ESTIMATION OF CLEAR SKY SOLAR RADIATION FOR DHAKA CITY

By

Tanzira Israt Jahan

ID: 2009-3-55-010

Supervised by

Dr. Md. Habibur Rahman

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Thesis Report

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has been approved

April,2014

Dr. Md. Habibur Rahman

Adjunct Professor

Department of Electronics and Communications Engineering

EAST WEST UNIVERSITY, BANGLADESH

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Signature of Supervisor

Rahman 26/04/14

Dr. Md. Habibur Rahman

Adjunct Professor

Department of ECE

EAST WEST UNIVERSITY,

BANGLADESH

Signature of Authors

Israt

Tanzira Israt Jahan

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Abstract

Solar electricity is one of the most emerging technologies around the world. In almost every corner of the world people are doing research works on how to improve the efficiency of this technology. This is because the solar cell technology, to produce power is still not that much highly efficient considering both the costs and the amount of power produced. Solar power is rapidly gaining notoriety as an important means of expanding renewable energy resources. It is technology of obtaining useable energy from the sun. Sun provides energy in the form of radiation over the UV, visible and infrared spectrum. Only certain wavelengths are used to produce electricity by the solar cell. It is necessary to calculate solar radiation and to estimate the PV output power on any particular day of the year for various applications. To run photovoltaic systems properly the estimation of PV output is also important. The output power of a PV panel can be estimated if the amount of solar energy incident on it, efficiency of the panel and its area are known. The area and the efficiency of a panel can be obtained from the manufacturer's data. In this thesis, we calculate clear sky solar radiation for Dhaka city. The details of the calculation and analysis can be found in the whole report. All the calculations, tables and graphs shown in this report were done in the Microsoft Excel Worksheet.

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Chapter 1

INTRODUCTION

Most sources of energy on Earth are the sun. Still now the world is depending on the energy produced by burning the fuels obtained from the fossils. These include coal, oil, natural gas etc. At the current rate of consumption it is estimated that the supply of world in the world will last for only next 30 years and the supply of coal will last for next 250 years. Also because of the heavy consumption of these fossil fuels the problems regarding the global warming like sea level rising are becoming major concerns for the present world. For these reasons it has become urgent to find some alternative sources of energy that are unlimited in amount and can be recycled day by day and also don't be an issue for the global warming. From this urgency the study of solar electricity, renewable energies has become one of the most common studies around the world now-a-days.

Solar energy is the energy derived from the sun through the form of solar radiation. The sun provides around1366 watt/m^2 at the distance of the Earth's orbit, but less at found level. Collecting the sun light and converting it into electricity is what we call solar power. The sun delivers large amounts of energy to the surface of the Earth. Figuring out how to measure solar radiation which is useful to help determine the best position to place solar panels in order to generate the most solar power.

1.1 MOTIVATION

Electricity has become an irreplaceable part of our lives. Every second of every day, we need power to run machines that assists us in many ways. However, themore we consume the more we lose. Our fuel sources are slowly running out and soon there will be no more fuel to energize our machines. It has takes us on the brink of description to notice the alternate form of energy in our own backyard in the form of solar power. Sun is the main source of the power. And this power is called solar power. By using this power we easily make current. In this thesis we learn a brief knowledge of solar energy and it help to make the characteristic carve of the solar module.

1.2 SOLAR POWER IN BANGLADESH

In 1971, just 3% of Bangladesh's population had access to electricity. Today, that number has increased to around 40% of the population – still one of the lowest in the world – but access often amounts to just a few hours each day. Bangladesh claims the lowest per-capita consumption of commercial energy in South Asia, but there is a significant gap between supply and demand. Bangladesh's power system depends on fossil fuels supplied by both private sector and state-owned power plants. After system losses, the country's installed capacity for electricity generation can generate 3,800 megawatts of electricity per day; however, daily demand is near 6,000 megawatts per day. In general, rapid industrialization and urbanization has propelled the increase in demand for energy by 10% per year. What further exacerbates Bangladesh's energy problems is the fact that the country's power generation plants are dated and may need to be shut down sooner rather than later.

Clearly, the present gas production capacity in Bangladesh cannot support both domestic gas needs, as well as wider electricity generation for the country. On September 15, 2009, the Power Division of the Ministry of Power, Energy and Mineral Resources of Bangladesh pushed for urgent action to be taken to improve the country's energy outlook. The Power Division made recommendations such as ceasing gas supply to gas-fired power plants after 2012 to conserve gas reserves for domestic use.

The Government of Bangladesh is actively engaged in energy crisis management. The National Energy Policy has the explicit goal of supplying the whole country with electricity by 2020. Since 1996, the government has allowed private, independent power producers to enter the Bangladeshi market. It is already importing 100 megawatts of power from India and has negotiated with private companies renting plants to buy power at higher rates.

1.3 SOLAR ENERGY

Even with these measures, Bangladesh's gas reserves are quickly diminishing. For the country to fulfill its goal of universal electrification, Bangladesh needs to invest in alternative sources of energy. The energy needs of Bangladesh are great not just because of limited supply; the issue is also mainly one of access. About 80% of the population resides in areas where electricity is akin to a dream. There are estimates that many parts of the country will still not acquire electricity from the national grid for another 30 years. The national grid covers at most 20% of households, but this statistic does not capture the infrequency of access and the resources needed to bolster it.

Solar energy therefore has significant potential for Bangladesh. Solar power does not require sophisticated technology or know-how. It does not require fossil fuels to function, and is highly reliable: it is an economically feasible energy source. There are studies that suggest that if solar energy is adopted, as much as 10,000 megawatts daily of solar electricity can be created in the short- and medium-runs – this is equivalent to twice the total amount of electricity produced and supplied on the national grid.

In 2008, at the Washington International Renewable Energy Conference, Bangladesh pledged that 5% of its total electricity generation would come from renewable sources. In 2009, the Bangladesh Bank set up a US$29m fund to promote solar power. Private commercial banks and state-owned banks signed an agreement with the central bank that allowed banks to draw money from this fund under a refinancing scheme with a low-interest interest rate of 5%. The banks could then lend the funds to borrowers from the solar power sector at a ceiling interest rate of 10%.

Although the Government of Bangladesh, along with the central bank, have made strong moves to bolster its solar power investment, in general, banks have not been interested because they do not find solar technology as profitable as other areas of business. The task at hand now is to make solar energy investment more attractive for lenders so that this area of renewable energy can be stimulated and grown.

1.4 SCOPE OF THESIS

- DATA RECORDED:

  All data that had been collected will be recorded. Then after getting approval from the supervisor all data will be implemented into the final report at the end of this project development.

1.5 THESIS OUTLINES

This report consists of five chapters that describe in detail the work behind this thesis.

Chapter one is an introduction to the thesis. This chapter includes the importance of this thesis and motivation behind it.

Chapter two will discuss the study and all the theoretical ideas that are related to this thesis. This chapter includes the definition of solar radiation and pv panel.

Chapter three mainly focus on calculation of the solar radiation measurement system in detail.

Chapter four focuses on the results obtained from this thesis and graphical representation of the hourly solar radiation variation for each month.

Chapter five, the last chapter concludes the project and some suggestions are given.

CHAPTER TWO

THEORY BEHIND THIS THESIS

2.1 SOLAR RADIATION

Solar energy is the energy derived from the sun through the form of solar radiation. Solar energy travels from sun to earth in the form of electromagnetic radiation. There are many forms of electromagnetic radiation, such as radio waves, ultrasonic waves, infrared wave, visible light, ultraviolet light, x-rays, gamma rays and cosmic rays. These different forms of electromagnetic radiation are all characterized by their wavelength and frequency. Long wavelength electromagnetic radiation has a low frequency and short wavelength electromagnetic radiation has a high frequency.

Solar radiation is a term used to describe visible and near-visible (ultraviolet and near infrared) radiation emitted from the sun. Solar radiation has most of its energy between wavelengths of 10^{-7} and 3×10^{-6} m. The include UV light, visible light and infrared radiation. Visible light and near-infrared (wavelength of 7×10^{-7} to 1.5×10^{-6} m) make up over 90% of the solar radiation reaching the Earth's atmosphere. Less than 10% of solar radiation is ultraviolet (UV) light (wavelength of 10^{-8} to 4×10^{-7} m).

2.2 TERRESTRIAL SOLAR RADIATION

Terrestrial solar radiation that which reaches the earth's surface, is sometimes broken down into two components-beam radiation and diffuse radiation. Beam radiation is solar radiation that passes through the atmosphere in essentially a straight line without being reflected, scattered or absorbed by particles or gases in the air. Diffuse radiation is solar radiation, which is scattered, reflected or absorbed by molecules of air, water vapor, aerosols and dust particles, but ultimately still reaches the Earth's surface. The total solar radiation is the sun of the beam radiation and diffuse radiation on a surface. The most common measurement of solar radiation are total radiation on a horizontal surface, often referred to as global radiation.

2.3 SOLAR RADIATION IN BANGLADEH

The long term average sunshine data indicates that the period of bright sunshine hours in the coastal regions of Bangladesh varies from 3 to 11 hours daily. The insolation in Bangladesh varies from 3.8kwh/m^2/day to 6.4kwh/m^2/day at an average of 5kwh/m^2/day. These indicate that there are good prospects for solar thermal and photovoltaic application in the country.

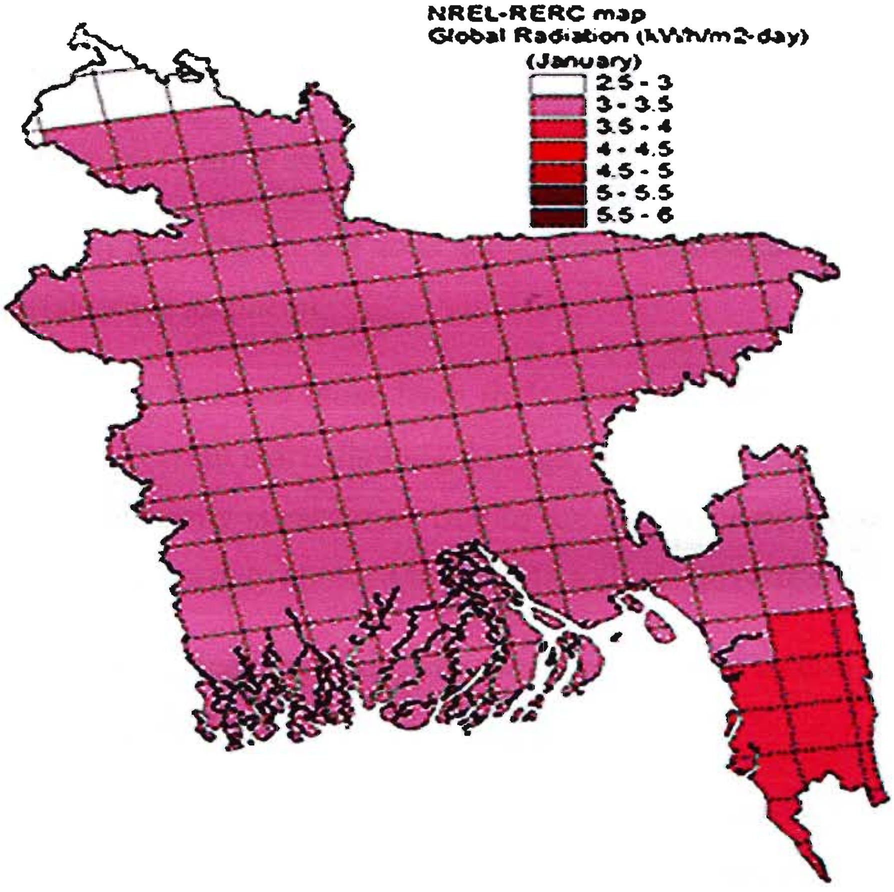

Figure 1: Solar radiation in Bangladesh

2.4 SOLAR CELLS AND MODULES

Solar cell is a cell that converts solar energy to electrical energy. A solar cell is a solid state electrical device that converts the energy of light directly into electricity by the photovoltaic effect. Many solar cells are used to make solar modules which are used to capture energy from sunlight. When multiple modules are arranged together the resulting integrated group of modules all oriented in one plane is referred to in the solar industry as a solar panel. Photovoltaic modules often have a sheet of glass on the front (sun up) side, allowing light to pass while protecting the semiconductor wafers from abrasion and impact due to wind-driven debris, rain, hail etc. solar cells are also usually connected in series in modules, creating an additive voltage.

The solar cell works in three steps:

1. Photons in sunlight hit the solar panel and are absorbed by semiconductor materials, such as silicon.

2. Electrons are knocked loose from their atoms, causing an electric potential difference. Current starts flowing through the material to cancel the potential and this electricity is captured. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.

3. An array of solar cells converts are solar energy into a usable amount of direct current (DC) electricity.

The efficiency of a solar cell may be broken down into reflectance, thermodynamic efficiency, charge carrier separation efficiency and conductive efficiency. The overall efficiency is the product of each of these individual effeciencies.

2.5 PV PANELS

Photovoltaic Panels are used to transform sunlight energy into electrical energy. "PV panel" is the common name for a photovoltaic panel. Literally translated photovoltaic means "light-electricity". It is formed from photo- which means light and voltaic which means electrical current or electricity. PV panels are made up of smaller sections called solar cells. Solar cells, like batteries, each have a rated value of voltage (V or volts) and amperage (A or amps). The total power in wattage (W or watts) delivered is the voltage times the amperage.

Volts x Amps = Watts or V x A=W

Batteries can be arranged in parallel or in series depending on the requirements of the device we want to power.

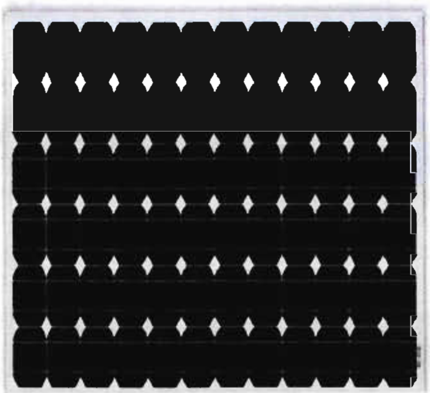

Figure 2: PV Panels

2.6 ADVANTAGE AND DISADVANTAGE OF PHOTOVOLTAIC

Solar electricity, also known as photovoltaic (PV), has shown since the 1970's that the human race can get a substantial portion of its electrical power without burning fossil fuels (coal, oil or natural gas) or creating nuclear fission reactions. Photovoltaic helps us avoid most of the threats associated with our present techniques of electricity production and also has many other benefits. Photovoltaic has shown that it can generate electricity for the human race for a wide range of applications, scales, climates, and geographic locations. Photovoltaic can bring electricity to a rural homemaker who lives 100 kilometers and 100 years away from the nearest electric grid connection in their country, thus allowing their family to have clean, electric lights instead of kerosene lamps, to listen to a radio, and to run a sewing machine for additional income. Or, photovoltaic can provide electricity to remote transmitter stations in the mountains allowing better communication without building a road to deliver diesel fuel for its generator.

Table 1 lists some of the advantages and disadvantages of photovoltaic. We can see thatthey include both technical and nontechnical issues. Often, the advantages and disadvantages of photovoltaic are almost completely opposite of conventional fossil fuel power plants. For example, fossil-fuel plants have disadvantages of: a wide range of environmentally hazardous emissions, steadily increasing fuel costs, they are not modular (deployable in small increments), and they suffer low public opinion (no one wants a coal burning power plant in their neighborhood). Photovoltaic suffers none of these problems.

The two common traits are that both PV and fossil fueled power plants are very reliable but lack the advantage of storage.

Also several of the disadvantages are nontechnical but relate to economics and infrastructure. They are partially compensated for by a very high public acceptance and awareness of the environmental benefits. During the late 1990s, the average growth rate of PV production was over 33% per annum .

Table 1 Advantages and disadvantages of photovoltaic

Advantage of photovoltaic	Disadvantages of photovoltaic
1. Fuel source is vast and essentially infinite	1. Fuel source is diffuse (sunlight is a relatively low-density energy)
2. No emissions, no combustion or radioactive fuel for disposal (does not contribute perceptibly to global climate change or pollution)	2. High installation costs
3. Low operating costs (no fuel)	3. Poorer reliability of auxiliary (balance of system) elements including storage
4. No moving parts	4. Lack of widespread commercially available system integration and installation so far
5. Ambient temperature operation (no high temperature corrosion or safety issues)	5. Lack of economical efficient energy storage
6. High reliability in modules (>20 years)	
7. Modular (small or large increments)	
8. Quick installation	
9. Can be integrated into new or existing building structures	
10. Can be installed at nearly any point-ofuse	
11. Daily output peak may match local demand	
12. High public acceptance	

2.7 CHARACTERISTIC OF PHOTOVOLTAIC ENERGY CONVERSION

Photovoltaic aims at two areas of application. One is the power supply for off-grid professional devices and supply systems (e.g. telecommunication equipment, solar home systems) and the other is large-scale electricity generation as a substitute for and a complement to today's non-sustainable energy processes. With respect to the latter, the global potential of PV electricity is of key importance.

Photovoltaic energy conversion meets the important requirements of a sustainable energy production in an obvious way. During operation there is no harmful emission or transformation of matter (generation of pollutants), nor any production of noise or other by-products. PV energy conversion is a technologically elegant one-step process avoiding conventional thermodynamic or mechanical intermediate steps. On the other hand, production of PV modules and system components will – as any industrial device production – include material transformation and the production of wastes. Thus, it is extremely important to realize PV conversion technologies that comply with the requirements of environmentally friendly production schemes. Photovoltaic energy conversion is highly modular. Installations may vary between miliwatts for consumer products (watches) to megawatts in the case of grid-connected power plants. From a market point of view, this gives rise to a broad variety of PV applications. For the professional energy supply business, modularity is especially important with respect to the development of electricity supply systems in many rural and remote areas where grid extension is economically not feasible. Starting from low power installations, PV modules may be gradually added to suitable systems in order to cope with the growing energy demands. In this way electricity supplies can be realized avoiding too high initial investments. In the context of rural electrification and also for the professional energy supply of off-grid electronic devices, the low maintenance characteristic of photovoltaic is regarded as a considerable advantage. The absence of moving parts, the robustness against harsh environment and the lack of fuel supply requirements (exception: hybrid systems) make photovoltaic a well-suited energy supply technique for a vast area of stand-alone energy supplies.

2.8 LIMITS OF PHOTOVOLTAIC CONVERSION

Efficiency is an important matter in the PV conversion of solar energy because the sun is a source of power whose density is not very low, so it gives some expectations on the feasibility of its generalized cost-effective use in electric power production. However, this density is not so high as to render this task easy. After a quarter of a century of attempting it, cost still does not allow a generalized use of this conversion technology. Efficiency forecasts have been carried out from the very beginning of PV conversion to guide the research activity. In solar cells the efficiency is strongly related to the generation of electron–hole pairs caused by the light, and their recombination before being delivered to the external circuit at a certain voltage. This recombination is due to a large variety of mechanisms and cannot be easily linked to the material used to make the cell. Nevertheless, already in 1975 Lofersky had established an empirical link that allowed him to predict which materials were most promising for solar cell fabrication.

In 1960, Shockley and Queisser pointed out that the ultimate recombination mechanisms – impossible to avoid – was just the detailed balance counterpart of the generation mechanisms. This allowed them to determine the maximum efficiency to be expected from a solar cell. This efficiency limit (40.7% for the photon spectrum approximated by a black body at 6000 K) is not too high because solar cells make rather ineffective use of the sun's photons. Many of them are not absorbed, and the energy of many of the absorbed ones is only poorly exploited.

CHAPTER THREE

CALCULATION OF SOLAR RADIATION FOR DHAKA CITY

3.1 CALCULATION OF BEAM RADIATION AND DIFFUSE RADIATION

There are two components of solar radiation, one is beam radiation and the other is diffuse radiation. Solar radiation means the summation of beam and diffuse radiation. Both the components contribute to the PV output power. To calculate the beam radiation, Hottel's empirical formula of atmospheric transmittance for beam radiation has been used. The equation is given below:

$$\tau_b = a_0 + a_1 e^{-k/\cos\theta_z} \qquad (3.1)$$

where, τ_b= atmospheric transmittance for beam radiation (G_{bn}/G_{on})

G_{bn} = beam radiation on the n^{th} day of the year

G_{on} = extraterrestrial radiation on the n^{th} day of the year

θ_Z = zenith angle

a_0, a_1 and k are constants. The constants a_0, a_1 and k for the standard atmosphere with 23 km visibility are found from a_0^*,a_1^* and k^* which are given for altitudes less than 2.5 km by

a_0^*= 0.4237-0.00821(6-A)^2

= 0.4237-0.00821(6-1.046)^2

= 0.2222

a_1^*= 0.5055+0.00595(6.5-A)^2

=0.5055+0.00595(6.5-1.046)^2

=0.6824

k^*= 0.2711+0.01858(2.5-A)^2

$=0.2711+0.01858(2.5-1.046)^2$

$=0.3103$

Where A is the altitude of Bangladesh which value is 1.046 approximately.

Correction factors are applied to a_0^*, a_1^* and k^* to allow for changes in climate types. The correction factors $r_0= a_0/a_0^*$, $r_1= a_1/a_1^*$ and $r_k= k/k^*$ are given in table 3.1. Considering the weather of Dhaka is Mid-latitude summer.

3.1Correction factor for climate type

Climate type	r_0	r_1	r_k
Tropical	0.95	0.98	1.02
Mid-latitude summer	0.97	0.99	1.02
Subarctic summer	0.99	0.99	1.01
Mid-latitude winter	1.03	1.01	1.00

Considering the weather of Dhaka is Mid-latitude summer. Then the constants values are,

$a_0= 0.215537$

$a_1= 0.67566$

and $k= 0.31651$

The expression for extraterrestrial radiation is

$$G_{on} = G_{sc}\left(1 + 0.033\ COS\ \frac{360\ n}{365}\right)$$

where, G_{sc} = solar constant = 1353 W/m^2

n = day of the year

Now, multiplying equation (3.1) by equation (3.2), equation (3.3) can be obtained.

$$G_{bn} = G_{sc}\left(1 + 0.033\cos\frac{360\,n}{365}\right) \times \left(a_0 + a_1 e^{-k/\cos\theta_z}\right) \qquad (3.3)$$

To calculate the value of G_{bn} for all day long, we have to replace θz of equation (3.3) by local time of the place where the beam radiation is to be calculated. For a horizontal surface $\theta z = \theta$ (incidence angle) and for inclined surface we have to use θz calculated for horizontal surface. There is a standard equation for the incidence angle, which is given below.

$$\cos\theta = \sin\delta\sin\varphi\cos\beta - \sin\delta\cos\varphi\sin\beta\cos\gamma + \cos\delta\cos\varphi\cos\beta\cos\omega + \cos\delta\sin\varphi\sin\beta\cos\gamma\cos\omega + \cos\delta\sin\beta\sin\gamma\sin\omega \qquad (4.4)$$

where, δ = sun declination

ω = hour angle

β = slope of the surface

γ = surface azimuth angle and

φ = latitude of the place

Considering the surface azimuth angle $\gamma = 0$ and the slope of the surface $\beta = 0$ (as we will first develop an equation for horizontal surface), equation (3.4) reduces to

$$\cos\theta = \sin\delta\ \sin\varphi\ + \cos\delta\cos\varphi\cos\omega \qquad (3.5)$$

The values of the parameters of this equation are

δ = sun declination $= 23.45\sin(360\dfrac{284+n}{365})$

φ = latitude of Dhaka = 23.709°N

ω = hour angle = $\dfrac{720 \text{ min} - slt \text{ (min)}}{4}$

slt =solar time = Local time+4(L_{st}-L_{loc})+E

E = equation of time = 9.87 sin 2B – 7.53 cos B

– 1.5 sin B, B = 360(n-81)/364

L_{st} = longitude based on which local time is calculated

=90.04° E

L_{loc} = longitude of Dhaka = 90°

Putting all these values into equation (3.5) we can get $cos\theta$ in terms of local time and using this value into equation (3.3) we can calculate the beam radiation for any time of a particular day of the year. This calculated value is, it can be seen that the radiation changes abruptly at sunrise and sunset time, whereas the practically measured solar radiation changes gradually. Hence, to overcome this abrupt change, Hottel's equation has been modified by multiplying the constant term by an exponential function, which is related to zenith angle. The modified equation is shown below.

$$G'_{bn} = G_{sc}\left(1 + 0.033 \cos \tfrac{360\, n}{365}\right) \times \left\{a_0\left(1 - e^{\xi_b COS\, \theta_Z}\right) + a_1 e^{-k / \cos \theta_Z}\right\} \quad (3.6)$$

where, G'_{bn} = modified beam radiation

ξ_b = a constant = 6

To calculate the diffuse radiation, Liu and Jordan's empirical formula for the transmission co-efficient of diffuse radiation (τ_d) [73] has been used. The equation is given below

$$\tau_d = 0.2710 - 0.2939\tau_b \qquad (3.7)$$

Multiplying equation (3.2) by equation (3.7), the clear sky diffuse radiation can be calculated as:

$$G_{dn} = G_{sc}\left(1+0.033COS\frac{360n}{365}\right)\times(0.2710-0.2939\tau_b) \qquad (3.8)$$

where, G_{dn} = diffuse radiation on the n[th] day of the year.

This diffuse radiation that has also abrupt changes at sunrise and sunset time. So, this empirical formula for τ_d has also been modified in the same way, as described for beam radiation.

The modified diffuse equation is given below.

$$G'_{dn} = G_{sc}(1 + 0.033\,COS\,\frac{360\,n}{365})\times$$

$$\{0.2710(1- e^{-\xi_d COS\,\theta_z}) - 0.2939\tau_b\} \qquad (3.9)$$

where, G'_{dn} = modified diffuse radiation

ξ_d = a constant = 6.

The modified equation changes the diffuse radiation only at the sunrise and sunset time.

Finally, the solar radiation has been calculated by adding the beam and diffuse radiations as:

$$G'_{tn} = G'_{bn} + G'_{dn} \qquad (3.10)$$

where, G'_{tn} = modified (total) solar radiation on the n[th] day of the year.

3.2 PROGRAM

```
/ This program the modification both in beam and diffuse

#include <math.h>

#include<stdio.h>

#include<conio.h>

#define pi 3.14159265358979323 85

#define p 23.75*pi/180 //latitude of the place of question

#define b 23*pi/180 //declination of the pannel

main()

{

        clrscr();

        FILE *fpt;

        int n;

        float i,a0=.2222,a1=.0.6824,k=.0.31651;//constants of the Hottel equation

        float e,e1,d,o,dgo,oz,tb,td,st,sr,b1;

        if((fpt=fopen("Jan.txt","w"))==NULL)

        printf("\ERROR- Loading File\n");

        else

        {
```

```
n=1;//day of the year

// var of ext rad

e=1353.0*(1+0.033*cos(pi*n*360/(180.0*365)));

// var of sun derc

d=23.45*sin((360.0/365.0)*pi*(284.0+n)/180.0);

// Sunrise hour angle

sr=acos(-1*tan(p)*tan(pi*d/180.0));

for(i=4;i<=20;i=i+.1)

{

        b1=pi*360*(n-81)/(364.0*180);

        //equation of the time

        e1=9.87*sin(2*b1)-7.53*cos(b1)-1.5*sin(b1);

        //Solar time

        st=i*60+35.6+e1;

        //hour angle o

        o=-pi*(720-st)/(4*180);

        if(fabs(o)>sr) fprintf(fpt,"%.2f\t%.2f\n",i,0);

        else

        {
```

```
//cos 0z

oz=(sin(p)*sin(d*pi/180)+cos(p)*cos(d*pi/180)*cos(o));

//Hottel equation for transmittance of beam radiation

tb=a0*(1-exp(-oz*6))+a1*exp(-k/oz);

//Liu and Jordan equation for transmittance of beam radiation

td=(1-exp(-oz*6))*(0.2710-0.2939*tb);

//Calculation of total radiation

dgo=tb*e+e*td;

fprintf(fpt,"%.2f\t%.2f\n",i,dgo);

printf("%f %f\n",d,o*180/pi);

}

}

fclose(fpt);

}

getch();

return 0;

}
```

CHAPTER FOUR

RESULTS

4.1 Solar radiation for the month of January

n	Solar time	Solar radiation	n	Solar time	Solar radiation
1	4	0	15	4	0
1	4.1	0	15	4.1	0
1	4.2	0	15	4.2	0
1	4.3	0	15	4.3	0
1	4.4	0	15	4.4	0
1	4.5	0	15	4.5	0
1	4.6	0	15	4.6	0
1	4.7	0	15	4.7	0
1	4.8	0	15	4.8	0
1	4.9	0	15	4.9	0
1	5	0	15	5	0
1	5.1	0	15	5.1	0
1	5.2	0	15	5.2	0
1	5.3	0	15	5.3	0
1	5.4	0	15	5.4	0
1	5.5	0	15	5.5	0
1	5.6	0	15	5.6	0
1	5.7	0	15	5.7	0
1	5.8	0	15	5.8	0
1	5.9	0	15	5.9	0
1	6	0	15	6	0
1	6.1	0	15	6.1	0
1	6.2	0	15	6.2	0
1	6.3	0	15	6.3	0
1	6.4	0	15	6.4	0
1	6.5	0	15	6.5	0
1	6.6	0	15	6.6	0
1	6.7	0	15	6.7	0
1	6.8	23.65	15	6.8	0
1	6.9	106.08	15	6.9	80.44
1	7	176.98	15	7	155.59
1	7.1	242.54	15	7.1	223.19
1	7.2	306.37	15	7.2	288.49
1	7.3	368.14	15	7.3	351.98
1	7.4	426.59	15	7.4	412.41
1	7.5	480.83	15	7.5	468.69
1	7.6	530.49	15	7.6	520.29
1	7.7	575.56	15	7.7	567.14
1	7.8	616.26	15	7.8	609.43
1	7.9	652.92	15	7.9	647.47
1	8	685.9	15	8	681.65
1	8.1	715.57	15	8.1	712.36

1	8.2	742.29	15	8.2	739.97
1	8.3	766.39	15	8.3	764.82
1	8.4	788.15	15	8.4	787.23
1	8.5	807.83	15	8.5	807.47
1	8.6	825.68	15	8.6	825.79
1	8.7	841.88	15	8.7	842.41
1	8.8	856.63	15	8.8	857.52
1	8.9	870.08	15	8.9	871.28
1	9	882.36	15	9	883.84
1	9.1	893.6	15	9.1	895.32
1	9.2	903.89	15	9.2	905.83
1	9.3	913.35	15	9.3	915.48
1	9.4	922.03	15	9.4	924.34
1	9.5	930.03	15	9.5	932.49
1	9.6	937.39	15	9.6	940
1	9.7	944.17	15	9.7	946.92
1	9.8	950.43	15	9.8	953.3
1	9.9	956.2	15	9.9	959.19
1	10	961.53	15	10	964.63
1	10.1	966.44	15	10.1	969.65
1	10.2	970.97	15	10.2	974.29
1	10.3	975.14	15	10.3	978.56
1	10.4	978.98	15	10.4	982.5
1	10.5	982.5	15	10.5	986.13
1	10.6	985.73	15	10.6	989.46
1	10.7	988.69	15	10.7	992.52
1	10.8	991.38	15	10.8	995.32
1	10.9	993.82	15	10.9	997.86
1	11	996.02	15	11	1000.17
1	11.1	997.99	15	11.1	1002.26
1	11.2	999.75	15	11.2	1004.13
1	11.3	1001.29	15	11.3	1005.79
1	11.4	1002.63	15	11.4	1007.25
1	11.5	1003.77	15	11.5	1008.52
1	11.6	1004.71	15	11.6	1009.59
1	11.7	1005.47	15	11.7	1010.48
1	11.8	1006.03	15	11.8	1011.19
1	11.9	1006.41	15	11.9	1011.72
1	12	1006.61	15	12	1012.07
1	12.1	1006.62	15	12.1	1012.25
1	12.2	1006.45	15	12.2	1012.26
1	12.3	1006.1	15	12.3	1012.08
1	12.4	1005.56	15	12.4	1011.74
1	12.5	1004.84	15	12.5	1011.22
1	12.6	1003.92	15	12.6	1010.51
1	12.7	1002.81	15	12.7	1009.63

1	12.8	1001.5	15	12.8	1008.56
1	12.9	999.99	15	12.9	1007.31
1	13	998.27	15	13	1005.86
1	13.1	996.33	15	13.1	1004.2
1	13.2	994.16	15	13.2	1002.34
1	13.3	991.76	15	13.3	1000.27
1	13.4	989.1	15	13.4	997.97
1	13.5	986.19	15	13.5	995.43
1	13.6	983	15	13.6	992.64
1	13.7	979.52	15	13.7	989.6
1	13.8	975.73	15	13.8	986.28
1	13.9	971.61	15	13.9	982.66
1	14	967.14	15	14	978.73
1	14.1	962.28	15	14.1	974.47
1	14.2	957.02	15	14.2	969.85
1	14.3	951.32	15	14.3	964.85
1	14.4	945.14	15	14.4	959.43
1	14.5	938.43	15	14.5	953.56
1	14.6	931.16	15	14.6	947.2
1	14.7	923.27	15	14.7	940.3
1	14.8	914.69	15	14.8	932.82
1	14.9	905.35	15	14.9	924.69
1	15	895.18	15	15	915.86
1	15.1	884.09	15	15.1	906.25
1	15.2	871.97	15	15.2	895.78
1	15.3	858.71	15	15.3	884.34
1	15.4	844.16	15	15.4	871.83
1	15.5	828.18	15	15.5	858.13
1	15.6	810.6	15	15.6	843.08
1	15.7	791.2	15	15.7	826.52
1	15.8	769.77	15	15.8	808.28
1	15.9	746.04	15	15.9	788.12
1	16	719.73	15	16	765.81
1	16.1	690.51	15	16.1	741.06
1	16.2	658.04	15	16.2	713.58
1	16.3	621.96	15	16.3	683.01
1	16.4	581.88	15	16.4	648.98
1	16.5	537.48	15	16.5	611.11
1	16.6	488.51	15	16.6	569.01
1	16.7	434.94	15	16.7	522.36
1	16.8	377.07	15	16.8	470.95
1	16.9	315.72	15	16.9	414.86
1	17	252.12	15	17	354.59
1	17.1	186.92	15	17.1	291.19
1	17.2	117.23	15	17.2	225.96
1	17.3	36.78	15	17.3	158.53

1	17.4	0	15	17.4	83.84
1	17.5	0	15	17.5	0
1	17.6	0	15	17.6	0
1	17.7	0	15	17.7	0
1	17.8	0	15	17.8	0
1	17.9	0	15	17.9	0
1	18	0	15	18	0
1	18.1	0	15	18.1	0
1	18.2	0	15	18.2	0
1	18.3	0	15	18.3	0
1	18.4	0	15	18.4	0
1	18.5	0	15	18.5	0
1	18.6	0	15	18.6	0
1	18.7	0	15	18.7	0
1	18.8	0	15	18.8	0
1	18.9	0	15	18.9	0
1	19	0	15	19	0
1	19.1	0	15	19.1	0
1	19.2	0	15	19.2	0
1	19.3	0	15	19.3	0
1	19.4	0	15	19.4	0
1	19.5	0	15	19.5	0
1	19.6	0	15	19.6	0
1	19.7	0	15	19.7	0
1	19.8	0	15	19.8	0
1	19.9	0	15	19.9	0

4.2 Solar radiation for the month of February

n	Solar time	Solar radiation	n	Solar time	Solar radiation
32	4	0	46	4	0
32	4.1	0	46	4.1	0
32	4.2	0	46	4.2	0
32	4.3	0	46	4.3	0
32	4.4	0	46	4.4	0
32	4.5	0	46	4.5	0
32	4.6	0	46	4.6	0
32	4.7	0	46	4.7	0
32	4.8	0	46	4.8	0
32	4.9	0	46	4.9	0
32	5	0	46	5	0
32	5.1	0	46	5.1	0
32	5.2	0	46	5.2	0
32	5.3	0	46	5.3	0
32	5.4	0	46	5.4	0
32	5.5	0	46	5.5	0
32	5.6	0	46	5.6	0
32	5.7	0	46	5.7	0
32	5.8	0	46	5.8	0
32	5.9	0	46	5.9	0
32	6	0	46	6	0
32	6.1	0	46	6.1	0
32	6.2	0	46	6.2	0
32	6.3	0	46	6.3	0
32	6.4	0	46	6.4	0
32	6.5	0	46	6.5	0
32	6.6	0	46	6.6	0
32	6.7	0	46	6.7	58.9
32	6.8	40.84	46	6.8	140.44
32	6.9	123.63	46	6.9	212.27
32	7	195.43	46	7	281.18
32	7.1	263.21	46	7.1	348.29
32	7.2	329.36	46	7.2	412.13
32	7.3	392.81	46	7.3	471.41
32	7.4	452.21	46	7.4	525.5
32	7.5	506.79	46	7.5	574.34
32	7.6	556.34	46	7.6	618.17
32	7.7	600.99	46	7.7	657.37
32	7.8	641.08	46	7.8	692.4
32	7.9	676.99	46	7.9	723.7
32	8	709.17	46	8	751.71
32	8.1	738.01	46	8.1	776.81
32	8.2	763.9	46	8.2	799.36

32	8.3	787.18	46	8.3	819.65
32	8.4	808.16	46	8.4	837.96
32	8.5	827.1	46	8.5	854.52
32	8.6	844.24	46	8.6	869.54
32	8.7	859.79	46	8.7	883.19
32	8.8	873.93	46	8.8	895.62
32	8.9	886.82	46	8.9	906.98
32	9	898.58	46	9	917.38
32	9.1	909.34	46	9.1	926.91
32	9.2	919.2	46	9.2	935.67
32	9.3	928.26	46	9.3	943.72
32	9.4	936.59	46	9.4	951.15
32	9.5	944.26	46	9.5	958
32	9.6	951.33	46	9.6	964.34
32	9.7	957.86	46	9.7	970.19
32	9.8	963.89	46	9.8	975.61
32	9.9	969.46	46	9.9	980.63
32	10	974.61	46	10	985.28
32	10.1	979.38	46	10.1	989.58
32	10.2	983.78	46	10.2	993.57
32	10.3	987.85	46	10.3	997.26
32	10.4	991.61	46	10.4	1000.68
32	10.5	995.08	46	10.5	1003.84
32	10.6	998.28	46	10.6	1006.75
32	10.7	1001.22	46	10.7	1009.43
32	10.8	1003.91	46	10.8	1011.89
32	10.9	1006.38	46	10.9	1014.15
32	11	1008.63	46	11	1016.21
32	11.1	1010.66	46	11.1	1018.08
32	11.2	1012.5	46	11.2	1019.77
32	11.3	1014.14	46	11.3	1021.28
32	11.4	1015.6	46	11.4	1022.63
32	11.5	1016.88	46	11.5	1023.81
32	11.6	1017.98	46	11.6	1024.84
32	11.7	1018.91	46	11.7	1025.7
32	11.8	1019.68	46	11.8	1026.42
32	11.9	1020.28	46	11.9	1026.99
32	12	1020.71	46	12	1027.41
32	12.1	1020.99	46	12.1	1027.68
32	12.2	1021.11	46	12.2	1027.81
32	12.3	1021.07	46	12.3	1027.8
32	12.4	1020.87	46	12.4	1027.64
32	12.5	1020.52	46	12.5	1027.34
32	12.6	1020	46	12.6	1026.89
32	12.7	1019.32	46	12.7	1026.29
32	12.8	1018.47	46	12.8	1025.55

32	12.9	1017.45	46	12.9	1024.65
32	13	1016.26	46	13	1023.59
32	13.1	1014.9	46	13.1	1022.38
32	13.2	1013.35	46	13.2	1021
32	13.3	1011.61	46	13.3	1019.45
32	13.4	1009.68	46	13.4	1017.73
32	13.5	1007.54	46	13.5	1015.82
32	13.6	1005.18	46	13.6	1013.72
32	13.7	1002.6	46	13.7	1011.43
32	13.8	999.79	46	13.8	1008.92
32	13.9	996.72	46	13.9	1006.2
32	14	993.39	46	14	1003.24
32	14.1	989.78	46	14.1	1000.03
32	14.2	985.87	46	14.2	996.56
32	14.3	981.64	46	14.3	992.82
32	14.4	977.06	46	14.4	988.77
32	14.5	972.1	46	14.5	984.4
32	14.6	966.75	46	14.6	979.68
32	14.7	960.95	46	14.7	974.58
32	14.8	954.68	46	14.8	969.08
32	14.9	947.89	46	14.9	963.14
32	15	940.53	46	15	956.71
32	15.1	932.54	46	15.1	949.74
32	15.2	923.85	46	15.2	942.2
32	15.3	914.4	46	15.3	934.01
32	15.4	904.11	46	15.4	925.11
32	15.5	892.86	46	15.5	915.41
32	15.6	880.56	46	15.6	904.84
32	15.7	867.07	46	15.7	893.28
32	15.8	852.25	46	15.8	880.62
32	15.9	835.93	46	15.9	866.71
32	16	817.92	46	16	851.4
32	16.1	798	46	16.1	834.52
32	16.2	775.91	46	16.2	815.84
32	16.3	751.37	46	16.3	795.13
32	16.4	724.06	46	16.4	772.11
32	16.5	693.61	46	16.5	746.47
32	16.6	659.62	46	16.6	717.85
32	16.7	621.69	46	16.7	685.85
32	16.8	579.38	46	16.8	650.04
32	16.9	532.32	46	16.9	609.97
32	17	480.27	46	17	565.19
32	17.1	423.24	46	17.1	515.33
32	17.2	361.68	46	17.2	460.2
32	17.3	296.69	46	17.3	399.96
32	17.4	229.71	46	17.4	335.35

32	17.5	160.62	46	17.5	267.8
32	17.6	84.2	46	17.6	198.58
32	17.7	0	46	17.7	125.5
32	17.8	0	46	17.8	41.24
32	17.9	0	46	17.9	0
32	18	0	46	18	0
32	18.1	0	46	18.1	0
32	18.2	0	46	18.2	0
32	18.3	0	46	18.3	0
32	18.4	0	46	18.4	0
32	18.5	0	46	18.5	0
32	18.6	0	46	18.6	0
32	18.7	0	46	18.7	0
32	18.8	0	46	18.8	0
32	18.9	0	46	18.9	0
32	19	0	46	19	0
32	19.1	0	46	19.1	0
32	19.2	0	46	19.2	0
32	19.3	0	46	19.3	0
32	19.4	0	46	19.4	0
32	19.5	0	46	19.5	0
32	19.6	0	46	19.6	0
32	19.7	0	46	19.7	0
32	19.8	0	46	19.8	0
32	19.9	0	46	19.9	0

4.3 Graphical representation of the hourly solar radiation variation for each month

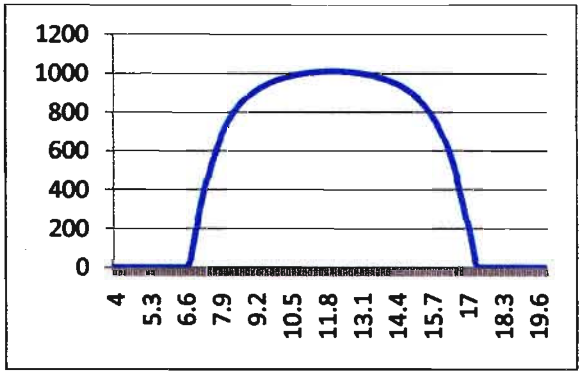

Figure 3: 1st January

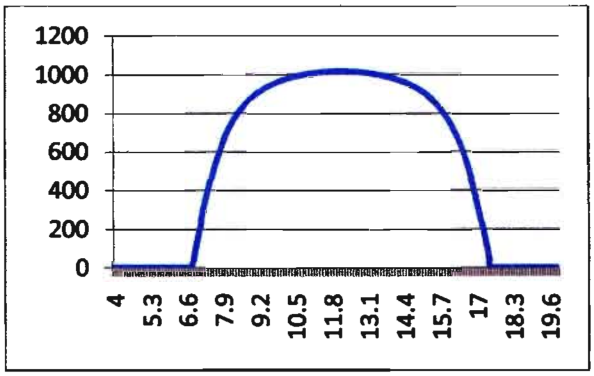

Figure 4: 15th January

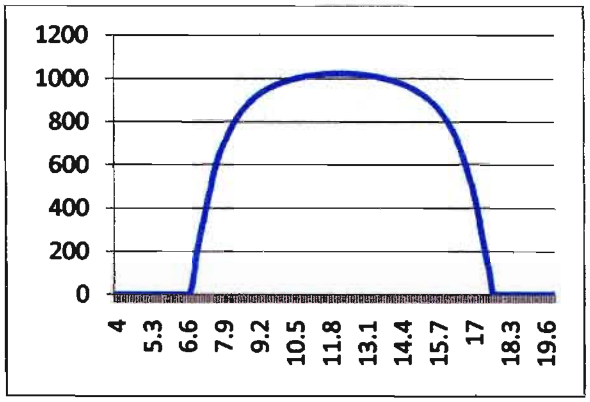

Figure 5: 1st February

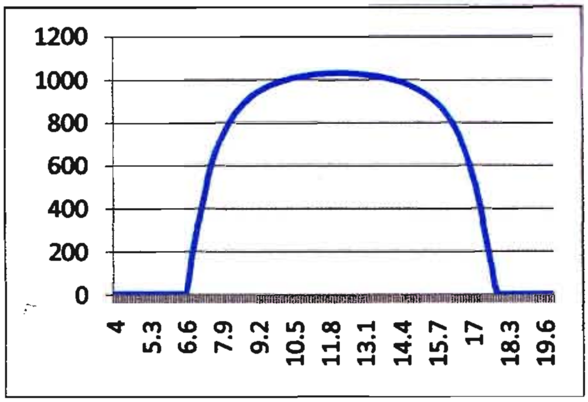

Figure 6: 15th February

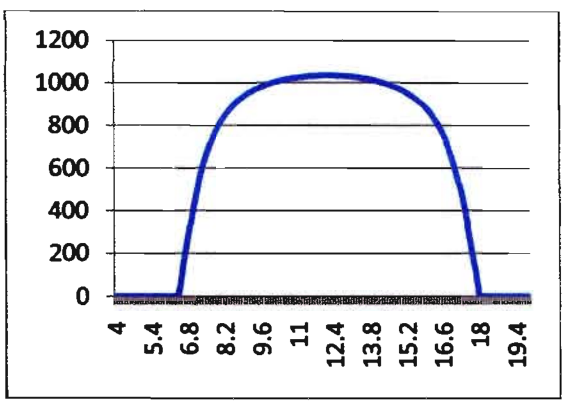

Figure 7: 1st March

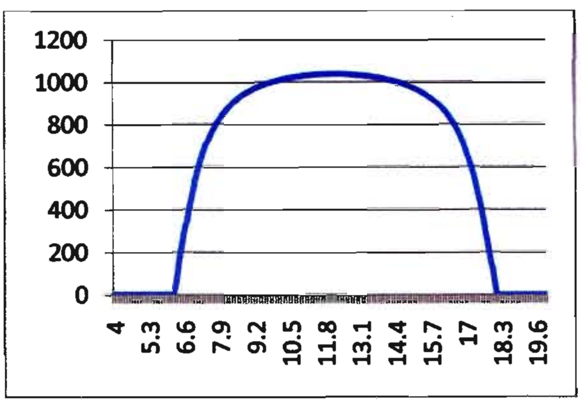

Figure 8: 15th March

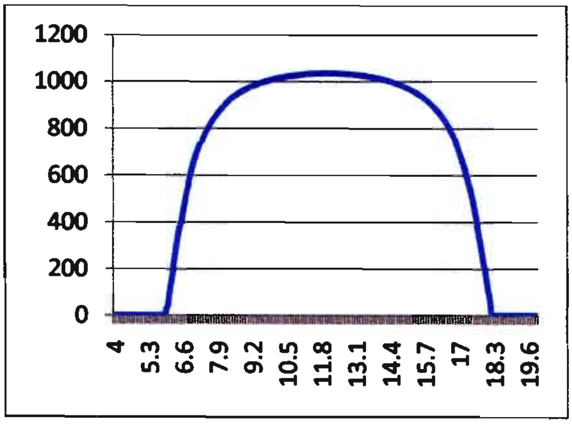

Figure 9: 1st April

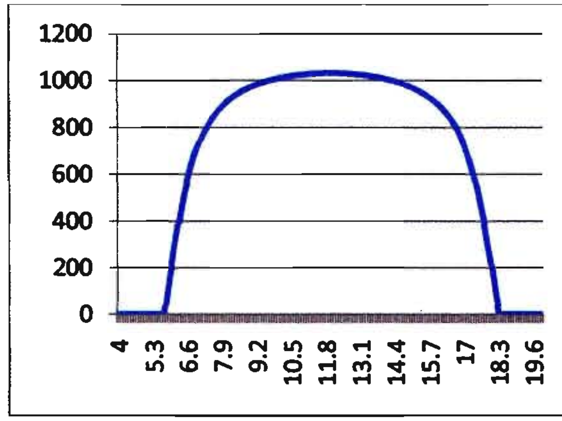

Figure 10: 15th April

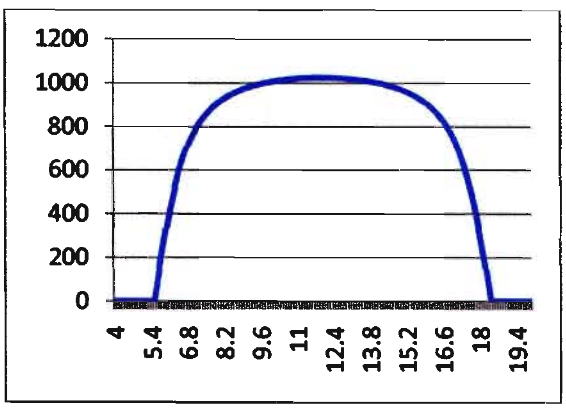

Figure 11: 1st May

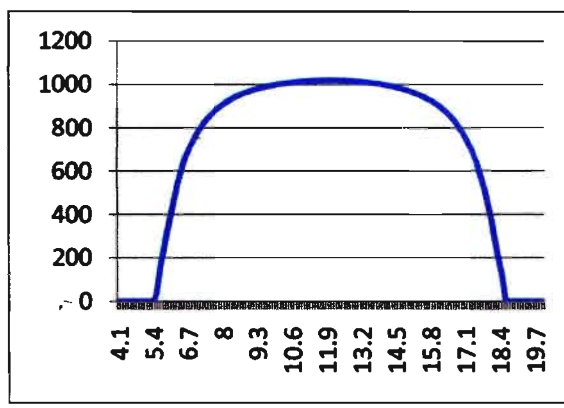

Figure 12: 15th May

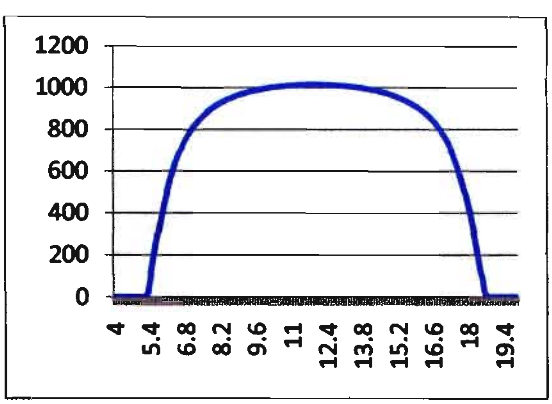

Figure 13: 1st June

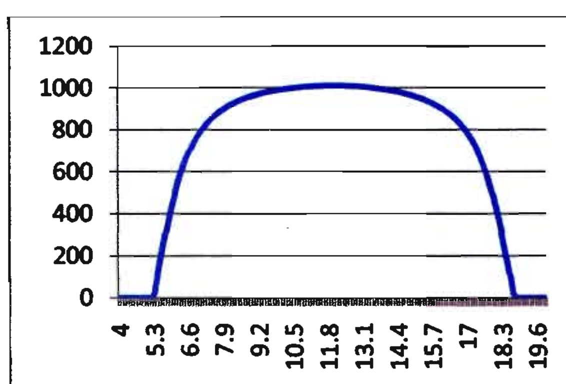

Figure 14: 15th June

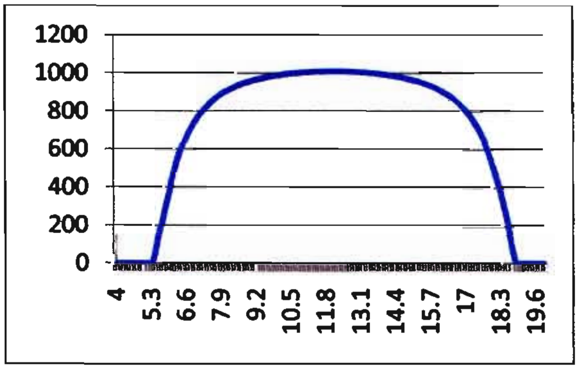

Figure 15: 1st July

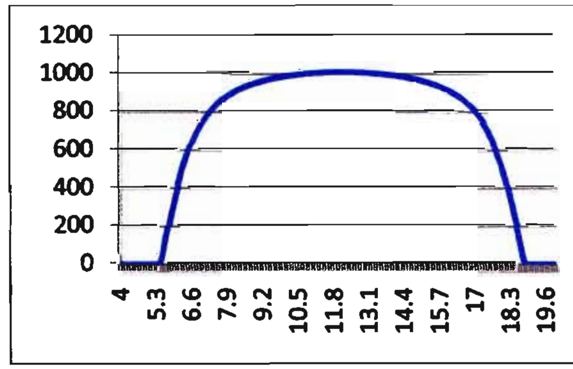

Figure 16: 15th July

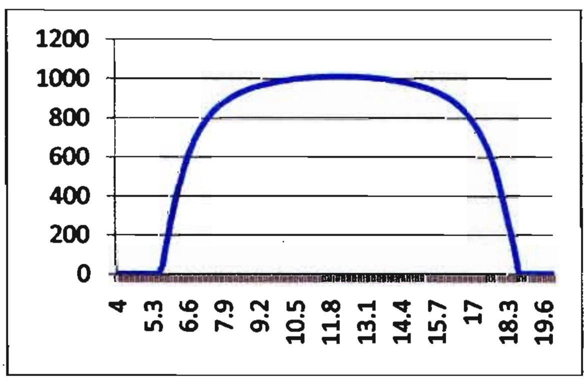

Figure 17: 1st August

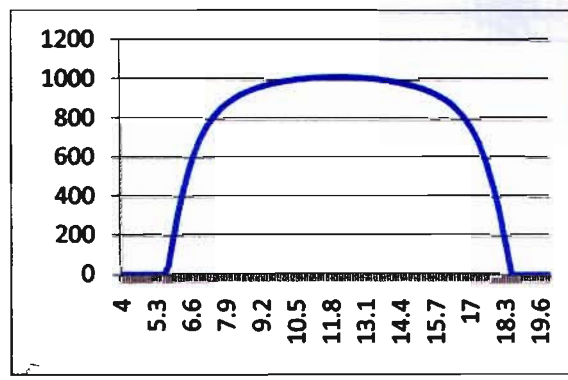

Figure 18: 15th August

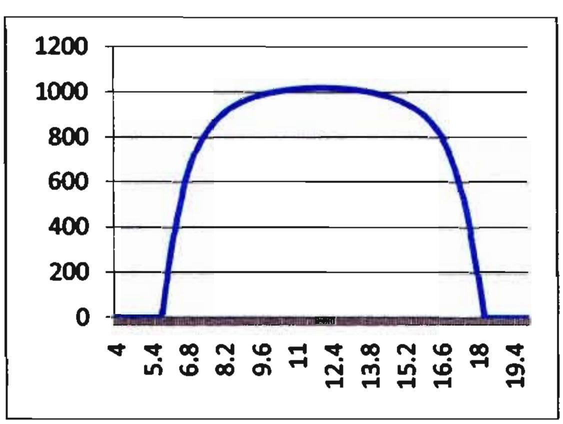

Figure 19: 1st September

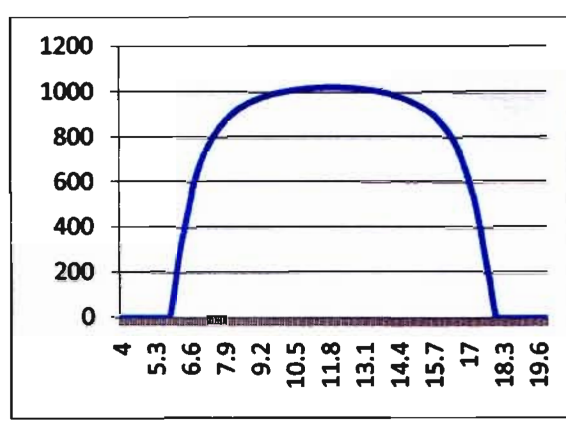

Figure20: 15th September

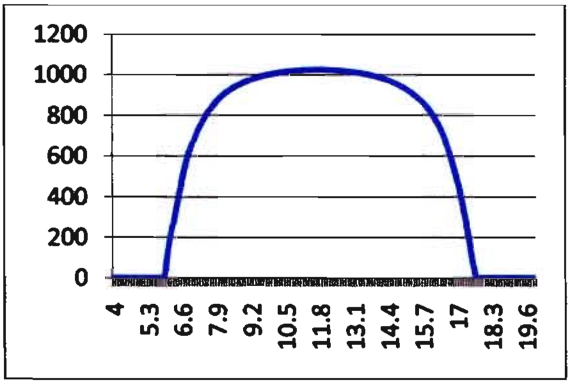

Figure 21: 1st October

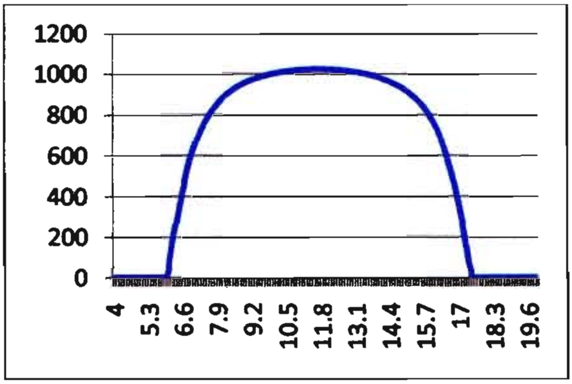

Figure 22: 15th October

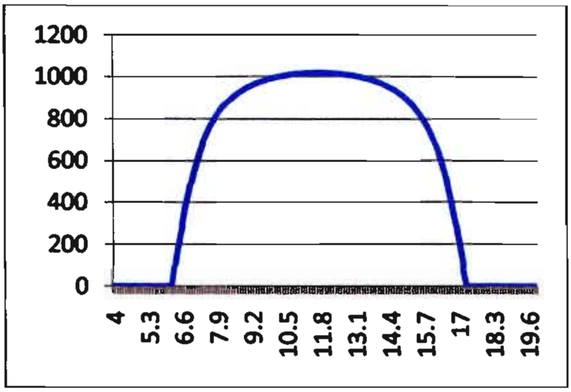

Figure 23: 1st November

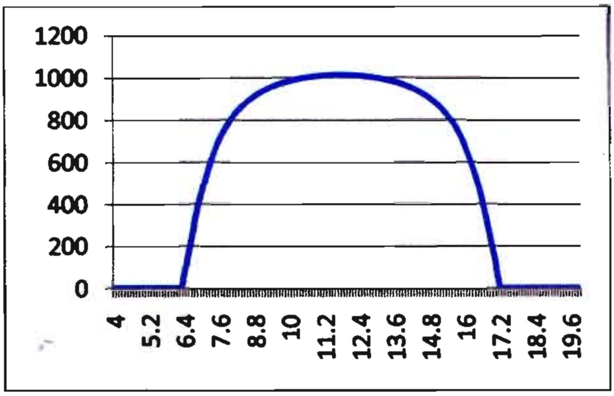

Figure 24: 15th November

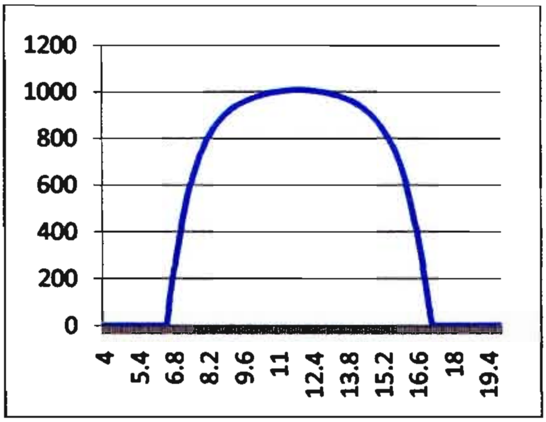

Figure25: 1st December

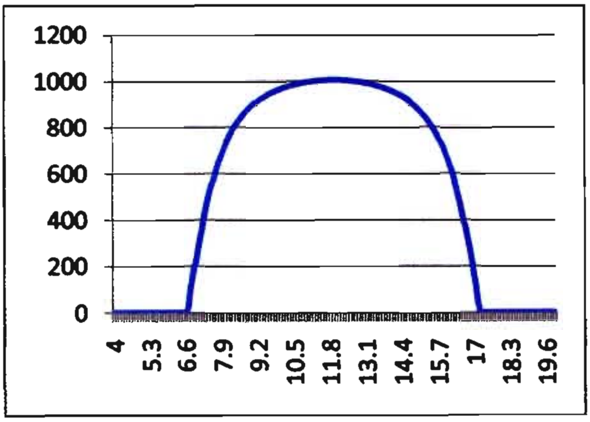

Figure 26: 15th December

CHAPTER FIVE

CONCLUSION

Here we collected our data at 4am to 7pm. At high noon, the angle at which the sun's ray strikes the earth's surface is most direct and sunlight feels hot. In this case we get more solar radiation at 12.00pm. At sunrise and sunset, the angle is less direct and the sunlight feels weak so we get less solar radiation.

The total amount of solar radiation received by a horizontal surface. This value includes both Direct Normal Irradiance and Diffuse Horizontal Irradiance.

Direct Normal Irradiance is solar radiation that comes in a straight line from the direction of the sun at its current position in the sky. Diffuse Horizontal Irradiance is solar radiation that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere and comes equally from all directions.

On a clear day, most of the solar radiation received by a horizontal surface will be Direct Normal Irradiance, while on a cloudy day most will be Diffuse Horizontal Irradiance.

Some factors that reduce the solar intensity:

- Atmospheric conditions also reduce the intensity of the sunlight before it reaches the surface of the earth. Air pollution and clouds may absorb up a percentage of the solar energy.
- Shadows from trees and other tall obstacles can reduce the efficiency of the system. Debris such as leaves and dust can also prevent the system from attaining accurate results.
- We get lowest reading is while the sun is just rising in the sky.

CHAPTER SIX

REFERENCES

[1] http://urbanpoverty.intellecap.com/?p=26

[2] http://www.baes-ltd.com/solar energy.html

[3] http://en.wikipedia.org/wiki/Renewable energy in Bangladesh

[4] M. H. Rahman, K. Nakamura, and S. Yamashiro "Development of a Distributed Power Generator of PV-ECS Using a Day-Ahead Weather Forecast," Proc. of *The Int. Conference on Electrical Engineering*, ICEE-126 (Pro. CD), Japan, July 2004.

[5] M. H. Rahman, J. Nakayama, K. Nakamura, and S. Yamashiro, "A Viable Grid-Connected PV-ECS System Using a Day-Ahead Weather Forecast," Proc. of *The Int. Conference on Power System Technology,* MB6.1 (Pro. CD), Singapore, Nov. 2004

[6] S. Rahman and B. D. Kroposki, "Photovoltaics and Demand Side Management Performance Analysis at a University Building," *IEEE Trans. on Energy Conversion*, vol. 8, no. 3, pp. 491-498, Sep. 1993.