

MICROCONTROLLER BASED MULTILEVEL SUN TRACKING SOLAR PV SYSTEM

**A report submitted to department of Electrical & Electronic
Engineering, BRAC University in fulfilment of the requirements for
Thesis work**

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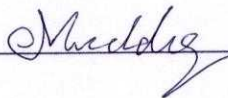
MICROCONTROLLER BASED MULTILEVEL SUN TRACKING SOLAR PV SYSTEM

DECLARATION

We do hereby declare that the thesis titled "Microcontroller based multilevel sun tracking solar PV system" is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfilment of the Bachelor of Science in Electrical and Electronics Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

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ABSTRACT

Electricity generation has now become a mammoth task for a country like Bangladesh while development is directly proportional to energy production. It is also posing a great threat to our climate. Moreover, country like Bangladesh is experiencing severe energy crisis, therefore we are emphasizing on solar PV as it is renewable and climate friendly. This paper aims to make effective use of solar panels so that these solar panels can be used in urban areas with less space. The usual method of setting solar panels is inefficient and requires a lot of space to generate sufficient power for urban areas. This project aims at this problem and can be a solution to this. This paper is on multilevel solar panels organized in a modified and modern structure to minimize the floor area and maximize power generation through tracking the sun. This is a microcontroller based automatic system which can track the sun and change the position of the panels by horizontal rotation and sliding mechanism to maximize power generation throughout the day. This could be a solution for rooftop space problem in urban areas.

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TABLE OF CONTENTS

	PAGE
TITLE	01
DECLARATION.....	02
ABSTRACT.....	03
ACKNOWLEDGEMENTS.....	04
TABLE OF CONTENTS.....	05
1.1 INTRODUCTION.....	08
1.2 SYSTEM DESCRIPTION.....	09
1.2.1 MULTILEVEL SYSTEM.....	11
1.2.1.1 PANEL SELECTION AND SIZE.....	11
1.2.1.2 ORGANIZING PANELS ANDSETTING.....	12
1.2.2 SUN TRACKER.....	13
1.2.2.1 HORIZONTAL AXIS SUNTRACKER.....	13
1.2.2.2 VERTICAL AXIS SUNTRACKER.....	14
1.2.2.3 TILTED AXES SUN TRACKER.....	14
1.2.2.4 TWO AXES MOUNT SOLAR TRACKER.....	15
1.2.2.5 OUR PROJECT AND TRACKING SYSTEM.....	15
1.2.3 CONTROL UNIT AND ITS OPERATION.....	16
1.2.3.1 HOW THE SUN POSITION IS CALCULATED.....	16
1.2.3.2 FINDING OUT THE HOUR ANGLE OF ROTATION.....	17
1.2.4 SERVO MOTOR.....	18
1.2.5 GLIDING MECHANISM AND ITS OPERATION.....	19

1.3 OVEVIEW OF A COMPLETE STANDALONE MULTI-LEVEL PHOTO-VOLTAIC SYSTEM.....	21
1.4 DESIGNING THE SYSTEM.....	22
1.4.1 FINDING OUT THE DISTANCE BETWEEN TWO PANELS.....	23
1.4.1.1 MATLAB CODE FOR FINDING OPTIMUM DISTANCE.....	25
1.4.2 FINDING OUT THE GLIDING DISTANCE.....	27
1.4.3 FINDING OUT THE TILT OR INCLINATION ANGLE.....	27
1.4.4 MOTOR SELECTION OF SUITABLE TORQUE AND POWER.....	29
1.5 EFFICIENCY OF THE SYSTEM.....	31
1.5.1 FINDING SOLAR ENERGY FALLEN ON A PANEL.....	31
1.5.1.1 CALCULATING TOTAL ENERGY FALLEN ON A ROTATING PANEL IN A DAY.....	32
1.5.1.2 CALCULATING TOTAL ENERGY FALLEN ON A FIXED PANEL IN A DAY.....	34
1.6 FUTURE DEVELOPMENT.....	37
1.7 CONCLUSION.....	38
1.8 REFERENCES.....	39

LIST OF TABLES

1.1.1 DAYTIME AND ALTITUDE FOR DHAKA THROUGHOUT THE YEAR.....	27
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LIST OF FIGURES

1.1.1 COMPLETE STRUCTURE OF THE SYSTEM.....	10
1.1.2 MULTILEVEL STRUCTURE OF THE SYSTEM.....	12
1.1.3 HORIZONTAL AXIS SUN TRACKER.....	13
1.1.4 TILTED AXES SUN TRACKER.....	14
1.1.5 CIRCUIT OF THE CONTROL UNIT.....	16

1.1.6 DIFFERENT SOLAR ANGLES.....	17
1.1.7 SIDEVIEW OF THE GLIDING MECHANISM OF THE SYSTEM.....	19
1.1.8 A COMPLETE SOALR PV SYSTEM USING OUR DESIGN.....	21
1.1.9 FINDING DISTANCE BETWEEN TWO PANLES.....	23
1.1.10 TOTAL DISTANCE Vs ALTITUDE ANGKE CURVE.....	26
1.1.11 FINDING OUT TORQUE.....	29
1.1.12 MATLAB CODE.....	32
1.1.13 MATLAB CODE.....	33
1.1.14 EFFECTIVE AREA CALCULATION.....	34
1.1.15 MATLAB CODE.....	35

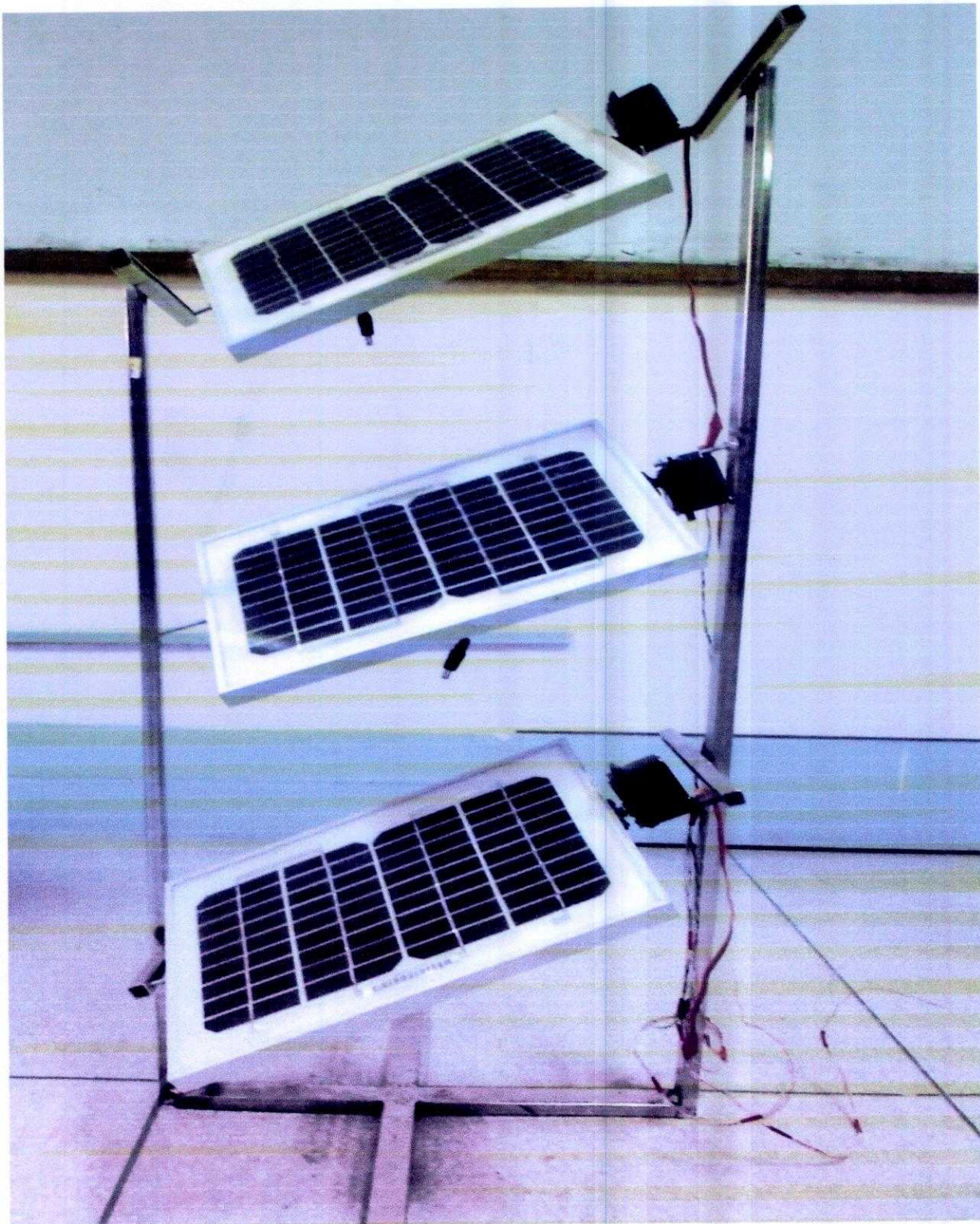
1.1 INTRODUCTION

One of the major concern of today's world is 'Energy production' more specifically 'Clean Energy Production' and that is why scientists throughout the world are now moving towards renewable energy. Because, it is easy to use, more sustainable than any other energy sources and very safe to our environment as it doesn't emit Greenhouse gases. For a developing country like Bangladesh, the demand for electricity is increasing every minute. But the production is way behind than our demand and it is also dependent on fossil fuel which emits a lot of greenhouse gases. To fulfil this ever increasing demand we need to go for other energy sources and solar energy is one of them. As we are tropical country, we have a lot of solar radiation throughout the year. Annual amount of radiation varies from 1840 to 1575 kwh/m² which is 50-100% higher than in Europe. Taking an average solar radiation of 1900 kWh per square meter, total annual solar radiation in Bangladesh is equivalent to $10^{10} \times 10^{18}$ J. [1]. Therefore we could use this vast amount of resources by implementing solar photo-voltaic systems. But the conventional PV modules are less efficient and they require a lot of floor space. In urban areas the energy demand is sky high but there is a shortage of space as most of the buildings are now high-rise apartments. So space is a major concern for setting up solar PV modules in urban areas where rooftop space is small. For solving this problem this paper describes a way for setting up PV modules in a modern and scientific way.

The system described here is consisting of PV solar module, modified horizontal axis tracking and a special sliding mechanism along with a modern structure. The whole system is completely automatic controlled by a micro-controller. Special motors have been used to perform the tracking and sliding mechanism throughout the day. This is a multi-level system of three PV modules stacking one above another as in figure-(1) to minimize the space. Here three panels can be operated in a space of two and the tracking and sliding makes it more efficient than fixed panel system. So this system could be used in urban areas quite efficiently where rooftop space is limited to and more power is needed as both are satisfied in it.

1.2 SYSTEM DESCRIPTION

Solar panels collect solar radiation from the sun and actively convert or transform that energy to electricity. Solar panels are comprised of several individual solar cells which function similarly. The more the number of solar panels used, the more is the output of electricity generated. Since it is not always possible to keep enough space for solar panels on buildings' rooftops, we are trying to design such solar panels system that the space used is less for installation but electricity generation will be more by using multiple solar panels in a rack. Providing electricity to each flat in a high-rise building will require many solar panels for electricity generation and this can be achieved by using our system.



1.1.1 Figure: Complete structure of the system

According to the name of our project, “Microcontroller based multilevel sun tracking solar PV system”, it has five major aspects. These are:

- Multilevel system
- Sun tracker
- Control unit
- Servo motor
- Gliding mechanism

1.2.1 Multi-level system

Multi-level structure contains three panels just one above another. This is done in the following manner.

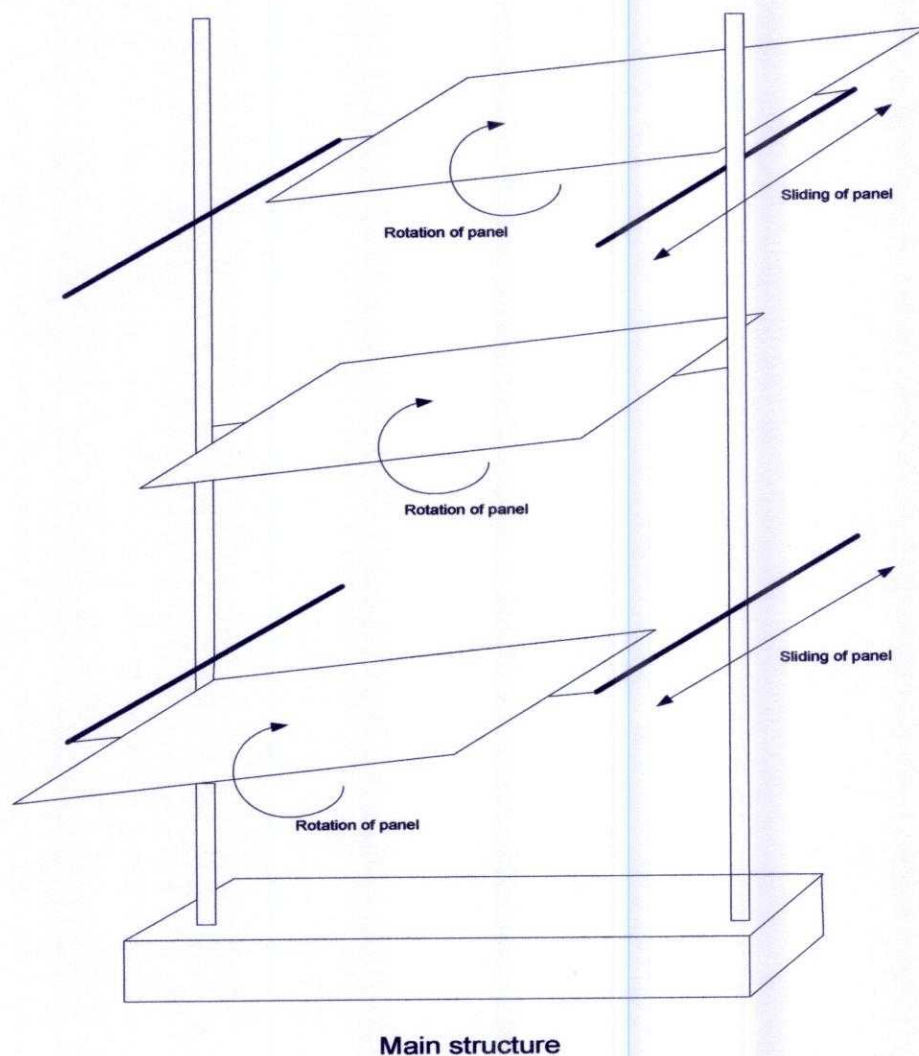
1.2.1.1 Panel selection and size

There are different types of solar panels available in the market. But in our project we have chosen polycrystalline solar panel with solid structure for its low price, availability in the market and these are easy to work with. Our panels will be all 100 watt each. The dimension is:

Length: 1245 mm.

Width: 668 m

1.2.1.2 Organizing panels and setting



1.1.2 Figure: Multi-level structure of the system

In this project we are going to use three panels at a time (each 100 watts) all together in a rack one above another. This will be done in a well-defined structure. The intermediate distance between panels will be kept such that the shadow of upper panel does not fall on the lower one. Again the panels can have a gliding mechanism when shadow occurs to minimize shadow and giving proper light to the lower panels. This will be controlled by a microcontroller based

controller. Each and every panel will be supported by a servo motor to have the rotation around the horizontal axis to have maximum sun light. Rotation of these motors will be controlled by another micro controller based controller on the basis of solar hour angle.

The panels will be set up on a frame that will hold all the panels' one above another. The distance between two panels will be kept as same as their width to have limited shadow on lower panels when the sun is up over head.

1.2.2Sun tracker

There are different types of sun trackers found. These are used for special purposes. Some of these tracking systems are discussed below:

1.2.2.1 Horizontal axis sun tracker:

The axis of rotation for horizontal single axis tracker is horizontal with respect to the ground. The posts at either end of the axis of rotation of a horizontal single axis tracker can be shared between trackers to lower the installation cost. Field layouts with horizontal single axis trackers are very flexible. The simple geometry means that keeping the entire axis of rotation parallel to one another is all that is required for appropriately positioning the trackers with respect to one another.



1.1.3 Figure: Horizontal axis sun tracker

1.2.2.2 Vertical axis sun tracker:

The axis of rotation for vertical single axis trackers is vertical with respect to the ground. These trackers rotate from East to West over the course of the day. Such trackers are more effective at high latitudes than are horizontal axis trackers. Field layouts must consider shading to avoid unnecessary energy losses and to optimize land utilization. Also optimization for dense packing is limited due to the nature of the shading over the course of a year.

1.2.2.3 Tilted axes sun tracker:

All trackers with axes of rotation between horizontal and vertical are considered tilted single axis trackers. Tracker tilt angles are often limited to reduce the wind profile and decrease the elevated end's height off the ground. Field layouts must consider shading to avoid unnecessary losses and to optimize land utilization. With backtracking, they can be packed without shading perpendicular to their axis of rotation at any density. However, the packing parallel to their axis of rotation is limited by the tilt angle and the latitude.



1.1.4 Figure: Tilted axis sun tracker

1.2.2.4 Two axes mount solar tracker:

Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. The axis that is fixed with respect to the ground can be considered a primary axis. The axis that is referenced to the primary axis can be considered a secondary axis.

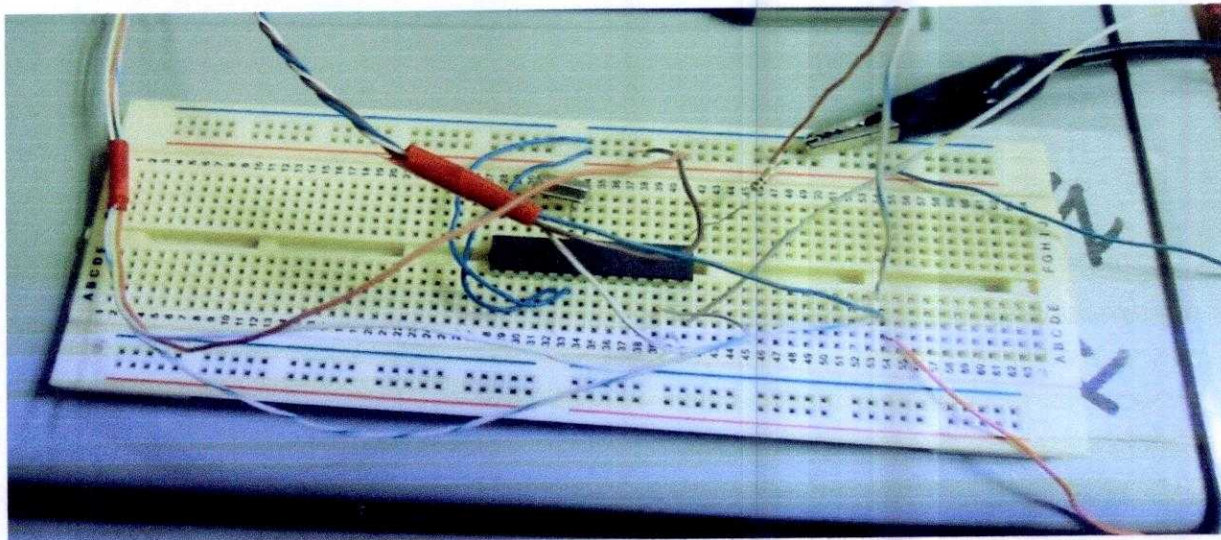
1.2.2.5 Our project and tracking system

In our project we are going to use the “Tilted-Axes tracking system” though it has some limitations in winter. That means our panels will rotate only around a tilted axis to track the sun's position throughout the day. These trackers are tilted at a particular angle; therefore it gives best tracking result and power in a particular season. If the tilt angle is close to the latitude then the system would be more productive in summer and if it is 15 degree greater than latitude then it is designed for winter specially. In our country more power problem happens in summer when load-shedding is on the peak. So we are making the system summer efficient. The calculation of the tilt angle or inclination is given later.

A single control unit and several motors will be used to actuate multiple rows of panels for active mechanisms. As we have multiple panels in our system, this tracking system gives us more simplicity and flexibility to work. And to avoid the problem during winter we can choose an inclination angle with vertical to set the panels which is for Bangladesh approximately 23 degree (**latitude**). So every panel used in our system will rotate around an axis which will be inclined at an angle about 23 degrees to the vertical. The rotation of all the panels will be controlled by a micro controller chip mounted on the system.

1.2.3 Control unit and its operation

A control unit consisting of a micro controller chip, an oscillator and few other electronic components. Micro-controller has been programmed such a way that it takes time and day number as input and calculates the particular time's sun position.



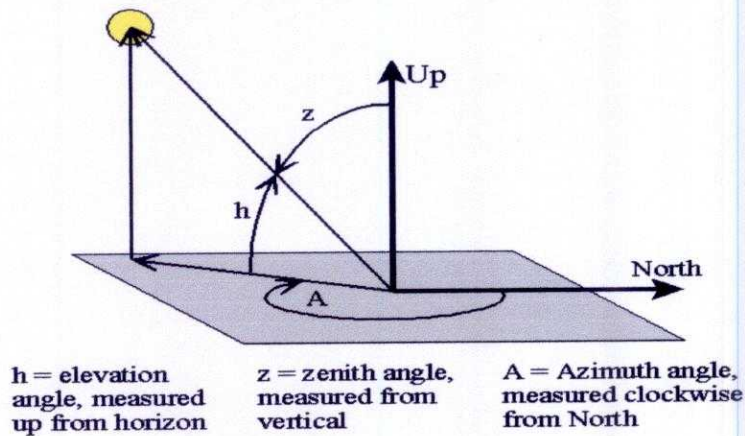
1.1.5 Figure: Circuit of the control unit

1.2.3.1 How sun position is calculated

There are different ways of calculating sun position. Here in our project we will use elevation, azimuth, solar hour angle and sun rise & set time equations to find out the sun position and rotate the panels.

Elevation angle or altitude: Angle measured up from the horizon.

Azimuth: Angle measured clock wise from the north.



1.1.6 Figure: Different solar angles

Solar Hour Angle: How much degree angle the sun goes in an hour in a certain time is called solar hour angle and it is approximately 15 degree.

In our project we are just using the solar hour angle for controlling rotation of the panels. For a particular time of a day, sun position can be found by using the following equation:

1.2.3.2 Finding out hour angle for rotation

Latitude, $\varphi = 23.7^\circ$

Declination angle, $\delta = 23.45^\circ \times \sin B$ where, $B = \frac{(n+284)360}{365}$

Sun rise angle, $\omega_s = -\cos^{-1}(-\tan\varphi \times \tan\delta)$

Total daylight hour, $DH = \frac{48}{360} \times \omega_s$

THEREFORE ANGULAR ROTATION PER HOUR $\theta = \frac{\omega_s}{DH}$ DEGREE

Starting time of rotation = sun rise time

Stopping time of rotation and reset= sun set time

Hour between solar noon and sun rise-set time = $\frac{\omega_s}{15}$

Equation of time $ET = 9.83 \sin(2D) - 7.53 \cos(D) - 1.5 \sin(D)$ Where, $D = \frac{n-80}{365} \times 360$

Sun rise time in actual solar time (AST) = $720 \text{ mins} + \omega_s \times (4 \text{ mins/deg})$

Sun rise time in local solar time (LST) = $AST - (4 \text{ mins})(LSTM - \text{longitude}) - ET$

Where, LSTM = local solar time meridian

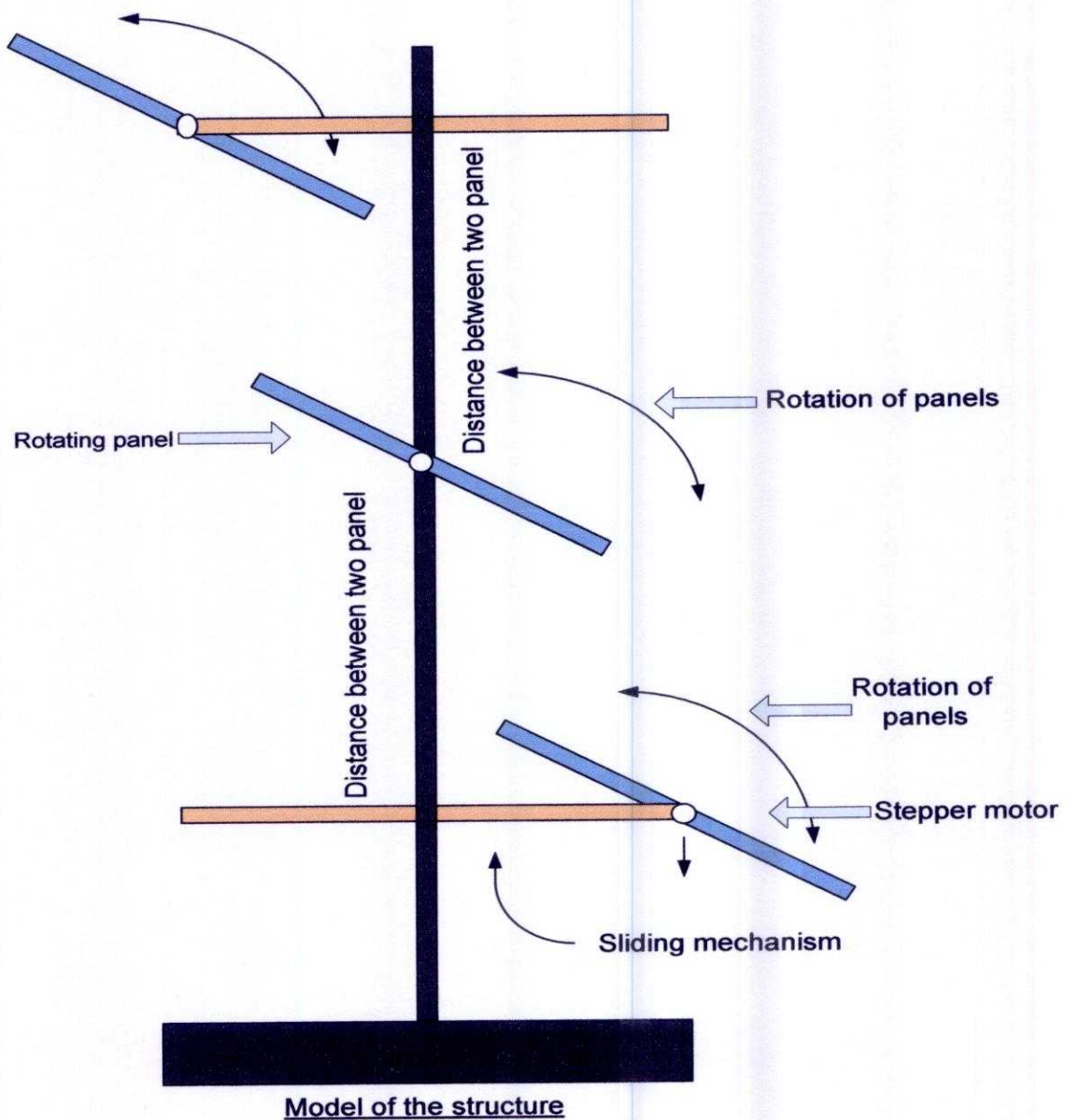
And LSTM = $15^\circ \times \left(\frac{\text{longitude}}{15} \right)$ round to integer

So micro-controller will calculate solar hour angle for a particular day and time and then send the command to servo motor to rotate that particular angle after one hour. Micro-controller will also calculate sun rise and set time from the above equations to start and stop the rotation and reset the panels for the next day after sunset.

1.2.4 Servo motor

We are using three servo motors to rotate the panels which are run by the power generated by the solar panels. It is an alternative of stepper motor. We are controlling the servo motor with the microcontroller.

1.2.5 Gliding mechanism and its operation

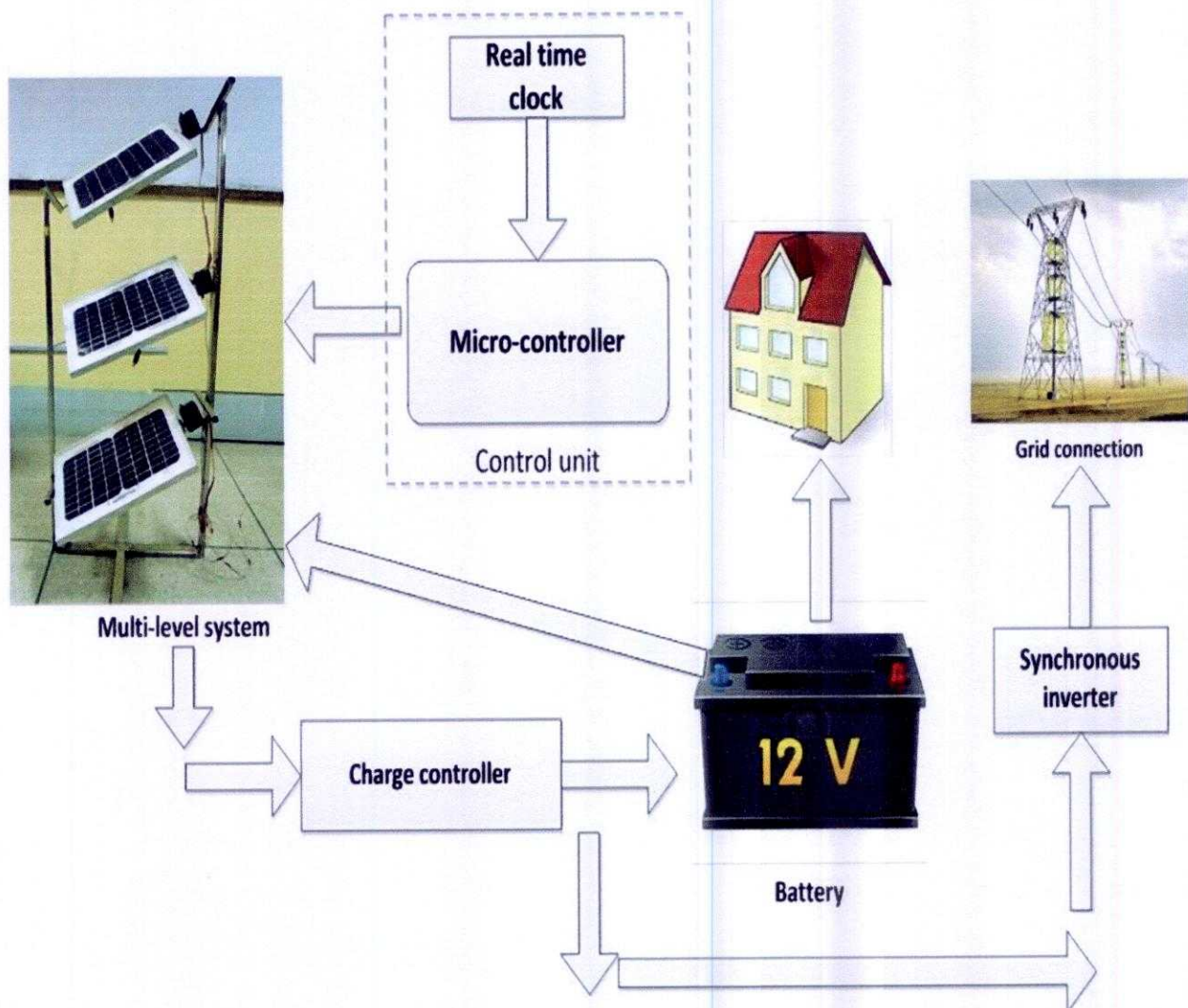


1.1.7 Figure: Side view and gliding mechanism of the system

This is a special mechanism that includes both ways gliding of the panel. The upper and lower panels can move freely over a steel frame for a certain distance. The distance of gliding is a compromise between surface area and cost. As we want to minimize the surface area the distance should be as minimum as possible. Further calculation is shown in the design part.

As described before the panels are set one above another at a fixed distance between them, therefore after a certain period of time in day sun will make an angle with respect to horizontal that will cause shadow effect. The shadow will increase as the angle increases further. The lower two panel will experience this shadow. Now if the panels glide like the figure above until the solar meridian and then reverse the direction of gliding then the shadow will be minimized greatly.

1.3 OVERVIEW OF A COMPLETE STANDALONE MULTI-LEVEL PHOTO-VOLTAIC SYSTEM



1.1.8 Figure: A complete solar PV system using our design

1.4 DESIGNING THE SYSTEM

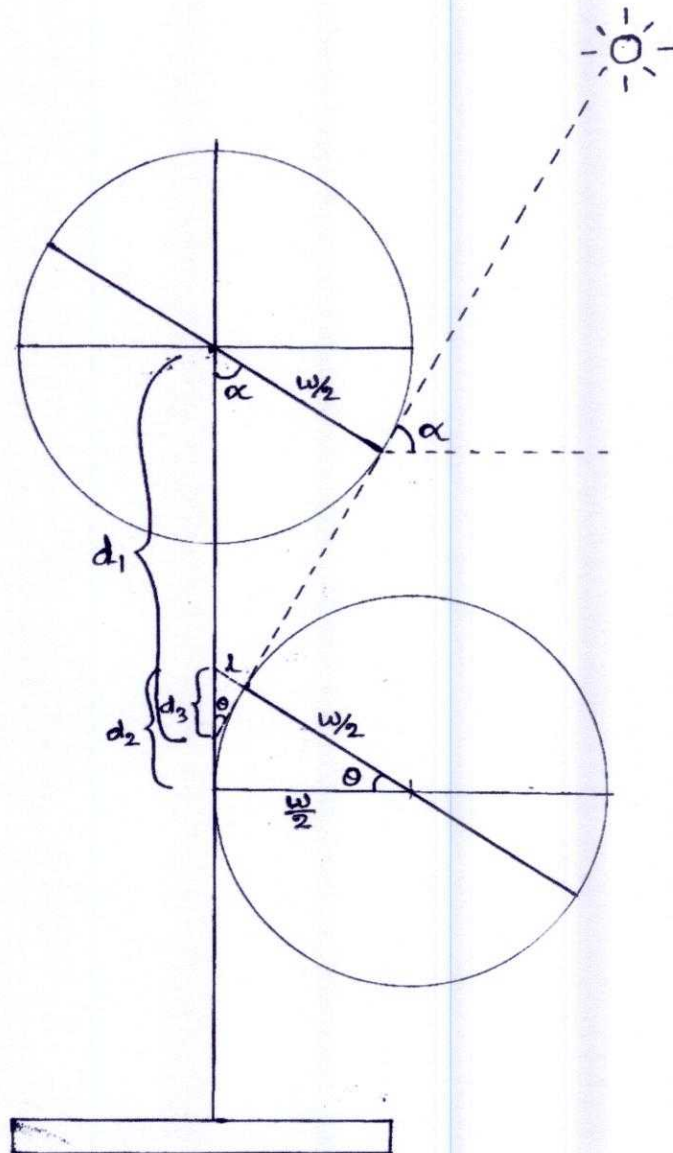
Designing of the system requires a bit complex calculations. First of all we need to look at the obstacles that hinder the design process.

First of all comes the distance between two panels. That means how much and how long solar radiation will be allowed to the 2nd and 3rd panel. The distance between two panel is proportional to the time span of solar radiation without shadow. If the distance is increased longer time of no shadow will occur and vice versa.

Secondly the tilting angle or the inclination angle of the rotation axis is another concern. As the declination angle of the sun varies round the year seasonally. So this is very important to adjust the tilt angle to have desired power in the desired season.

Thirdly the gliding distance has to be calculated in a way that will give an optimum space area and give no shadow span longer.

1.4.1 Finding out the distance between two panels



1.1.9 Figure: Finding distance between two panels

Here in this figure,

$$w = \text{width of the panel} = 668\text{mm} = .668\text{m}$$

$$\alpha = \text{altitude angle of sun w.r.t horizontal} \\ = 90^\circ - \theta$$

Now,

$$d1 = \frac{w}{2\sin\theta}$$

$$d2 = \frac{w \times \tan\theta}{2}$$

$$\left(\frac{w}{2} + l\right) = \frac{d2}{\sin\theta}$$

$$\therefore l = \frac{d2}{\sin\theta} - \frac{w}{2}$$

$$= \frac{w \tan\theta}{2\sin\theta} - \frac{w}{2}$$

$$= \frac{w}{2\cos\theta} - \frac{w}{2}$$

$$= \frac{w(1-\cos\theta)}{2\cos\theta}$$

$$d3 = \frac{l}{\sin\theta}$$

$$= \frac{w(1-\cos\theta)}{2\sin\theta\cos\theta}$$

And finally we get,

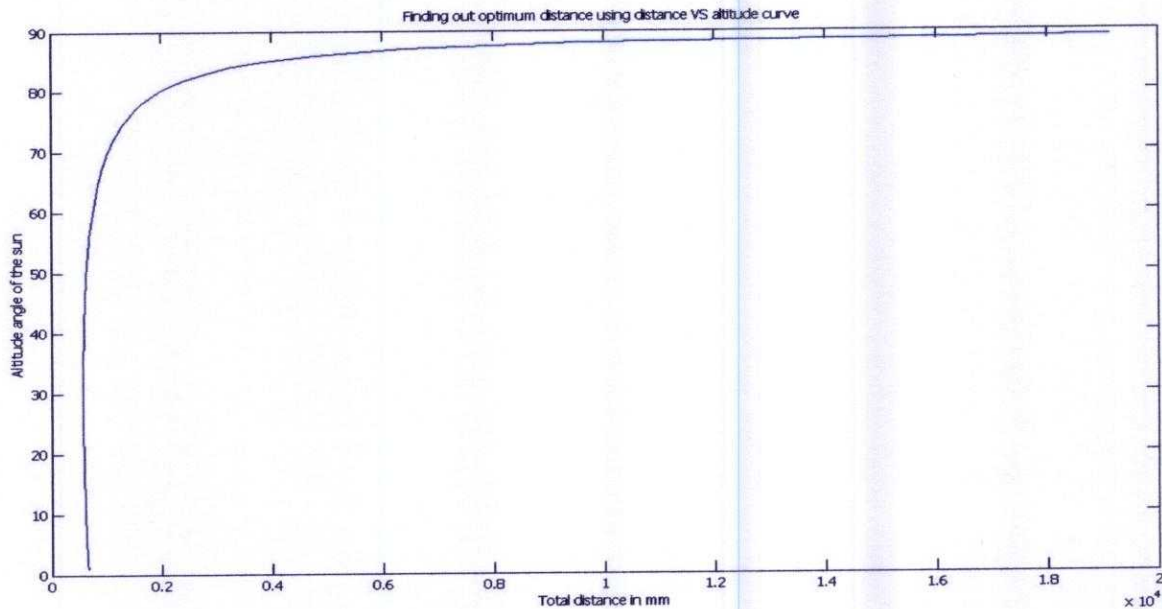
Total distance between two panels, $D = d1 + d2 - d3$

$$= \frac{w}{2\sin\theta} + \frac{w\tan\theta}{2} - \frac{w(1-\cos\theta)}{2\sin\theta\cos\theta}$$

1.4.1.1 Mat-lab code for finding optimum distance

%%finding out optimum distance using distance VS altitude curve%%

```
w=668;    %% width of the panel in mm  %%  
α=1:90;   %% altitude angle of sun w.r.t horizon = alpha(α)  %%  
  
d1=(1./(2.*sin((90-α)*pi/180))).*w;  
d2=((tan((90-α)*pi/180))./2).*w;  
d3=((1-cos((90-α)*pi/180))./(2.*sin((90-α)*pi/180).*cos((90-α)*pi/180))).*w;  
  
D=d1+d2-d3; %% total distance between two panel in mm  %%  
  
plot(D,α)
```



1.1.10 Figure: Total distance VS altitude angle curve

This plot shows us that the optimum distance lies between $\alpha = 60^\circ \rightarrow 80^\circ$

If we increase α more than 80° then there would be a huge increase in the distance D , which is very inefficient for the system.

For $\alpha = 60^\circ$ $D = 757.495 \text{ mm}$ 13.4% more than $w(668\text{mm})$

For $\alpha = 65^\circ$ $D = 864.3573 \text{ mm}$ 29.4% more than $w(668\text{mm})$

For $\alpha = 70^\circ$ $D = 1035.44 \text{ mm}$ 55% more than $w(668\text{mm})$

So we are choosing $\alpha (\text{final}) = 65^\circ$

Where $\alpha (\text{initial}) = 0^\circ$

1.4.2 Finding out the gliding distance

From the above calculations it is clear that if we keep the gliding distance to half of the panel width for both side then will get full shadow on the lower two panels for $\alpha = 65^\circ$ to 115° . for other angles we will get full radiation. So the distance is kept equal to the half width of a panel.

Gliding distance, $D = .668 \times .5 = .334$ meter

1.4.3 Finding out the tilt or inclination angle

For fixing up a fixed “Tilt or inclination angle” for a particular place we need to arrange a set of data for elevation angle or altitude for that particular place and choose a moderate value from there. In our project we have chosen Dhaka city and collected altitude angle for every month of a year. Here we used three values of altitude of day 1, 15 and 30 of every month to get average altitude of a month (data taken at solar noon). Following table shows those data:

1.1.1 Table: Day time and altitude for Dhaka throughout the year

Month	Day no.	Day time in hour	Solar noon altitude	Average day time in hour	Average solar noon altitude
January	1	10h 41m 31s	43.1°	10h 51m	45.5°
	15	10h 48m 59s	44.9°		
	30	11h 03m 31s	48.4°		
February	1	11h 04m 36s	48.9°	11h 21m	53.4°
	15	11h 21m 06s	53.3°		
	28	11h 38m 08s	58.0°		
	1	11h 40m 51s	58.7°		

March	15	12h 00m 11s	64.2°	12h	64.5°
	30	12h 21m 05s	70.5°		
April	1	12h 23m 51s	70.9°	12h 42m	76°
	15	12h 42m 45s	76.1°		
	30	13h 01m 34s	81.1°		
May	1	13h 02m 45s	81.4°	13h 15m	88.9°
	15	13h 17m 42s	85.1°		
	30	13h 29m 39s	88.1°		
June	1	13h 30m 50s	88.3°	13h 33m	89°
	15	13h 36m 06s	89.5°		
	30	13h 35m 17s	89.3°		
July	1	13h 35m 00s	89.2°	13h 25m	87.1°
	15	13h 28m 01s	87.6°		
	30	13h 15m 22s	84.5°		
August	1	13h 13m 21s	84.1°	12h 55m	79.7°
	15	12h 57m 42s	80.1°		
	30	12h 38m 45s	75.0°		
September	1	12h 36m 06s	74.3°	12h 16m	68.3°
	15	12h 17m 12s	69.0°		
	30	11h 56m 36s	63.2°		
October	1	11h 55m 14s	62.8°	11h 36m	57.5°
	15	11h 36m 19s	57.5°		
	30	11h 17m 11s	52.2°		
November	1	11h 14m 47s	51.6°	11h	47.9°
	15	10h 59m 25s	47.6°		
	30	10h 47m 00s	44.5°		
December	1	10h 46m 22s	44.3°	10h 42m	43.3°
	15	10h 40m 31s	42.9°		
	30	10h 41m 26s	43.0°		

From this table we can get a average value of altitude. So the average altitude will be,
Average altitude= $(45.5+53.4+64.5+76+88.9+89+87.1+79.7+68.3+57.5+47.9+43.3)/12$
 $=66.76^\circ$

So, inclination angle of panel= $(90^\circ-66.76^\circ) = 23.24^\circ$

In figure (1) all the panels are inclined at 23.24° to minimize the seasonal effect.

1.4.4 Motor selection of suitable torque and power

From the figure it is clear that we always need to rotate half of panel upward where we need to apply some force. The rest half of the panel will automatically go downward due to the gravitational force.

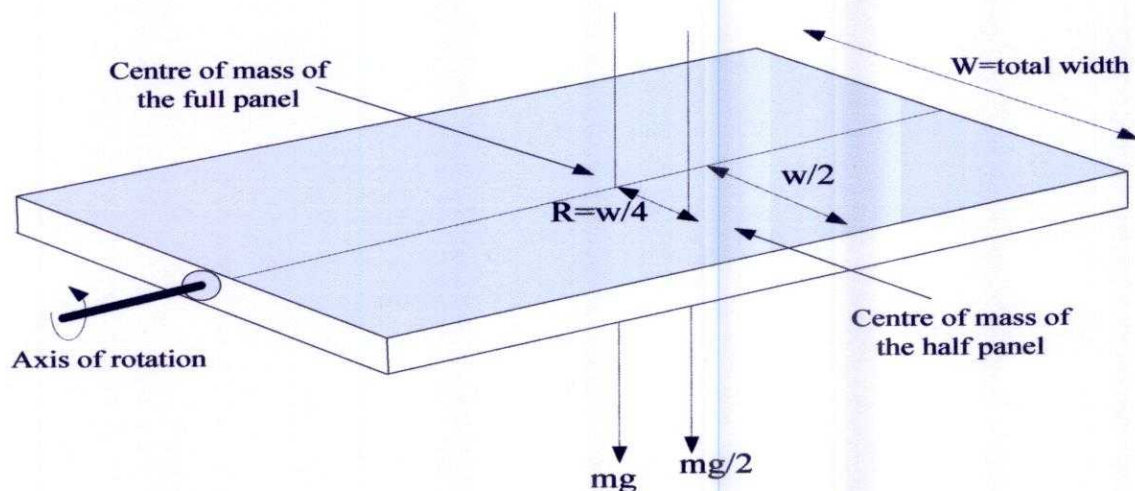


Fig -Finding the torque needed to rotate

1.1.11 Figure: Finding out torque

Here,

Mass of the panel $m = 11.6 \text{ kg}$

$$g = 9.8 \text{ m s}^{-2}$$

$$r = \frac{w}{4} = \frac{668}{4} = .167 \text{ m}$$

We know,

$$\begin{aligned}\text{Torque, } \tau &= fr \\ &= \frac{mgr}{2} \\ &= \frac{11.6 \text{ kg} \times 9.8 \text{ m s}^{-2} \times .167 \text{ m}}{2} \\ &= 9.5 \text{ Nm}\end{aligned}$$

Now we need find a suitable stepper motor to supply this amount of power. Therefore we need to calculate the power needed to supply this torque.

Let's consider a motor of $RPM = 60$

We know,

$$\text{Power } p = \frac{\tau \times 2\pi \times RPM}{60} \text{ watt}$$

$$= \frac{9.5 \text{ Nm} \times 2\pi \times 60}{60}$$

$$= 59.69 \text{ watt}$$

$$\cong 60 \text{ watt}$$

1.5 EFFICIENCY OF THE SYSTEM

1.5.1 Finding solar energy fallen on a panel

Here we are calculating energy using the following equations:

$$\text{Air mass, } AM = \frac{1}{\cos \theta}$$
$$= \frac{1}{\cos(90^\circ - \alpha)}$$

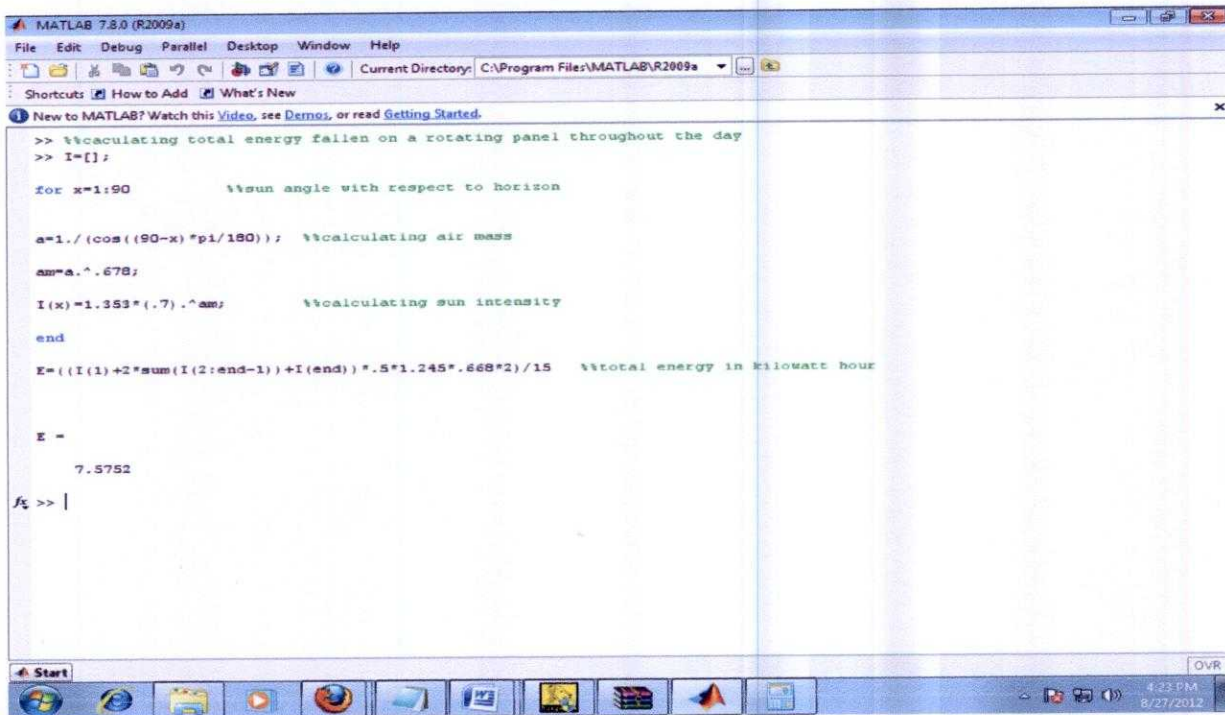
$$\text{Sun intensity, } I = 1.353 \times 0.7^{AM^{0.678}}$$

$$\text{Energy on a panel, } P = 2 \times \text{area of the panel} \times \int_{\alpha(\text{initial})}^{\alpha(\text{final})} I d\alpha$$

To find the integral we will use trapezoidal rule of numerical integration:

$$I = \int_{\alpha(\text{initial})}^{\alpha(\text{final})} I d\alpha \propto \frac{h}{2} [I_0 + 2(I_1 + I_2 + \dots + I_{n-1}) + I_n] \text{ where, } h = \text{data separation}$$

We will use the following Mat lab code to find power:



1.1.12 Figure: Mat-lab code

1.5.1.1 Calculating total energy fallen on a rotating panel in a day

```

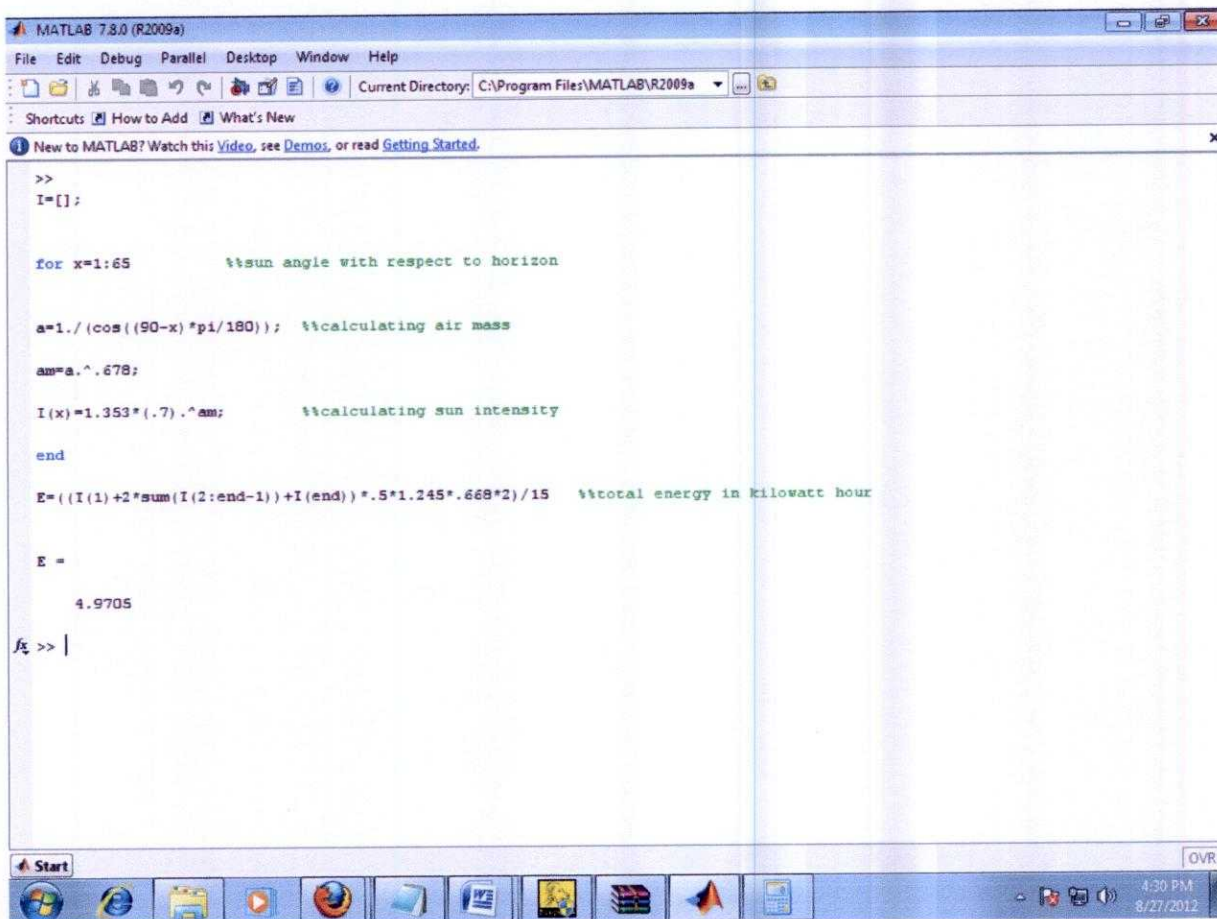
I=[];
for x=1:90      %%sun angle with respect to horizon

a=1./(cos((90-x)*pi/180)); %%calculating air mass
am=a.^678;
I(x)=1.353*(.7).^am;      %%calculating sun intensity
end
E=((I(1)+2*sum(I(2:end-1))+I(end))*5*1.245*.668*2)/15 %%total energy in kilowatt
hour
  
```

The first panel gets full exposure throughout the day and total energy fallen on this panel is= 7.5752 kilowatt hour.

The 2nd or the middle panel gets full exposure from 0 to 65 degree and 115 to 180 degree with respect to vertical in a day. So we can use the same Matlab code just changing the limit of the angle from 0 to 65 degree. Then the resulting multiplied by two will give the total energy of that panel throughout the day.

Therefore the code is:



```
>>
I=[];

for x=1:65           %%sun angle with respect to horizon

a=1./ (cos((90-x)*pi/180)); %%calculating air mass
am=a.^1.678;
I(x)=1.353*(.7).^am;    %%calculating sun intensity
end

E=( (I(1)+2*sum(I(2:end-1))+I(end))*.5*1.245*.668*2)/15  %%total energy in kilowatt hour

E =

    4.9705

fx >> |
```

1.1.13 Figure: Mat-lab code

```

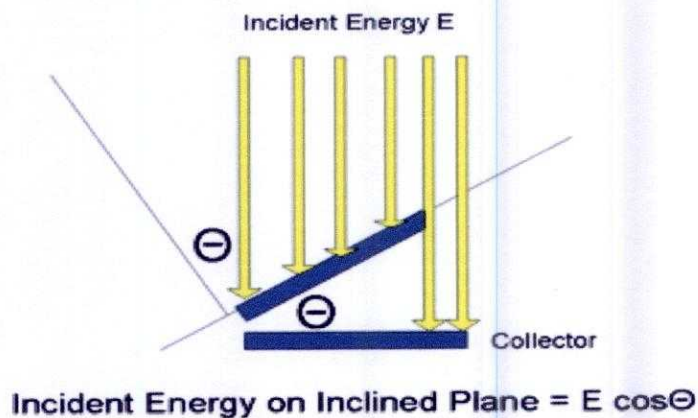
I= [];
for x=1:65      %%sun angle with respect to horizon
a=1. / (cos ((90-x)*pi/180)); %%calculating air mass
am=a.^.678;
I(x)=1.353*(.7).^am;    %%calculating sun intensity
end
E= ((I (1) +2*sum (I (2: end-1)) +I (end))*5*1.245*.668*2)/15  %%total energy in kilowatt
hour
E = 4.9705
So energy fallen on the second or middle panel= 4.9705 kilowatt hour in a day

```

Total energy on our system= Energy of (1st +2nd +3rd) panels
 =7.5752+7.5752+4.9705 kilowatt hour
 = 20.1209 kilowatt hour a day

1.5.1.2 Calculating total energy fallen on a fixed panel in a day

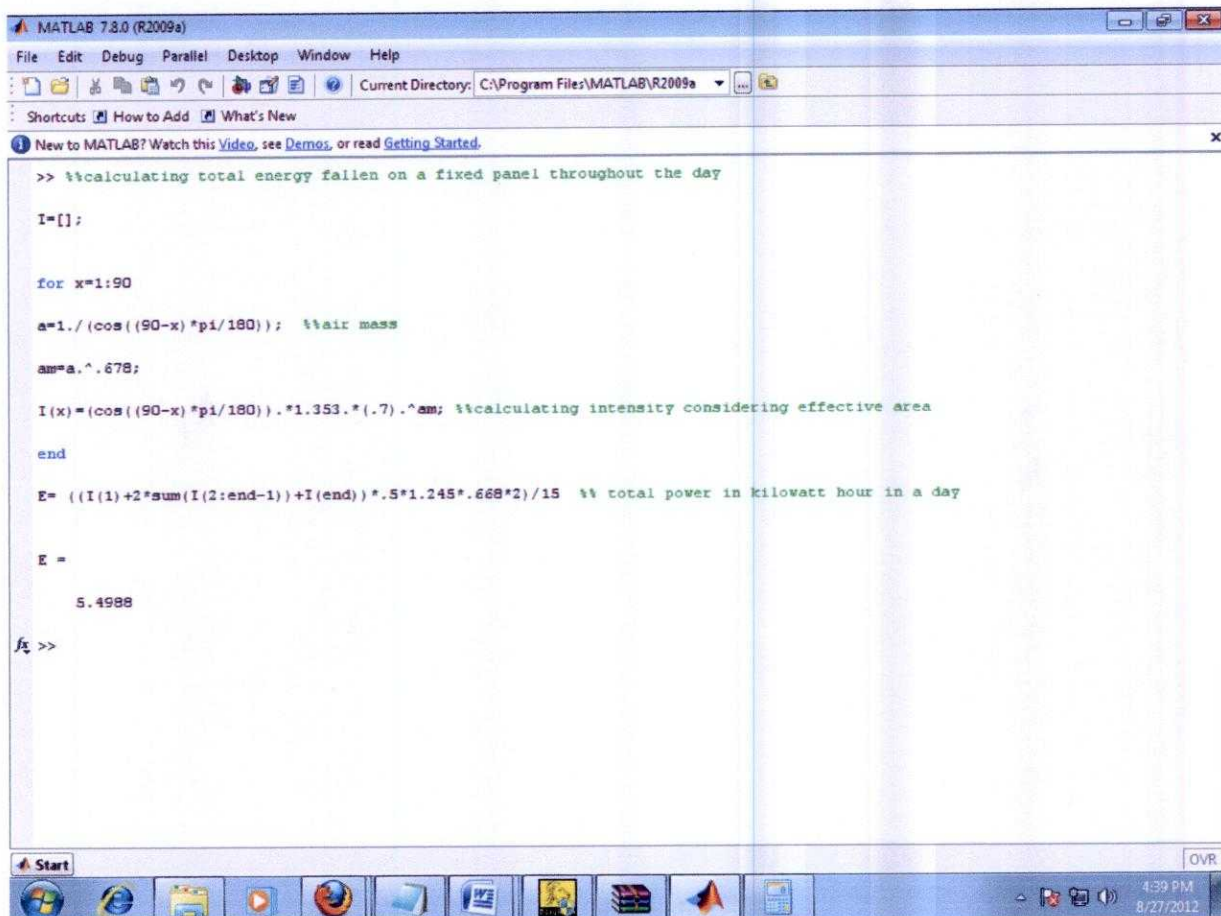
For calculating energy fallen on a fixed angle solar panel we have to consider the effective area of the panel as the panel is not rotating or tracking the sun. If energy fallen on a panel which is vertical to sun radiation is E then the actual energy fallen for a inclined panel will be this energy multiplied by the effective area of that panel.



1.1.14 Figure: Effective area calculation

If total area is A then Effective area= $A \cos \theta$

Energy fallen on a fixed panel can be calculated by the following Mat lab code:



```
>> %%calculating total energy fallen on a fixed panel throughout the day

I=[];

for x=1:90

a=1./ (cos ((90-x)*pi/180)); %%air mass

am=a.^0.678;

I(x)=(cos ((90-x)*pi/180)).*1.353.*(.7).^am; %%calculating intensity considering effective area

end

E= ((I(1)+2*sum(I(2:end-1))+I(end)).*5*1.245*.668*2)/15 %% total power in kilowatt hour in a day

E =

    5.4988

fx >>
```

1.1.15 Figure: Mat-lab code

```
%%calculating total energy fallen on a fixed panel throughout the day
```

```
I=[];
```

```
for x=1:90
```

```
a=1./ (cos ((90-x)*pi/180)); %%air mass
```

```
am=a.^0.678;
```

$I(x) = (\cos((90-x)*\pi/180)).*1.353.*(.7).^{\wedge}am$; %%calculating intensity considering effective area
end

$E = ((I(1) + 2*\text{sum}(I(2: \text{end}-1)) + I(\text{end}))*5*1.245*.668*2)/15$ % %% total power in kilowatt
hour in a day

Total energy fallen on three fixed panel = $3*5.4988$
= 16.4964 kilowatt hour

Total incident energy gain in our system or Energy gain = $(20.1209 - 16.4964)$ kilowatt hour a day
= 3.6245 kilowatt hour in a day

Percentage increase in energy = $\frac{3.6245}{16.4964} * 100$
= 22 %

Again area of a panel = $\text{width} \times \text{length} = 1.245 \times .668 \text{ m}^2 = .83166 \text{ m}^2$

Total area used in a fixed panel method = $\text{no of panel} \times \text{area of one panel}$
= $3 \times \text{area of a panel}$
= 2.49498 m^2

Total area used in our system = $2 \times \text{area of a panel} = 2 \times .83166 \text{ m}^2 = 1.66332 \text{ m}^2$

Therefore area saved = $\frac{2.49498 - 1.66332}{2.49498} \times 100 \% = 33.33 \%$

So we are getting 22% more incident solar energy by exploiting 33.33% less area than a fixed panel method.

1.6 FUTURE DEVELOPMENT

The solar panels system will be installed on a suitable place on rooftop of buildings in urban areas. Through this project we are converting sunlight into electricity to meet our demands for electricity for household purposes. As a result, our dependency on national grid power and frequent load-shedding problem will be decreased. In future we can use this system in offices and other places like in markets and shopping malls too. We can also provide the excess energy in national grid after fulfilling our requirements, so that it can help to remove the power shortage problem in Bangladesh and as well as in other developing countries which have severe energy crisis. Further modifications can be brought to this design in future while we do our thesis work.

One sided structure can be made using sophisticated mechanical design that will reduce the shadow to zero. This can be done by keeping the steel frame only at one side which doesn't face the sun. Especially designed gear and controls can do this.

Now a day's various types of solar concentrators are used to concentrate solar radiation and increase efficiency. In our system we can use these concentrators to increase solar radiation and have greater efficiency.

1.7 CONCLUSION

Solar power is actually one of the best methods of energy production for our country. Because solar panels simply convert the energy of the sun into useable energy, there are no harmful by products or threats to the environment. Since each photovoltaic panel has only about 40% efficiency, single solar panels are not sufficient power producers. So our rack system for holding the solar panels will be quite efficient in this case. If proper initiatives are taken, it would help ease the ongoing power crisis to a great extent. To conclude, we can say that solar power can be the ultimate solution for the present energy crisis we are facing and our system is going to help a lot in this attempt.

1.8 REFERENCES

1. Messenger, R. A. & Ventre, J., *Photovoltaic Systems Engineering*, CRC Press
2. Twidell, J. W. & Weir, A. D.(1986), *Renewable Energy Resources*, E & F.N. Spon, London
3. Dadamukhamedov S., Muminov, M. N., Tursunov & Khamrit, M.,(1998), *Solar Engineering*.
4. Zerlaut, G. A., *Solar Tracking Device*, US Patent 4.031.384.
5. Gordon. J. M. and Wenger, H. J.,(1991), *Solar Energy*, pp. 211-217.
6. Christina Honsberg and Stuart Bowden, viewed 1 September 2012,
<http://www.pveducation.org/pvcdrom>
7. Viewed 1 September 2012, <http://www.dhaka.climatemps.com/>
8. Schombert James, 19 March 2011, Earth Coordinate System, University of Oregon
Department of Physics, viewed 1 September 2012,
http://en.wikipedia.org/wiki/Horizontal_coordinate_system
9. SunAngle, viewed 1 September 2012, <http://www.susdesign.com/sunangle/>