRACU:**

First we have done preliminary design to gain primary knowledge and after that designed a project of grid connected system for BRACU. Here we have defined our location, orientation, and horizon. For location choosing, we have selected India as country instead of Bangladesh because we did not get Bangladesh in country selection option. Under India we have selected Dhaka as our site which matches with our latitude and longitude. Since we want to develop a PV system so we have chosen a module and an inverter, defined our monthly energy consumption rates and declared our planned power we want to generate. The parameters are given below in table 6 :

Table 6: Simulation Variant

Simulation parameters	Description
Collector plane orientation	Tilt : 23 degree
Horizon	Free horizon
PV module	Si-mono, Model EOS156 M60_250
Total no. of modules	493 (in series: 17 ; in parallel:29 strings)
Array global power	Nominal: 123 kwp ; effective power: 112kWp (50° c)
Array operating characteristics	U mpp: 506 V ; Impp: 222 A
System parameter	System type: Grid connected System
Inverter	Model: Protect-PV 100000 No. of inverter: 10 units
Inverter Characteristics	Operating voltage: 200-800 V Unit Nominal power: 10kW AC Total power: 100 kW AC

## 7.1 Simulation results

A PV system, designed for BRACU campus, has developed in PVSYST and its performance has simulated.

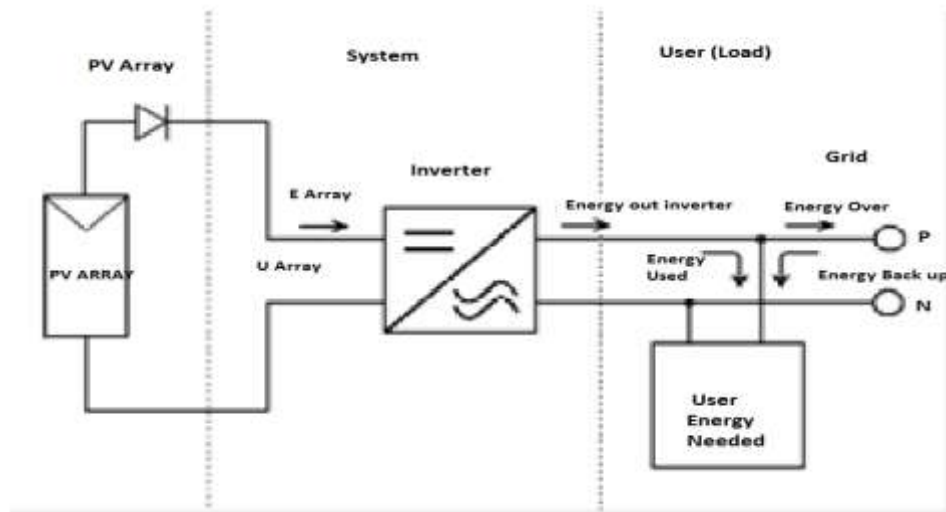


Figure 21. System schema



Figure 22. Simulation result

It shows that the designed PV system could be produced 186 MWh per year.

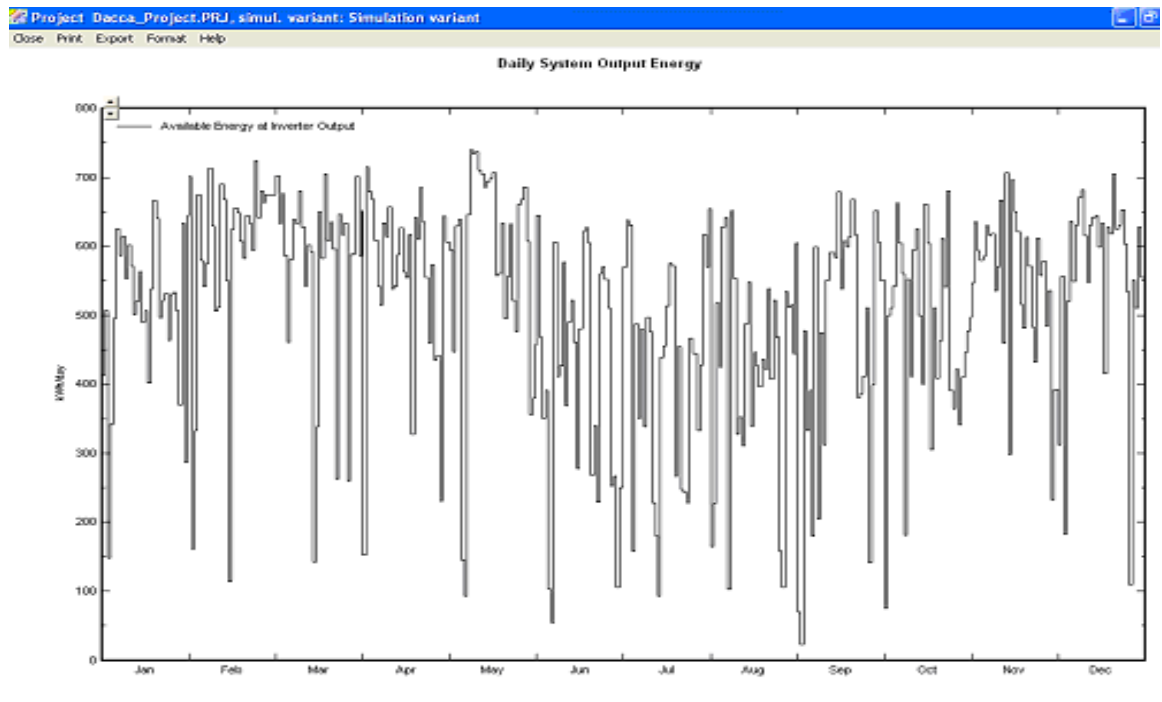


Figure 23. Daily energy output

The fig 23 shows that the daily energy output by our system throughout the year. From the figure we can see that the energy graph fluctuates depending on the insolation.

**Detail simulation results are presented here :**

Grid-Connected System: Simulation parameters					
Project :		Grid-Connected Project at Dacca			
Geographical Site		Dacca		Country	India
Situation		Latitude	23.5°N	Longitude	90.2°E
Time defined as		Legal Time	Time zone UT+6	Altitude	8 m
Meteo data :		Dacca , synthetic hourly data			
Simulation variant :		Simulation variant			
		Simulation date	28/11/10 18h23		
Simulation parameters					
Collector Plane Orientation		Tilt	23°	Azimuth	-17°
Horizon		Free Horizon			
Near Shadings		No Shadings			
PV Array Characteristics					
PV module	Si-mono	Model	SST 250-72M		
		Manufacturer	CEEG		
Number of PV modules		In series	17 modules	In parallel	29 strings
Total number of PV modules		Nb. modules	493	Unit Nom. Power	250 Wp
Array global power		Nominal (STC)	123 kWp	At operating cond.	110 kWp (50°C)
Array operating characteristics (50°C)		U mpp	515 V	I mpp	214 A
Total area		Module area	952 m²	Cell area	850 m²
PV Array loss factors					
Heat Loss Factor		ko (const)	29.0 W/m²K	kv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (800 W/m², Tamb=20°C, wind 1 m/s)				NOCT	45 °C
Wiring Ohmic Loss		Global array res.	77.4 mOhm	Loss Fraction	2.9 % at STC
Serie Diode Loss		Voltage Drop	0.7 V	Loss Fraction	0.1 % at STC
Module Quality Loss				Loss Fraction	3.0 %
Module Mismatch Losses				Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization		IAM =	1-bo (1/cos i - 1)	bo Parameter	0.05
System Parameter		System type	Grid-Connected System		
Inverter		Model	PVI-12.5-OUTD-S-IT		
		Manufacturer	Power One		
Inverter Characteristics		Operating Voltage	200-850 V	Unit Nom. Power	13 kW AC
Inverter pack		Number of Inverter	8 units	Total Power	104 kW AC

Figure 24. Simulation result

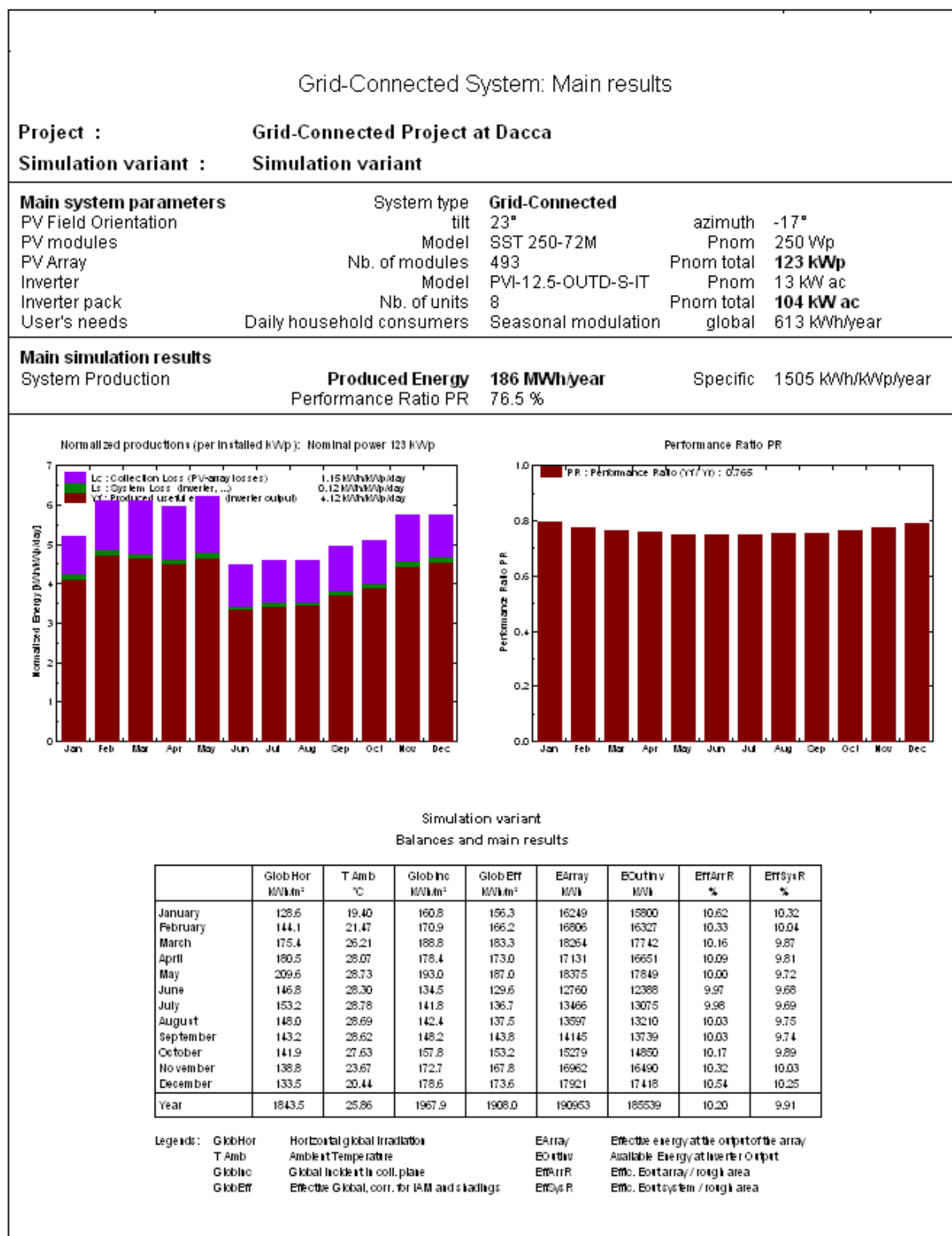


Figure 25. Simulation result

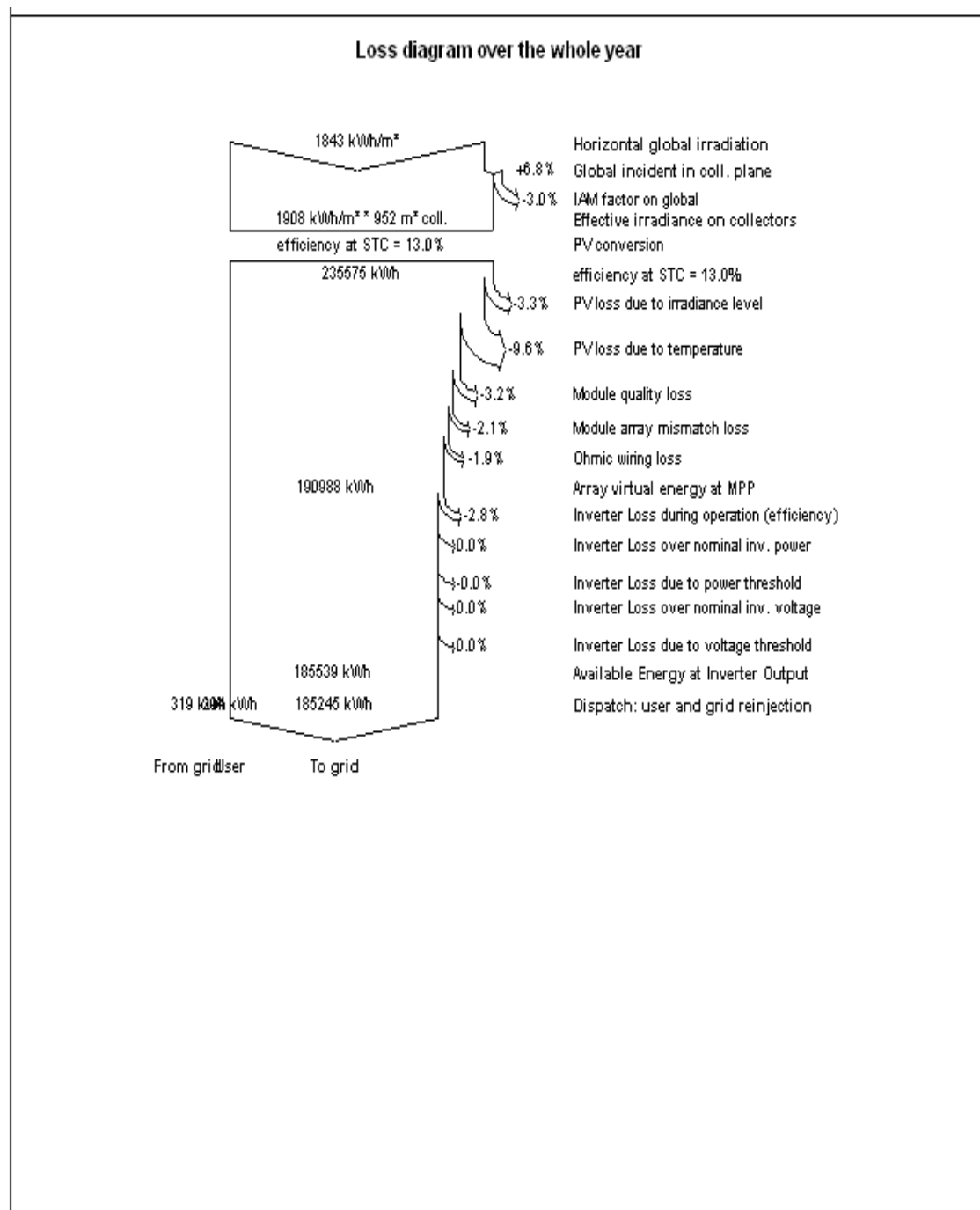


Figure 26. Simulation result



## 7.2 System capacity:

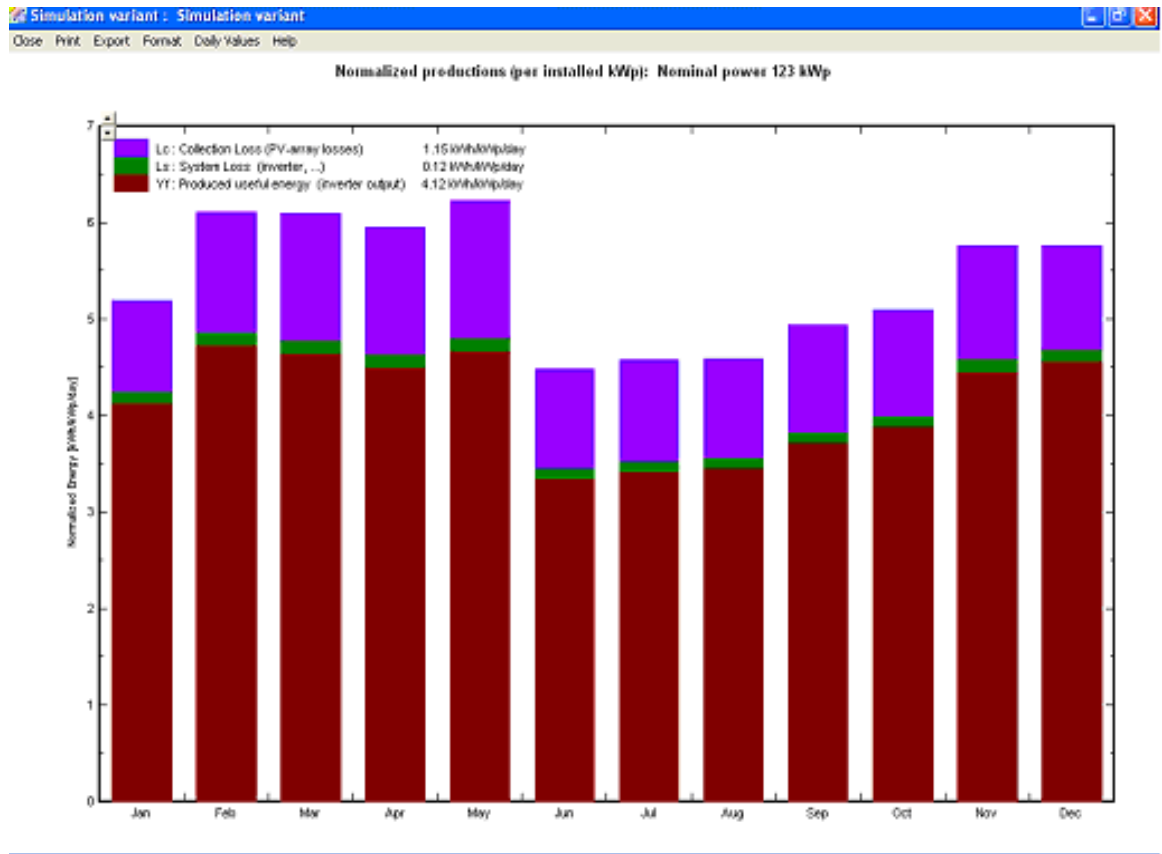


Figure 27. Monthly nominal power graph for 123 kW system

Our PV system's nominal power output is 123 kWp. Due to various factors such as site location, weather condition, insolation, irradiance, performances of PV modules and inverters and system losses, the power capacity of the system is reduced.

### Results from theoretical calculation

Considering these factors, the operating power output = (total no. of solar panel\*maximum power at defined irradiance of a solar panel) kWp

$$= (492 * 173.51) \text{ kWp}$$

$$= 86 \text{ kWp}$$

So, the total effective power output of designed PV system is 86 kW at 25°C.

From simulation results we have got the effective system capacity is 110 kW.

### 7.3 Comparison of results

From our previous calculation,

Our theoretically calculated energy production is 188MWh/year and

The energy production using PVSYST software is 186 MWh/year

For energy generation per year the theoretical value is nearly same to the simulation result.

For the designed system capacity, our theoretical value is little bit far away from simulation result.

### 8.0 Cost Calculation

To implement the proposed solar PV system for BRACU campus, we need to have a clear concept on the implementation cost. In these consequences, we have calculated the approximation cost in USD. Table 7 shows all components that we have required implementing a solar PV system. These components are: PV modules, inverters, combiner boxes, and surge arrestors, lightning rod, mounting, meters, wiring. also we have to consider the transportation, installation, LC and maintenance costs. We have considered this as the 40% of all components costs. After doing calculation the total cost stands around 608670.476 USD.

Table 7. Approximate cost calculation

Component	Description	Quantity	Cost
PV module	Samsung LPC250S	492	350,116.056 \$
inverter	ZONZEN ZZ-ZB10kW	14	42,000 \$
Combiner Box	SMA SCCB-10	14	6790 \$
Surge Arrester	--	14	1,200 \$
Lightning Rod	--	2	200 \$
Mounting	--	--	31428.57 \$
Meters	--	--	30 \$
Wiring	--	--	3000 \$
Transportation, installation, LC, maintenance	40% of all costs	--	173,905.85 \$
Total cost			608670.476 \$

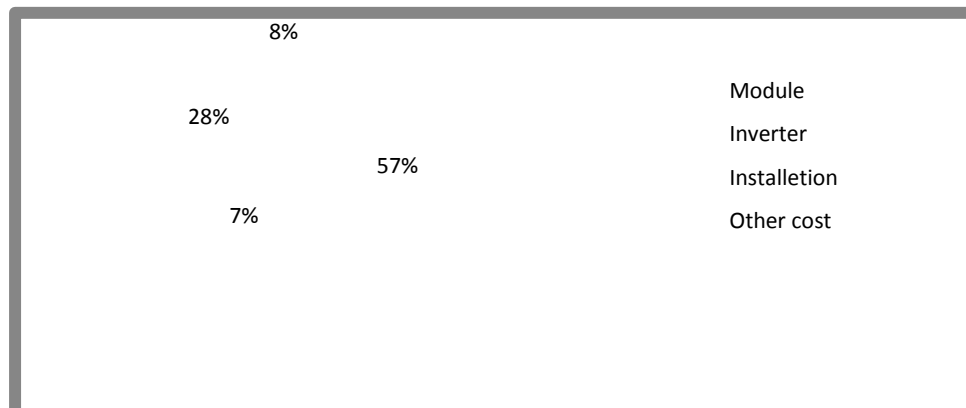


Figure28. Cost calculation in pie chart

From the fig. 28 the pie chart shows that 57% of total cost is the module cost, 36% cost is for installation, 7% inverter cost .

## 9.0 Per unit energy cost

We consider our proposed PV system life is 25 years. So, the cost per unit of energy by the designed system will be:

Total cost of the system	: 608670.476 \$ (from table6)
Average daily bright sunshine hours	: 7.55
Estimated capacity of the designed system in kW	: 86 [Chapter 7.2]
Avg. energy produced per day in kWh	: $86 \times 7.55 = 649.3$
Energy produced in 25 years in kWh	: $649.3 \times 25 \times 365 = 5924862.5$
Cost per unit of energy in USD produced in 25 years)	: (Total cost of the system/ Energy produced in 25 years)
	= $(608670.476 / 5924862.5)$
	= 0.1027

So we could be able to generate per unit of energy at 0.1027 \$ or  $(0.1027 \times 70)$  TK  
= 7.189 TK.

## **10. Conclusion**

We are facing fuel shortage for electricity generation and in the near future the whole world going to face the same scarcity because of world's limited fuel stock. So worldwide renewable energy demand and research are rising and our government also taking steps for green energy. So, we choose solar energy for BRAC University as secondary energy source.

## **11. Further works**

- Load calculation
- Reducing system cost
- System's cost payback analysis

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