Study of PV Implementation for Electricity Generation in Bangladesh

A Thesis Presented to

The Academic Faculty

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Declaration

We hereby declare that this thesis is our original work and it has been written by us in its entirety. We have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

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Acknowledgement

First of all we would like to thank almighty Allah to make this possible for us to take the paper into real form and obviously all credits and praises go to him. Besides, it would not be possible without the intensive help of our honorable supervisors. Actually this is an outcome of an allout effort of our thesis mates and the teachers who really co operate us in every single step.

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Contents

Abstract

The goal of this thesis is to make effective use of solar energy of Photovoltaic (PV) module so that we can get maximum power output from sunlight. Since the performance of a PV cell depends on maximum efficiency factors, mainly on solar radiation and temperature, this paper examines the performance parameters of PV module for various locations by analyzing twenty-two years average solar radiation data in Bangladesh. To examine the performance parameters, the Solarex MSX60, a typical 60W PV module is chosen. The mathematical model for the chosen module is implemented on Matlab. The result of this paper shows the effect of variation of solar radiation on PV module within Bangladesh. Eventually, this paper proposes suitable locations for implementing solar PV modules based on maximum efficiency within Bangladesh.

Chapter 1: Introduction

1.1 Thesis Outline:

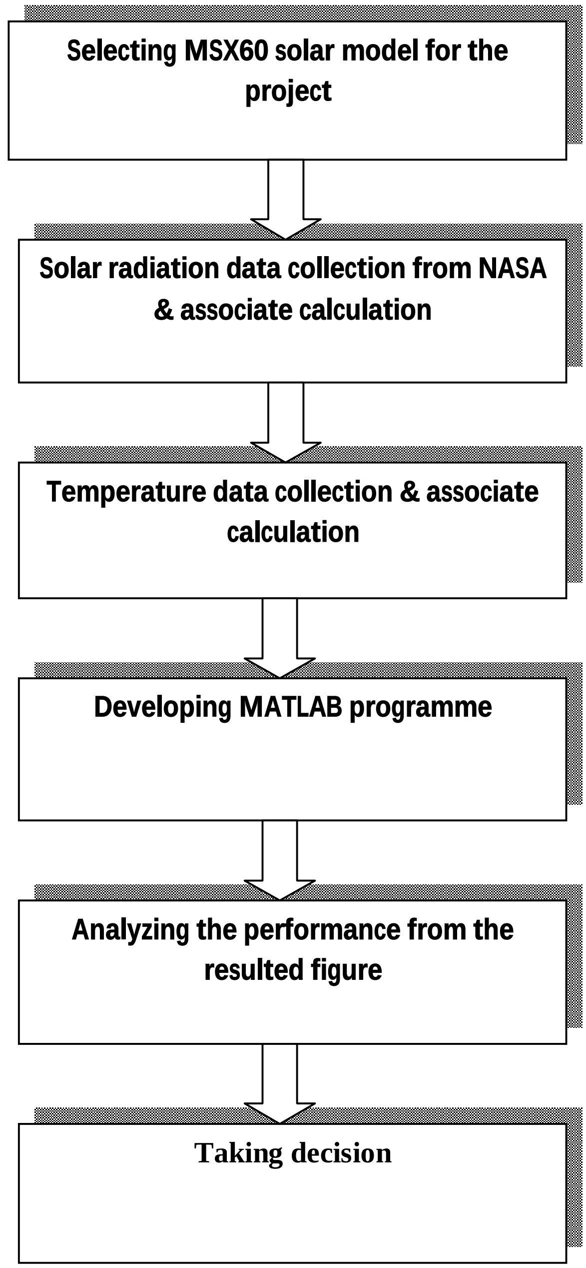
Solar is one of the best sources of clean renewable energy that can be used to generate Electricity in different ways. It is necessary to understand the importance of clean energy when it come the importance of saving our environment. Using the renewable energy sources will ensure a better earth for our future generation.

World's population is increasing day by day and it is becoming more challenging to meet the energy demand of this huge population with the traditional ways. The reserve of energy sources like coal, gas, oil etc are finishing everyday which eventually forces us to find alternative way of producing electricity.

Bangladesh is a small country with a large population. The infrastructure of our power generation is still primitive. It cannot fulfill the demand of energy of the people. To ensure a healthy economic growth of this country a sustainable energy policy is much more important than many other things. And solar energy can be a very good source of energy for Bangladesh especially when it is in a very favorable position for using solar radiation.

Our thesis deals with the efficient use of this prospective source in Bangladesh. We analyze the performance of a typical Solar cell by using some parameters throughout the country.

1.2 Thesis Structure



Chapter 2: Renewable Energy: Prospect Bangladesh

2.1 Renewable energy:

Energy sources that are replenished rapidly are termed as renewable energy**.** Some common forms of renewable energy are:

a) Solar energy
b) Wind power
c) Biomass
d) Tidal
e) Hydropower
f) Geothermal energy etc.

As renewable energy sources are very available we can get this energy for long time. But renewable energy has some drawbacks too. We do not control the source of energy. Also the availability of the energy is not same all the time.

World is heading towards renewable energy day by day. Some of the developed countries are using solar and wind energy for large scale power generation. At the end of 2012 there were a total of 10^5 MW Photovoltaic capacities throughout the world. There is also a total power of 318137 MW using wind power around the world. Germany, U.S.A, Italy, Spain are using solar power effectively while China, U.S.A, Germany, India are using wind energy.

But the most used form of renewable energy is Hydropower. More than 15% of world power generation is done by using this source. More than 3500 tera-watt hour electricity is produced by this way.

2.2 Use of Renewable Energy in Bangladesh:

In term of renewable energy Bangladesh mainly use hydropower plant. There is a hydropower plant in Kaptai, Rangamati. This plant is built by building a dam in the river “Karnafuli”. The capacity of the plant is 230 MW.

Bangladesh also uses some small power plant using solar power and wind energy which are not grid connected rather are used locally.

Bangladesh Government has a goal of providing electricity to all the people by 2020. And for that Government is taking various steps including more use of renewable energy. To fulfill the goal Bangladesh power development board (BPDB) has already formed a ***Directorate of Renewable Energy and Research & Development*** in 2010.

Our thesis only deals with the use of solar photovoltaic in Bangladesh. BPDB has implemented three solar projects in the hilly area of Bangladesh. Those are in Juraichori Upazilla, Barkal Upazilla and Thanchi Upazilla of Rangamati District. BPDB has ongoing projects of 8MW & 3MW Grid Connected Solar PV Power Plant at Kaptai Hydro Power Station & Sharishabari, Jamalpur respectively. Also there is a project of 30 MW Solar Park Project at new Dhorola Bridge, Kurigram. Bangladesh Government has already launched *"500 MW Solar Power Mission"* to promote the use of Renewable Energy to meet the increasing demand of electricity.

We try to find out the way of using solar PV throughout the country effectively. For that we consider the whole country to get the maximum benefit from installing large scale PV solar system.

2.3 Prospect of Solar Energy in Bangladesh:

Bangladesh is in a very favorable position for using solar radiation. The amount of solar radiation occurs here is very effective for Photovoltaic.

Around the whole world the greatest amount of solar energy is available between two broad bands which encircle the earth between 15” and 35” latitude north and south. Bangladesh s situated between 20”43’ north and 26”38’ south. So it is in the zone of the greatest amount of solar radiation.

Here annual amount of solar radiation varies in between 1575 kw/m^2 to 1840 kw/m^2.

This amount is almost 50-100% higher than most of the European countries. Though European countries are using solar power very effectively due to their technological advancement, Bangladesh has not been able to use this good source of energy that effectively.

Bangladesh has an average solar radiation that is equivalent to 1010 × 1018 Joule. Available energy in Bangladesh is above 208 watt/m^2 where Bangladesh is using only .15 watt/m^2.

So Bangladesh has a very good prospect of solar power if we can find out the proper way of installing solar system. More importantly solar power can be installed in large scale & can be connected to National grid.

Chapter 3: Modeling the PV Cell

3.1 Solar Energy:

Solar energy is one of the non-conventional sources of energy as it is used for less amount of power generation. It is clear from its name that the solar energy is obtained from the sun. Solar energy is classified as two types as below:

a. Solar thermal:

Solar radiation can be used directly in the earth. Artificial devices can be used to harness solar radiation in the form of heat directly.

Thermal solar energy collector essentially consists of an absorber which converts solar radiation into heat energy which subsequently collected by a liquid or solid medium.

b. Photoelectric/Photovoltaic:

The absorption of electromagnetic radiation in gases, liquids and solids gives rise to an electric effect.

In certain solids like semiconductors, this effect can be used to generate electricity.

Comparison of solar PV and solar thermal:

In solar PV system, a semiconductor device converts sunlight directly into electricity.

In solar thermal system, an absorbing material absorbs solar energy and then converts it to heat.

So, solar PV is a direct process of energy conversion while solar thermal is an indirect way of energy conversion.

Advantages of solar PV technology:

1. In solar PV technology, the conversion from solar energy to electricity occurs directly without any intermediate steps. Other renewable energy technologies like wind, solar thermal, biomass etc. require intermediate steps to convert the input energy form to electrical energy.

2. No moving part is involved in solar PV technology. So, it does not require maintenance or requires very little maintenance. Other renewable energy technologies like wind energy, biomass etc. have moving parts and require maintenance.

3. Unlike fossil fuel based technologies, solar PV technology does not emit greenhouse gases and harmful particles. So, it is a clean technology.

Disadvantages of solar PV technology:

1. Solar PV system cannot produce electricity in absence of sunlight. So, during night and cloudy days, it remains un-operational. Batteries are required to store the energy so that it can be used at night or on cloudy days.

2. The power produced by a PV module is proportional to its size. So, in order to produce large amount of power, we need bigger PV modules or large number of small PV modules. In either case, the required area is large.

3.2 What is a PV cell?

A PV cell is basically a silicon semiconductor junction device that contains a p-n junction similar to a diode. It generates electricity proportional to the incident sunlight. When light shines on the PV cell current flows from the p-type side to the n-type side across the p-n junction through wire which is known as light generated or photo current I_L .The equivalent circuit of a simple PV cell can be modelled by a current source in parallel with a diode, a shunt resistance expressing a leakage current and a series resistance describing an internal resistance to the current flow as depicted in figure 1[6].

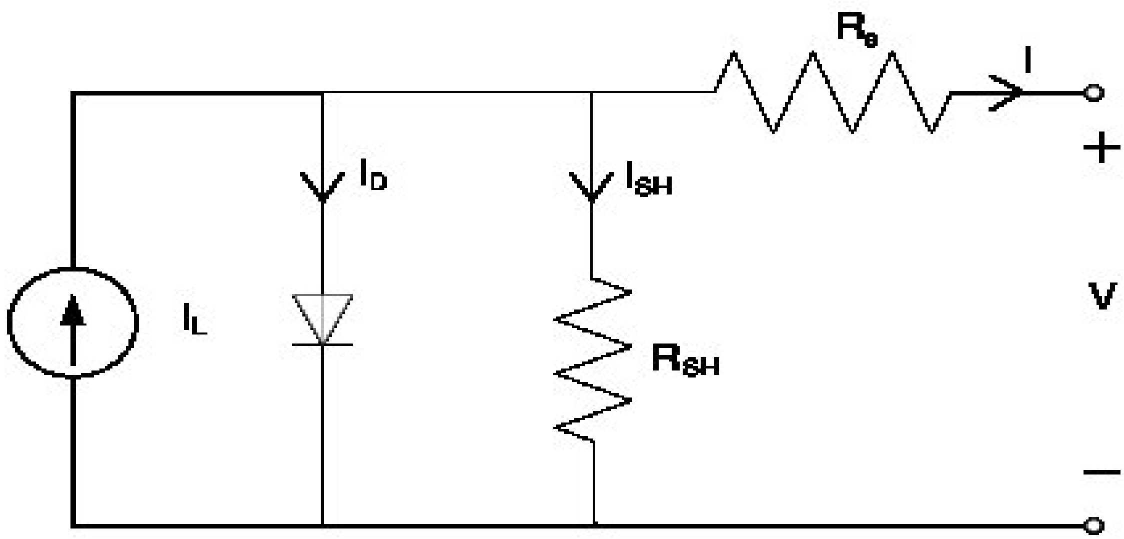


Figure 3.1: Electrical model of PV cell.

In summary, solar PV (Photovoltaic) is a semiconductor device that converts sunlight directly into electricity. When exposed to sunlight, a solar PV module or panel generates voltage and current at its output terminal (using photovoltaic effects) which can be used to meet electricity requirements.

The amount of power generated by a solar PV module depends on amount or intensity of solar radiation, size of the module. Electricity generated by a PV module is DC in nature. Inverter is used to convert it to AC.

3.3 The characteristics equations of a PV cell:

The photocurrent I_L of the PV cell is directly proportional to the solar insolation. The output current I of the cell is equal to photo generated current I_L, minus diode current I_D, minus shunt current I_{SH}. $I = I_L - I_D - I_{SH}$. As $R_{SH} \approx \propto$, so $I_{SH} \approx 0$.

$$I = I_L - I_D \quad \text{...} (1)$$

If I_s is the saturation current of the diode and $V_j = V + IR_s$ is the voltage across the diode, where V is the voltage across the output terminal of PV cell and R_S is the series resistance, then the current diverted through the diode is given by:

$$I_D = I_S \left\{ \exp\left[\frac{q(V + IR_S)}{nkT} \right] - 1 \right\} \quad \text{...} (2)$$

Thus the equations for the I-V characteristics of the PV cell are:

$$I_D = I_L - I_S \left\{ \exp\left[\frac{q(V + IR_S)}{nkT} \right] - 1 \right\} \quad \text{...} (3)$$

$$I_L = I_L(T_1)(1 + K_o(T - T_1)) \quad \text{..} (4)$$

$$I_L(T1) = G * Isc(T1,nom)/G(nom) \quad \text{..} (5)$$

$$K_o = (I_{SC}(T2) - I_{SC}(T1))/(T_2 - T_1) \quad \text{...} (6)$$

$$I_S = I_{S(T1)} * \left(T/T_1\right)^{3/n} * e^{-qVg/nk*(1/T-1/T1)} \text{.................................} (7)$$

$$I_{S(T1)} = I_{SC(T1)} \Big/ \left(e^{qVoc(T1)/nkT1} - 1\right) \text{..} (8)$$

$$R_S = -dV/dI_{Voc} - 1/X_V \text{...} (9)$$

$$X_V = I_{S(T1)} * q/nkT_1 * e^{qVoc(T1)/nkT1} \text{................................} (10)$$

Here n is known as diode quality factor which is 1 for ideal diode. R_S is a small resistance which represents internal losses due to current flow. The Boltzmann's constant,. $k = 1.380658 \times 10^{-23} JK^{-1}$.

3.4 Electrical parameters of a PV cell:

A real PV cell is characterized by the following electrical parameters[7]:

<u>Short circuit current:</u> Current that flows when $V = 0$ .It is due to the generation of light generated carriers. For an ideal PV cell $I_{SC} = I_L$ .Therefore, it is the largest amount of current which can be drawn from the PV cell.

<u>Open circuit voltage:</u> Maximum voltage available from a PV cell when $I = 0$ .The voltage of a PV cell at night is termed as V_{OC} . Mathematically,

$$V_{OC} = nkT/q * \ln\left(I_L/I_S + 1\right) \quad (11)$$

Here nkT/q is the thermal voltage and T is the absolute temperature of the PV cell.

Maximum power point: Operating points that provide maximum output power. Mathematically,

$$P_{\max} = V_{\max} * I_{\max} = V_{OC} * I_{SC} * FF \quad (12)$$

Here FF is the fill factor.

Efficiency: Determined as the fraction of incident power which is converted to electricity.

$$\eta = P_{\max} / P_{incident} = V_{\max} * I_{\max} / P_{inc} \quad (13)$$

Fill factor: It is the ratio of the maximum power from the PV cell to the product of V_{OC} and I_{SC} . Expressed as:

$$FF = P_{\max} / V_{OC} * I_{SC} = V_{\max} * I_{\max} / V_{OC} * I_{SC} \quad (14)$$

Fill factor is determined from measurement of the I-V curve and for good PV cells its value is greater than 0.7.The fill factor diminishes as the cell temperature is increased. The open circuit voltage increases logarithmically with the ambient irradiation, while the short circuit current is a linear function of the ambient irradiation. The dominant effect with increasing cell's temperature is the linear decrease of the open circuit voltage, the cell being thus less efficient. The short circuit current slightly increases with the cell temperature.

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3.5 Working principle of a PV cell:

Now we are going to demonstrate the internal mechanism of a solar cell. Basically solar cells are large area p-n junctions. When sunlight falls on solar cell, it produces current and voltage. This is due to the built in electric field between p-type and n-type material.

Basically in solar cell a wire of low resistance is connected between p-type and n-type materials. In dark no current is generated by the solar cell. So at night the output current of a solar cell is zero. But when light falls on the solar cell a current known as the conventional current produces across the solar cell and start flowing from the p-type side to the n-type side of the solar cell.

Basically solar cells are made of silicon. Sunlight has much more energy to break some bonds of silicon crystal. Bonding electrons are excited by sunlight into a higher energy state and the bond is broken. Under normal condition, only one bond among 100 million silicon bond is broken.

The excited electrons are act as free electrons and so they are now free to move throughout the solar cell. Similarly, the broken bonds act as holes and like free electrons they are now free to move throughout the materials.

These free electrons and holes stay close to each other. For each of the free electrons there will be a corresponding hole generated in the solar cell. For a short duration of time these free electrons and holes stay close to each other. By recombination process, these electrons and holes fall back into bonded position again. In this process the electrical energy of electron hole pairs is lost as heat and so too much recombination is bad for solar cell and it won’t work properly then.

3.6 Current produced by a PV cell:

Excitation of electrons and holes by sunlight occur throughout the volume of the solar cell. A built in electric field is produced at the junction of the material and because of this electric field the electrons are attracted by the positive charge on the n-type material side. Similarly, the holes are attracted by the negative charge on the p-type material side. Thus the separation of positive and negative charges occurs throughout the junction and so current starts flowing across the junction. The direction of this current flowing is opposite of motion of electrons that means in the same direction as the motion of holes. That means the current starts flowing from the n-type side to the p-type side throughout the junction.

If we want to measure this electric current we have to attach a current meter in series with the solar cell.

3.7 Voltage generated by a PV cell:

To extract power from the solar cell both voltage and current should be produced by the solar cell. When light falls on the solar cell the flow of electrons and holes causes a voltage to build up throughout the solar cell. Positive voltage is produced on the p-type side and negative voltage is produced on the n-type side.

If we want to measure this voltage we have to attach a voltmeter in series with the solar cell.

3.8 Power from a PV cell:

When the solar cell is short circuited, a thin wire is connected between the p-type side and n-type side of the solar cell. So a current is flowing across the solar cell but there is no voltage across the solar cell. On the other hand, if there is no wire between the contact or the wire is cut; then there is no current flowing but the voltage is generated across the junction.

So a wire with right value of resistance should be connected between the p-type and n-type side of the solar cell to extract the useful power from the solar cell. If we connect a wire of very low resistance value then more current will flow but the voltage drop will be very less across the junction. On the contrary, if we connect a wire of very high resistance value then a very little current will flow but the voltage drop will be very high across the junction.

Only when a wire with right resistance value is connected between the two contacts of the solar cell, there will be an optimal current flowing with an optimal voltage generated across the solar cell. Under this condition, the maximum power is generated across the load and this condition is known as "Maximum Power Point Tracking".

3.9 How to get large amount of power:

In order to generate large amount of power we have to combine many solar PV modules together. Let assume we want to generate 1000,000 W power. Normally solar PV modules are available for sizes 5W to 300W. So, if we consider 100W solar modules as example, then 10000 such modules combined together will produce 1000,000 W power. Such combination of PV modules is called PV array. In fact, it is possible to make a big solar cell power station by wiring many solar cells together.

3.10 Solarex MSX60 60W PV module:

In our experiments, we use Solarex MSX60 60W PV module to examine the performance parameters at different locations.

This module consists of 36 multi-crystalline silicon solar cells configured as two series strings of 18 cells each. When light incidents on it, it produces photocurrent, I_L directly proportional to the solar irradiation. A Matlab program was developed for implementing the model of this PV module. This program calculates the current (I) using typical electrical parameters of the module and the variable voltage (V), irradiation (G) and temperature (T).

3.11 Electrical characteristics of MSX60 60W PV module:

Parameter	*Value*
Maximum power, $P_{\max}$	*60W*
Voltage at $P_{\max}$ *,* $V_{\max}$	*17.1V*
Current at $P_{\max}$ *,* I_{max}	*3.5A*
Minimum $P_{\max}$	*58W*
Short-circuit current I_{SC}	*3.8A*
Open-circuit voltage V_{OC}	*21.1V*
Temperature coefficient of I_{SC}	$(0.065 \pm 0.015)\,\%/^{\circ}C$
Temperature coefficient of V_{OC}	$-(80 \pm 10)\,mV/^{\circ}C$
Temperature coefficient of power	$-(0.5 \pm 0.05)\,\%/^{\circ}C$
$NOCT^3$	$47 \pm 2^{\circ}C$
Maximum system voltage	*600V*
Maximum series fuse rating	*20A*

Table 1: Typical electrical characteristics of MSX60 60 PV module.

3.12 Matlab modelling and simulation of MSX60 60W PV cell:

Matlab code for MSX60 60W PV Cell:

```
functionIa = msx60i(Va,Suns,TaC)
% msx60.m model for the MSX-60 solar array
% current given voltage, illumination and temperature
% Ia = msx60(Va,G,T) = array voltage
% Ia,Va = array current,voltage
% G = num of Suns (1 Sun = 1000 W/m^2)
% T = Temp in Deg C
k = 1.38e-23; % Boltzman'sconst
q = 1.60e-19; % charge on an electron
% enter the following constants here, and the model will be
% calculated based on these. for 1000W/m^2
A = 1.2; % "diode quality" factor, =2 for crystaline, <2 for amorphous
Vg = 1.12; % band gap voltage, 1.12eV for xtal Si, ~1.75 for amorphous
Si.
Ns = 36; % number of series connected cells (diodes)
T1 = 273 + 25;
Voc_T1 = 21.06 /Ns; % open cct voltage per cell at temperature T1
Isc_T1 = 3.80; % short cct current per cell at temp T1
T2 = 273 + 75;
Voc_T2 = 17.05 /Ns; % open cct voltage per cell at temperature T2
Isc_T2 = 3.92; % short cct current per cell at temp T2
TaK = 273 + TaC; % array working temp
TrK = 273 + 25; % reference temp
% when Va = 0, light generated current Iph_T1 = array short cct current
% constant "a" can be determined from Iscvs T
Iph_T1 = Isc_T1 * Suns;
a = (Isc_T2 - Isc_T1)/Isc_T1 * 1/(T2 - T1);
Iph = Iph_T1 * (1 + a*(TaK - T1));
Vt_T1 = k * T1 / q; % = A * kT/q
Ir_T1 = Isc_T1 / (exp(Voc_T1/(A*Vt_T1))-1);
Ir_T2 = Isc_T2 / (exp(Voc_T2/(A*Vt_T1))-1);
b = Vg * q/(A*k);
Ir = Ir_T1 * (TaK/T1)^(3/A) .* exp(-b.*(1./TaK - 1/T1));
```

```
X2v = Ir_T1/(A*Vt_T1) * exp(Voc_T1/(A*Vt_T1));
dVdI_Voc = - 1.15/Ns / 2; % dV/dI at Voc per cell --% from
manufacturers graph
Rs = - dVdI_Voc - 1/X2v; % series resistance per cell
% Ia = 0:0.01:Iph;
Vt_Ta = A * 1.38e-23 * TaK / 1.60e-19;%=A*kT/q
% Ia1 = Iph - Ir.*( exp((Vc+Ia.*Rs)./Vt_Ta) -1);
% solve for Ia: f(Ia) = Iph - Ia - Ir.*( exp((Vc+Ia.*Rs)./Vt_Ta) -1) =
0;
% Newton’s method: Ia2 = Ia1 - f(Ia1)/f’(Ia1)
Vc = Va/Ns;
Ia = zeros(size(Vc));
% Iav = Ia;
for j=1:5;
Ia = Ia- ...
(Iph - Ia - Ir.*( exp((Vc+Ia.*Rs)./Vt_Ta) -1))...
./ (-1 - (Ir.*( exp((Vc+Ia.*Rs)./Vt_Ta) -1)).*Rs./Vt_Ta);
% Iav = [Iav;Ia]; % to observe convergence for debugging.
end
```

3.13 Characteristics curves:

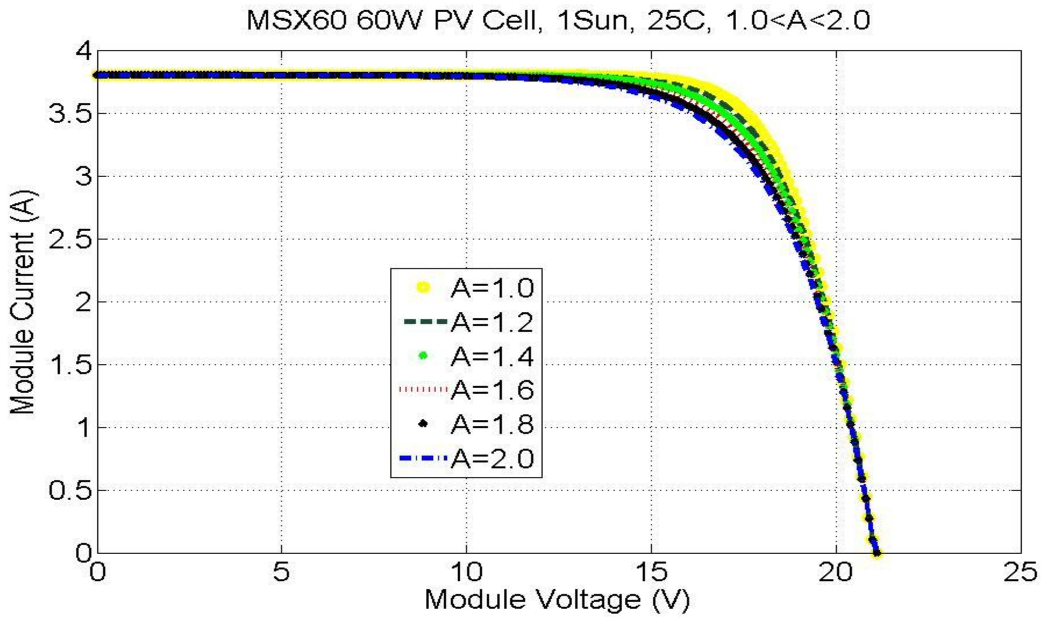

Figure 3.2: The Matlab model V-I curves for various diode quality factors

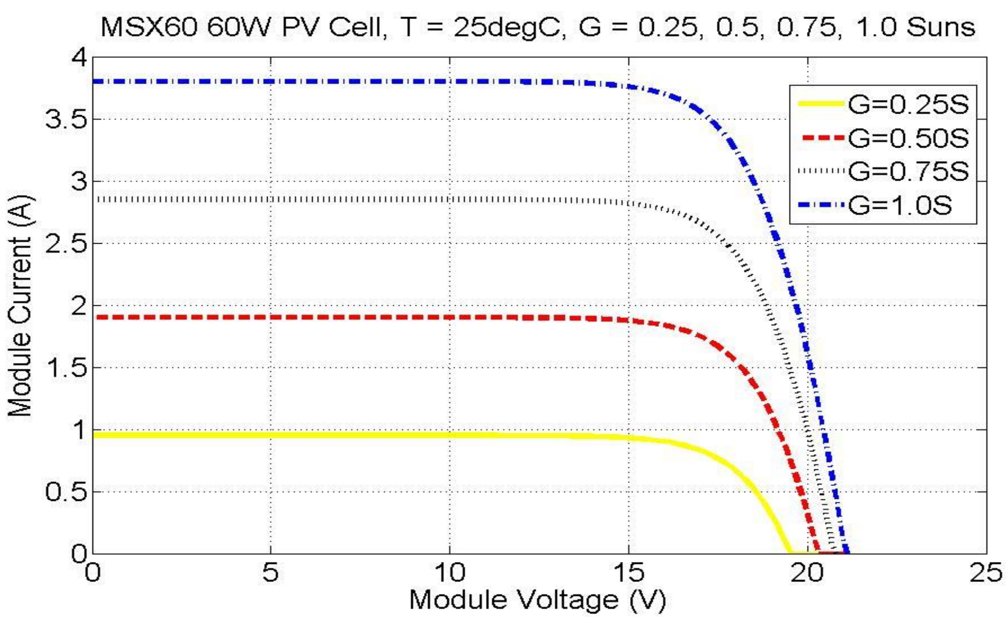

Figure 3.3: The Matlab model V-I curve for various irradiation levels.

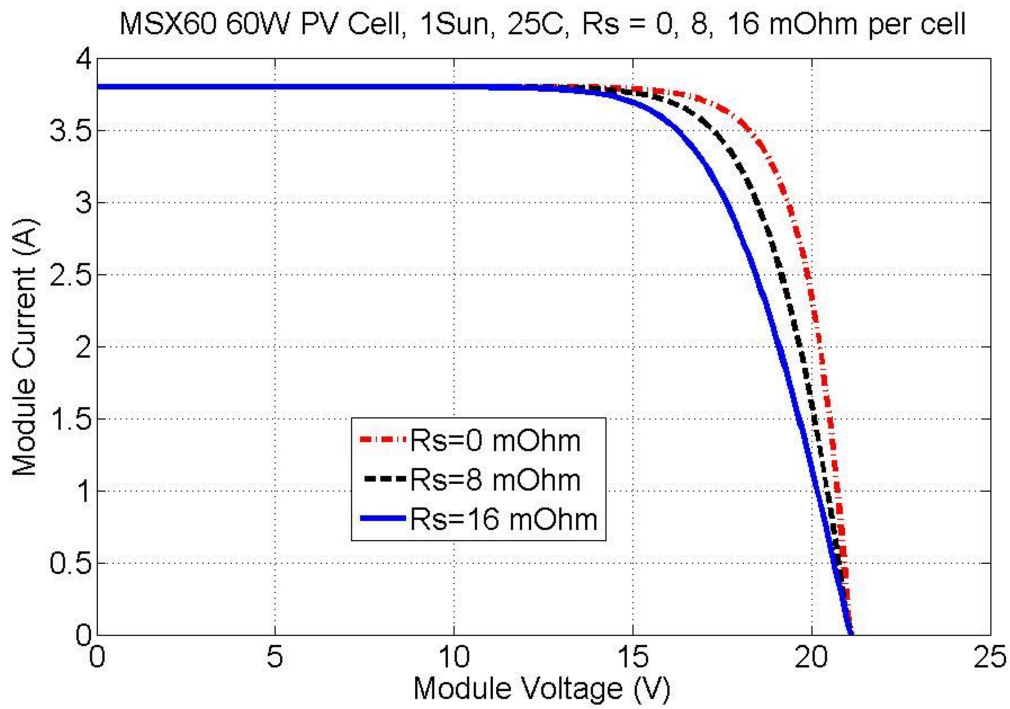

Figure 3.4: The Matlab model V-I curve for various model series resistances.

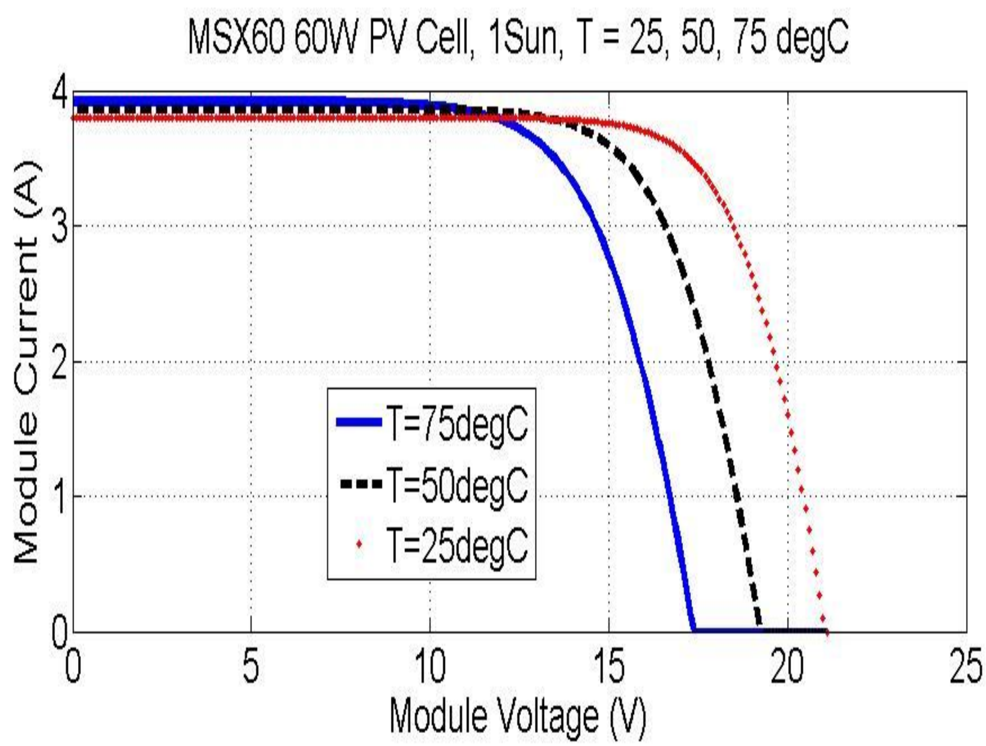

Figure3.5: The Matlab model V-I curve for various temperatures.

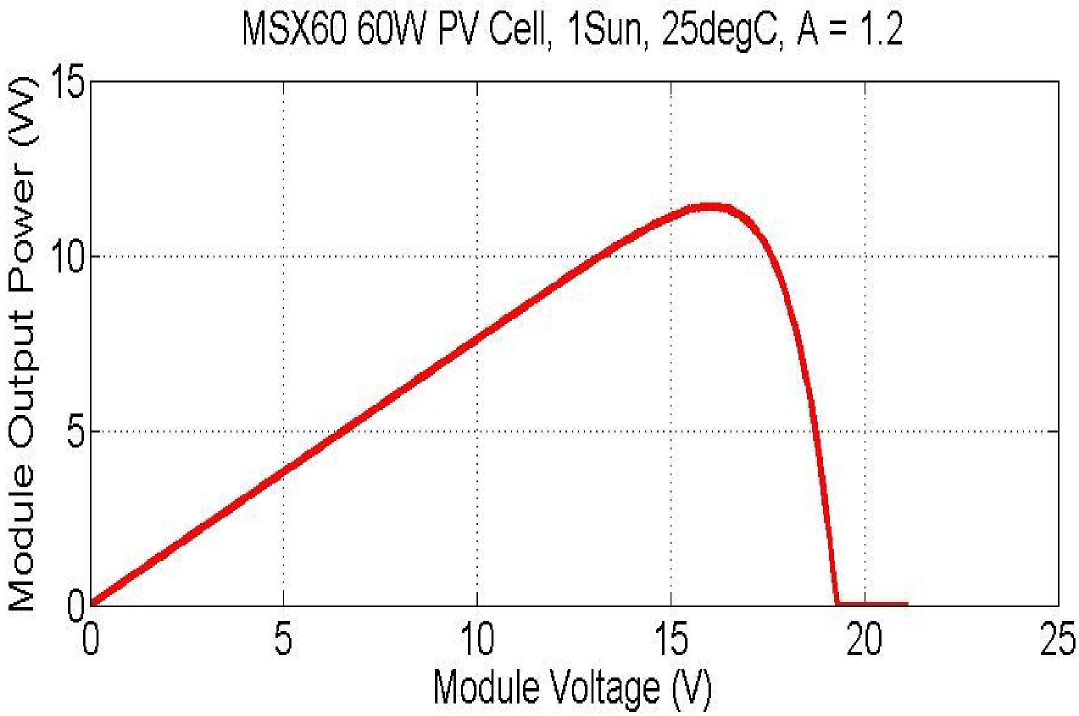

Figure 3.6: The Matlab model P-V curve for MSX60 60W solar cell under normal condition.

Chapter 4: Solar Radiation in Bangladesh

Bangladesh has enormous potentiality in renewable sources of energy. The proper utilization of the energy sources can be an active part in the development of the country. As the efficiency of a photovoltaic module mostly depends on the solar radiation, Bangladesh has a greater opportunity to utilize this radiation converting into useful form of energy.

From the geographical position of Bangladesh it is seen that, the position of our country is such that we can obtain two kinds of solar radiation very easily and spontaneously .This is an ideal location for solar energy.

[From **20°34″ North Latitude** to **26°38″ North Latitude**. From **88°01″ East Longitude** to **92°41″ East Longitude**]

There are many parameters that change the amount of beam and diffuse solar radiation such as time, date, latitude, altitude, declination angle, zenith angle, atmospheric transmittivity, water vapor, cloud condition, sunshine hours, maximum air temperature, relative humidity, elevation of the location etc. As the radiation type is two in nature, it is very difficult to obtain a generalize formula in order to estimate direct and diffuse solar radiation by considering all these parameters are responsible for the variation of the solar radiation.

The average available incident solar power in Bangladesh is close to 4.5kWh/m^2, and with 15 per cent efficiency of currently available commercial solar plants 0.67kWh/m^2 of electricity can be produced. For example, if we select a 100m by 100m land, and keep 33 per cent of the area for supporting structure, equipments and connections to the solar panels we can install solar panels of total 6700 square meter on that land, which will give us almost 10MWh of electricity. There are two technological options to generate electricity from sunlight. In solar thermal energy (STE) technology large concentrators are used to gather sunlight to heat water, and the steam can be used to drive turbine for electricity production. In photovoltaic (PV) technology, a semiconductor device, known as solar cell, is used to directly convert sunlight into electricity and the PV technology is the dominant choice for solar plants as the number of medium is less and so the losses are.

Graphical representation of average solar radiation in Bangladesh:

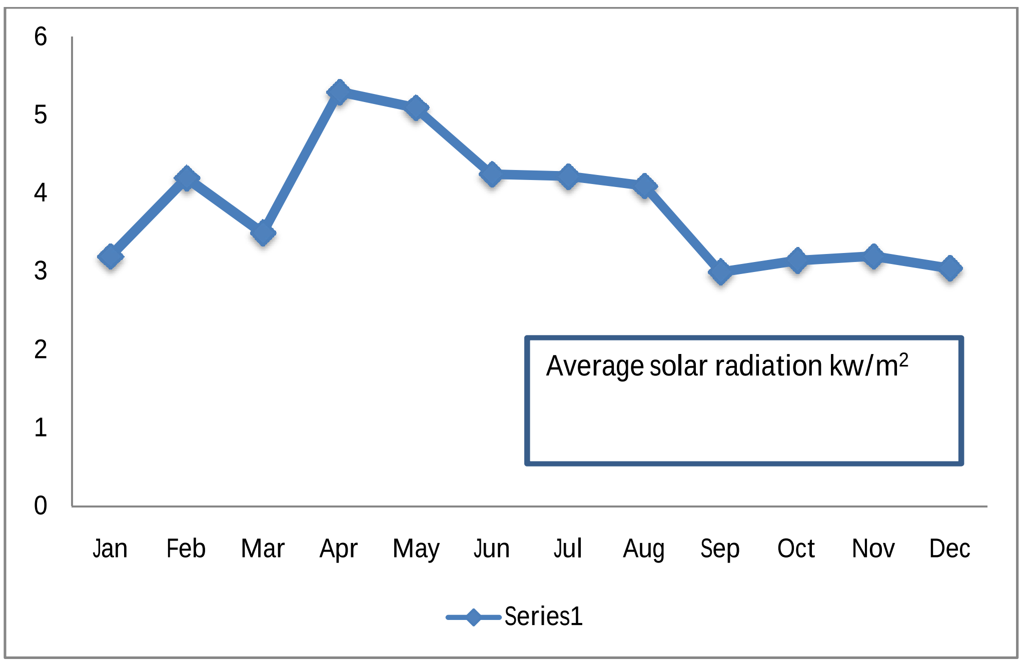

Fig 4.1: Average solar radiation in Bangladesh (considering the day)

This figure shows the solar radiation for each month in a year in Bangladesh. Here we can see that the maximum radiation is obtained in April , may and a part of June where the summer season lies actually and the radiation is lower for winter and lowest radiation is obtained in the rainy season.

Twenty-two years average solar radiation data according to NASA Surface Meteorology and Solar Energy is used to find out the variation of solar radiation in Bangladesh. The variations of weather are divided into three categories on the basis of twelve months are:

Summer (March-June), monsoon (July-October) and winter (November-February) respectively in seven different divisions of Bangladesh. Thus the data of seven divisions of Bangladesh were used. If we merge the three figures, we can see that the average solar radiation of Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna, and Barisal are 16.799MJ/m²/day, 16.695MJ/m²/day, 16.171MJ/m²/day, 17.414MJ/m²/day, 17.555MJ/m²/day, 16.788MJ/m²/day, 16.285MJ/m²/day respectively.

The comparison between the maximum solar radiation and the minimum solar during summer (March-June) radiation throughout the country shows that the Rangpur and the Rajshahi divisions have more solar radiation than the others. But Dhaka and Chittagong have less solar radiation variation throughout the whole year than the other divisions. Comparatively less variation in solar radiation helps to design PV module with less battery storage capacity and hence the cost of the module reduces. Solar radiation is at its highest values during summer (March-June) and at its lowest values during monsoon (July-October). The maximum values of radiation for Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna and Barisal are 19.302MJ/m²/day, 18.671MJ/m²/day, 18.153MJ/m²/day, 20.494MJ/m²/day, 20.762MJ/m²/day, 19.535MJ/m²/day and 18.559MJ/m²/day respectively and should be taken as the input of the PV cell. Similarly, the minimum values of radiation for Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna and Barisal are 15.025MJ/m²/day, 15.103MJ/m²/day, 14.343MJ/m²/day, 15.379MJ/m²/day, 15.466MJ/m²/day, 14.939MJ/m²/day and 14.325MJ/m²/day respectively and should be taken as the input of the PV cell during monsoon (July-October). Again, the middle values of the radiation for Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna and Barisal are 16.071MJ/m²/day, 16.313MJ/m²/day, 16.019MJ/m²/day, 16.373MJ/m²/day, 16.442MJ/m²/day, 15.881MJ/m²/day and 15.967MJ/m²/day respectively should be taken as the input of the PV cell during winter (November-February).

4.1 Data Collection Process:

According to three different seasons, radiations of the sun and the temperatures have been collected for last 22 years and an average was made accordingly. For collecting the temperature data, the meteorological department of Bangladesh was visited and for every division, temperature data was collected for each twelve months for the last twenty two years. An average of those temperatures was made to obtain the output curve of each division for three divided seasons.

For the radiation data, an authentic website hosted by **(NASA)** was used where the radiation for each place was obtained by inserting the value of latitude and longitude accordingly, thus the radiation data was collected for each of the seven divisions of Bangladesh and an average was made for the three divided seasons to obtain the output radiation curve.

The collected temperature data was divided according each twelve year and an average was made for the three different seasons.

The same process was followed for the radiation data also and thus we can differentiate the different radiation percentage and the amount of temperature for individual month in a year.

This statistics prove that the amount temperature is highest in summer season as the radiation percentage is also higher. In the rainy season this percentage is lowest for both radiation and amount of temperature and for the winter season this is slightly larger than rainy season.

As the amount of radiation varies with the geographical position even inside a country, it is obvious that the radiation and the temperature will be highest in the northern part of our country regardless any season. This works as the evidence of maximum efficiency of solar power system in our country.

Chapter 5: Result of the Simulation

The output power of a PV cell varies with the variation of solar irradiation when temperature is fixed and the characteristic of output power varies with the variation of ambient temperature when solar irradiation is fixed. For our research, we are interested to see the performance parameter s of MSX60 in seven different divisions for three different seasons: Summer (March-June), Monsoon (July-October) and winter (November-February).

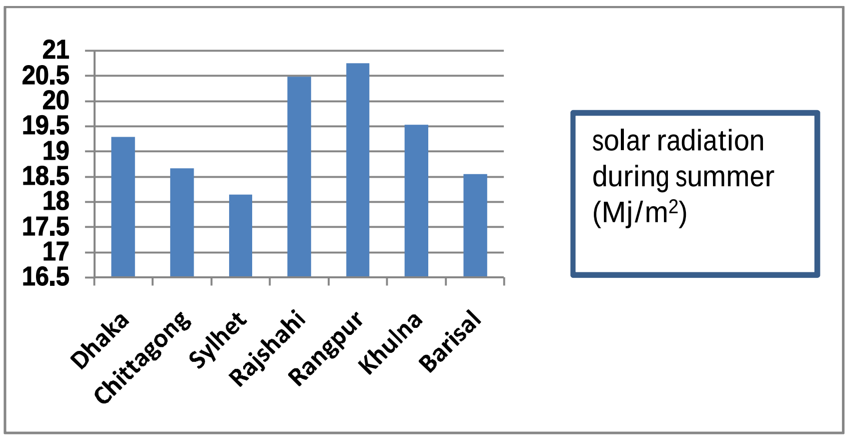

Fig 5.1: Solar Radiation during summer (March-June) in Bangladesh (considering whole day.)

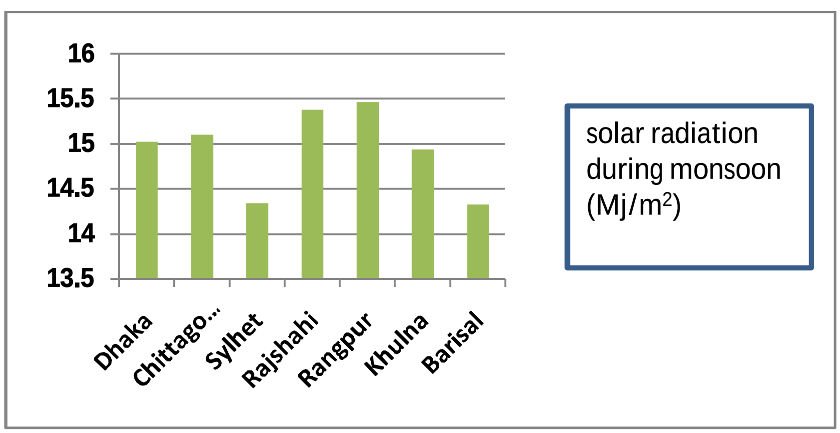

Fig 5.2: Solar Radiation during monsoon (July-October) in Bangladesh. (Considering whole day.)

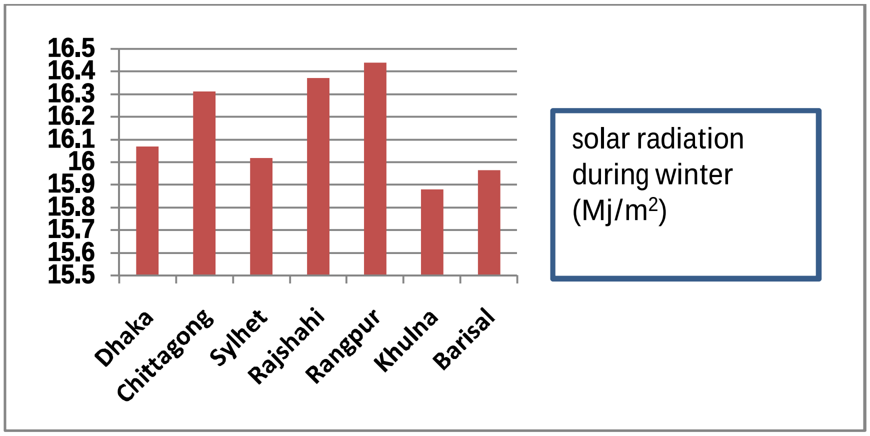

Fig 5.3: Solar Radiation during winter (November-February) in Bangladesh. (Considering whole day.)

5.1 Dhaka Division:

It has been found that the average temperature in Dhaka is 28°C during summer and from figure 5.1; the average solar radiation is 224watt/m². And the average temperature in Dhaka is 29°C during monsoon and from figure 5.2; the average solar radiation is 174watt/m². Again the average temperature in Dhaka is 21.1°C during winter and from figure 5.3, the average solar radiation is 187watt/m².

Figure 5.4 and Figure 5.5 demonstrate the current-voltage curve and power-voltage curve of MSX60 influenced by solar radiation and temperature of Dhaka.

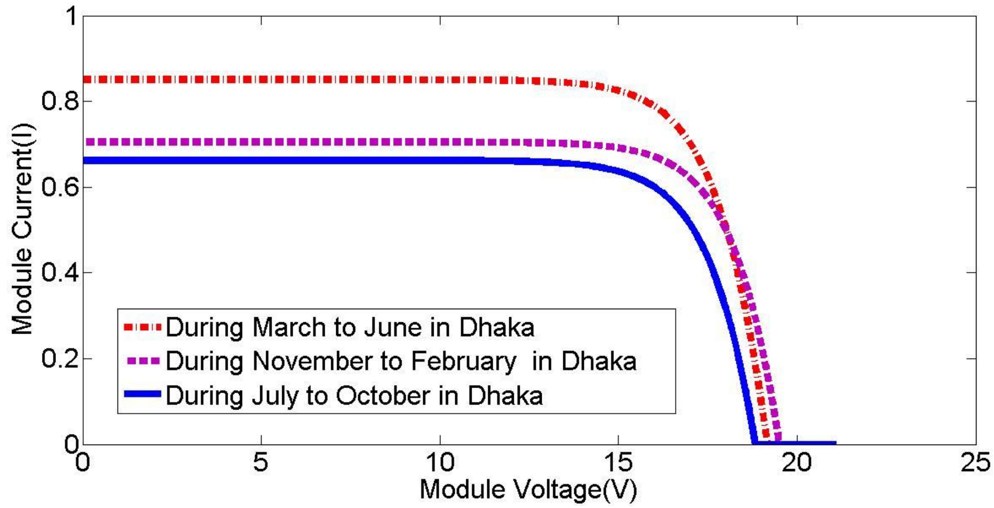

Fig 5.4: Simulated V-I curve of MSX60 for Dhaka

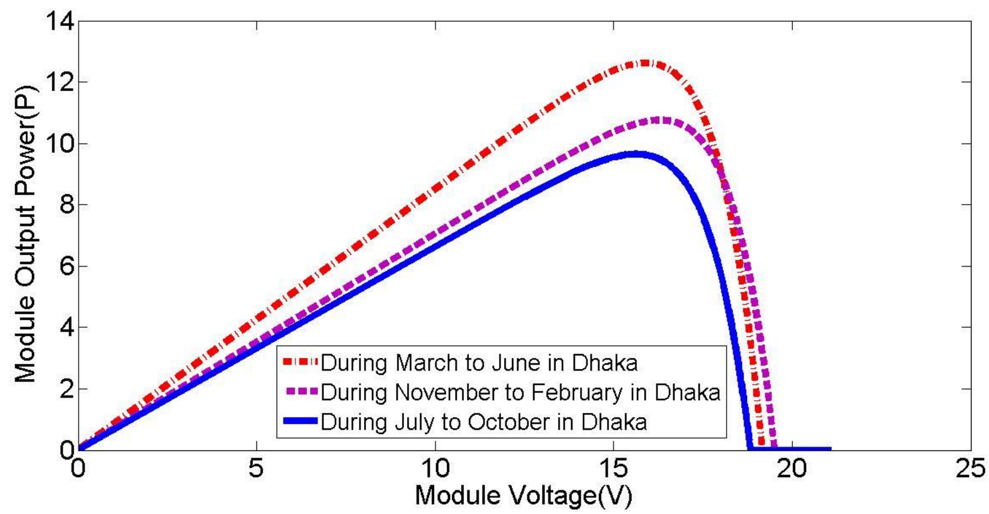

Fig 5.5: Simulated P-V curve of MSX60 for Dhaka

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5.2-Chittagong division:

It has been found that the average temperature in Chittagong 27.9°C and from figure 5.1; the average solar radiation is 217watt/m² during summer. And the average temperature and the average solar radiation are 28.3°C and 175watt/m² (from figure 5.2) respectively during monsoon in Chittagong. Again average temperature and the average solar radiation are 22°C and 189watt/m² (from figure 5.3) respectively during winter in Chittagong.

Figure 5.6 and Figure 5.7 demonstrate the current-voltage curve and power-voltage curve of MSX60 influenced by solar radiation and temperature of Chittagong.

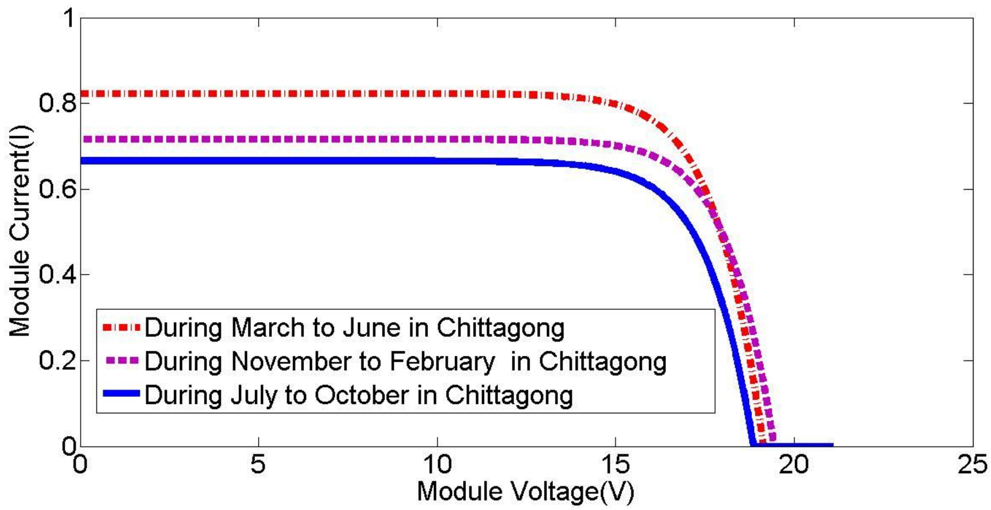

Fig 5.6: Simulated V-I curve of MSX60 for Chittagong.

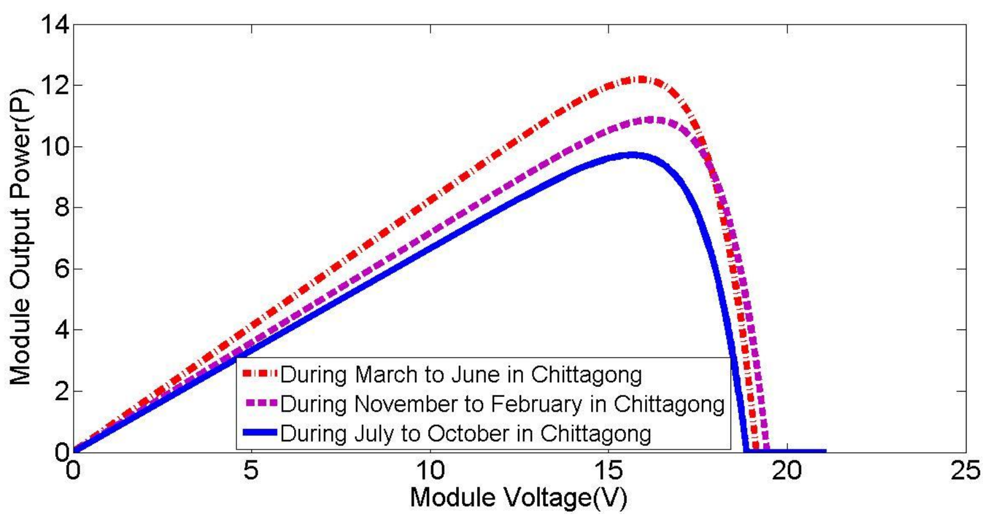

Fig 5.7: Simulated P-V curve of MSX60 for Chittagong.

5.3-Rajshahi division:

The average temperature and the average solar radiation are 29°C and 238 watt/m² (from figure 5.1) respectively during summer in Rajshahi. The average temperature and the average solar radiation are 28.9°C and 179 watt/m² (from figure 5.2) respectively during monsoon in Rajshahi. The average temperature and the average solar radiation are 20.4°C and 190 watt/m² (from figure 5.3) respectively during winter in Rajshahi.Figure 5.8 and Figure 5.9 demonstrate the current-voltage curve and power-voltage curve of MSX60 influenced by solar radiation and temperature of Rajshahi.

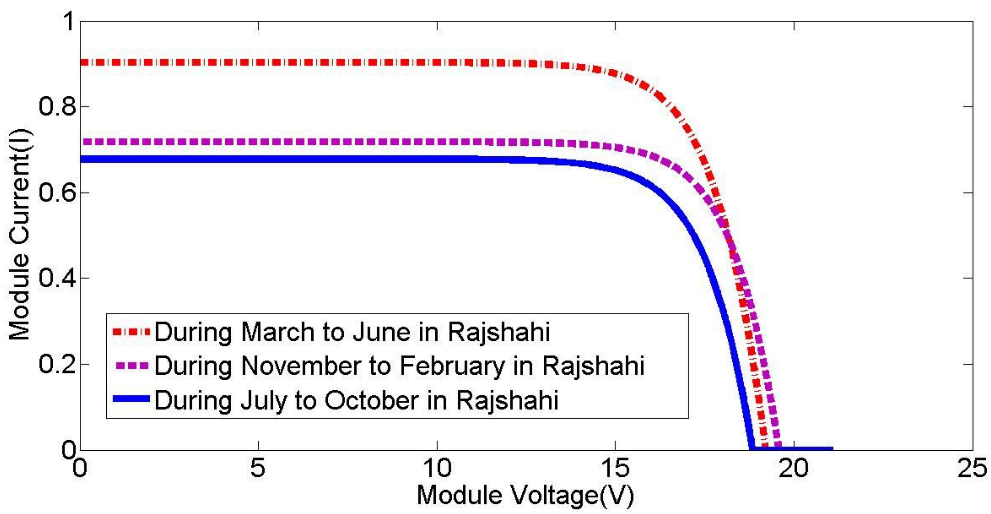

Fig 5.8: Simulated V-I curve of MSX60 for Rajshahi.

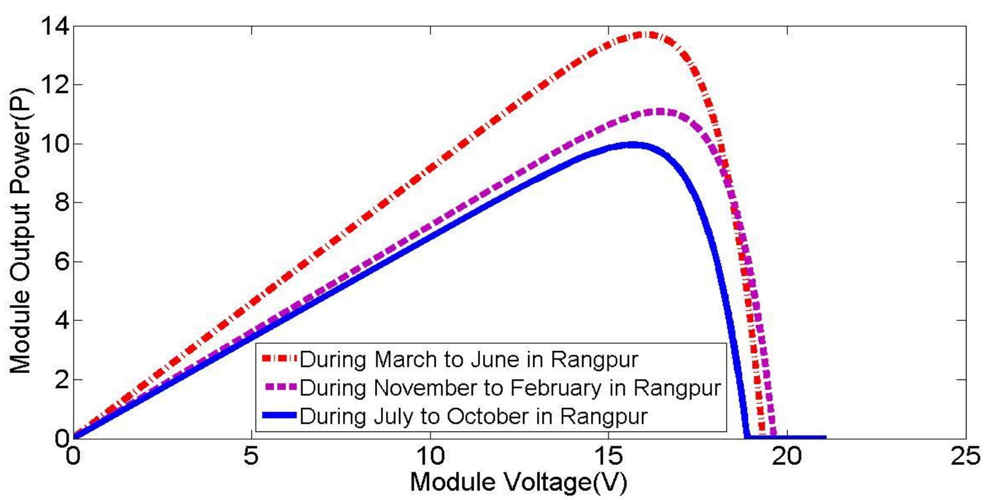

Fig 5.9: Simulated P-V curve of MSX60 for Rajshahi.

5.4-Khulna division:

The average temperature and the average solar radiation are 29.1°C and 227 watt/m² (from figure 5.1) respectively during summer in Khulna. The average temperature and the average solar radiation are 29°C and 173 watt/m² (from figure 5.2) respectively during monsoon in Khulna. The average temperature and the average solar radiation are 21.4°C and 184 watt/m² (from figure 5.3) respectively during winter in Khulna. Figure 5.10 and Figure 5.11 demonstrate the current-voltage curve and power-voltage curve of MSX60 influenced by solar radiation and temperature of Khulna.

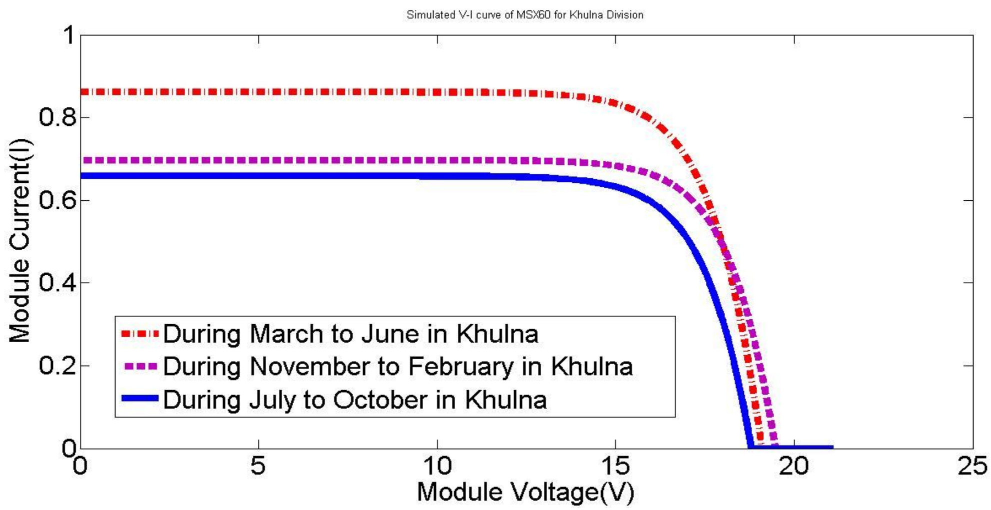

Fig 5.10: Simulated V-I curve of MSX60 for Khulna.

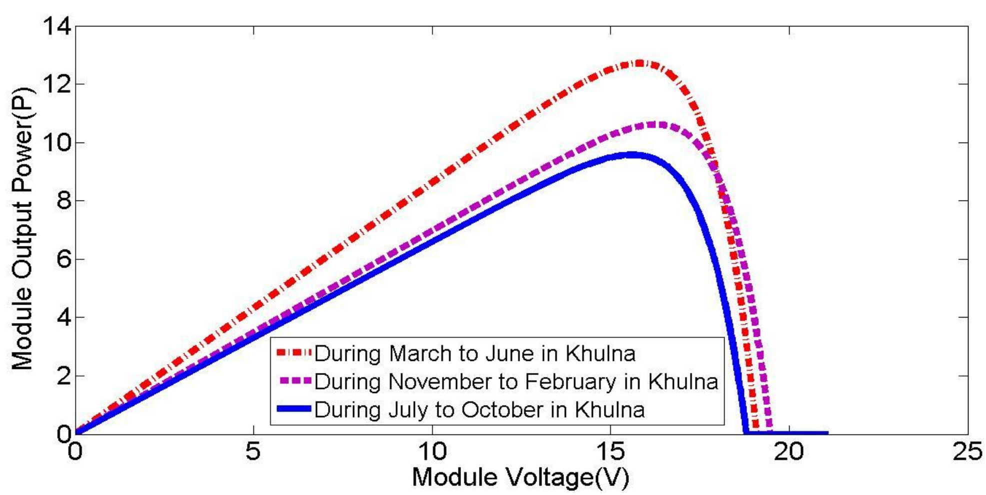

Fig 5.11: Simulated P-V curve of MSX60 for Khulna.

5.5-Rangpur division:

The average temperature and the average solar radiation are 27°C and 240 watt/m² (from figure 5.1) respectively during summer in Rangpur. The average temperature and the average solar radiation are 28.5°C and 180 watt/m² (from figure 5.2) respectively during monsoon in Rangpur. The average temperature and the average solar radiation are 20°C and 191 watt/m² (from figure 5.3) respectively during winter in Rangpur. Figure 5.11 and Figure 5.12 demonstrate the current-voltage curve and power-voltage curve of MSX60 influenced by solar radiation and temperature of Rangpur.

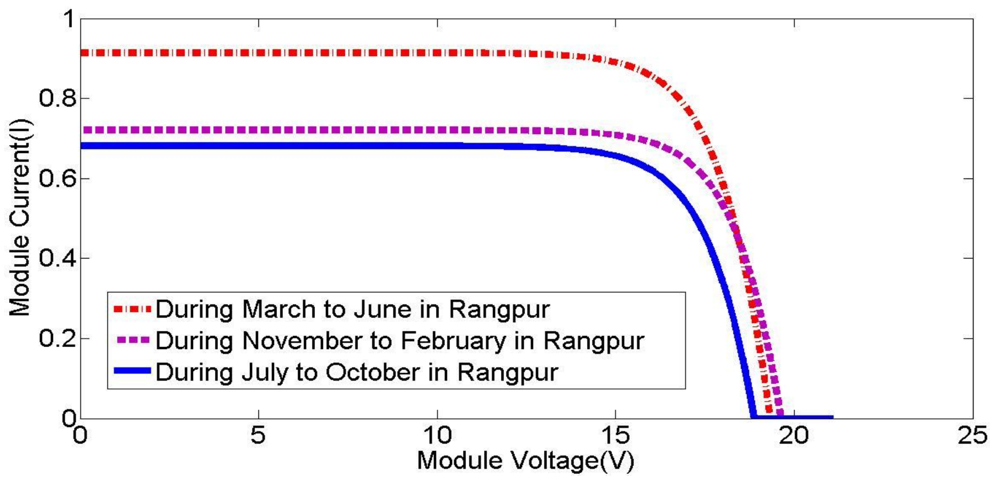

Fig 5.12: Simulated V-I curve of MSX60 for Rangpur.

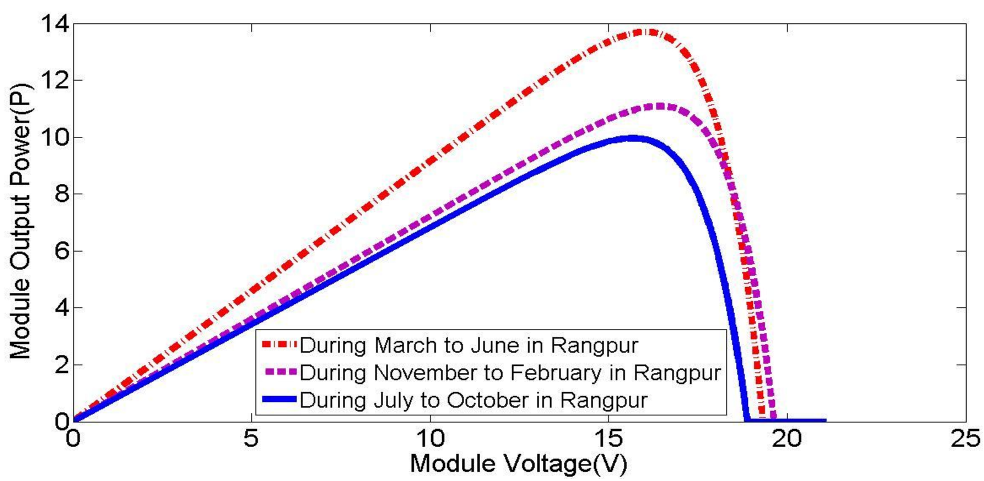

Fig 5.13: Simulated P-V curve of MSX60 for Rangpur.

5.6-Barisal division:

The average temperature and the average solar radiation are 28.4°C and 215 watt/m² (from figure 5.1) respectively during summer in Barisal. The average temperature and the average solar radiation are 28°C and 167 watt/m² (from figure 5.2) respectively during monsoon in Barisal. The average temperature and the average solar radiation are 22°C and 185 watt/m² (from figure 5.3) respectively during winter in Barisal. Figure 5.14 and Figure 5.15 demonstrate the current-voltage curve and power-voltage curve of MSX60 influenced by solar radiation and temperature of Barisal.

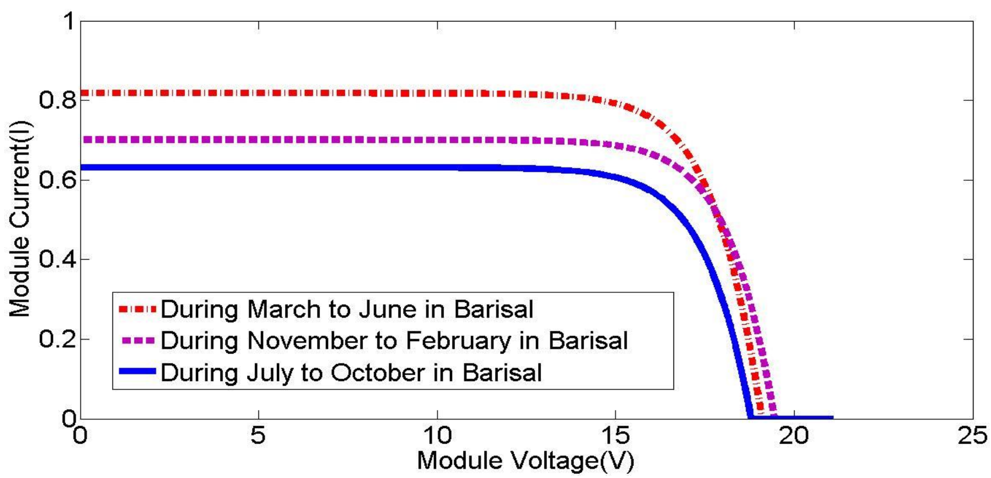

Fig 5.14: Simulated V-I curve of MSX60 for Barisal.

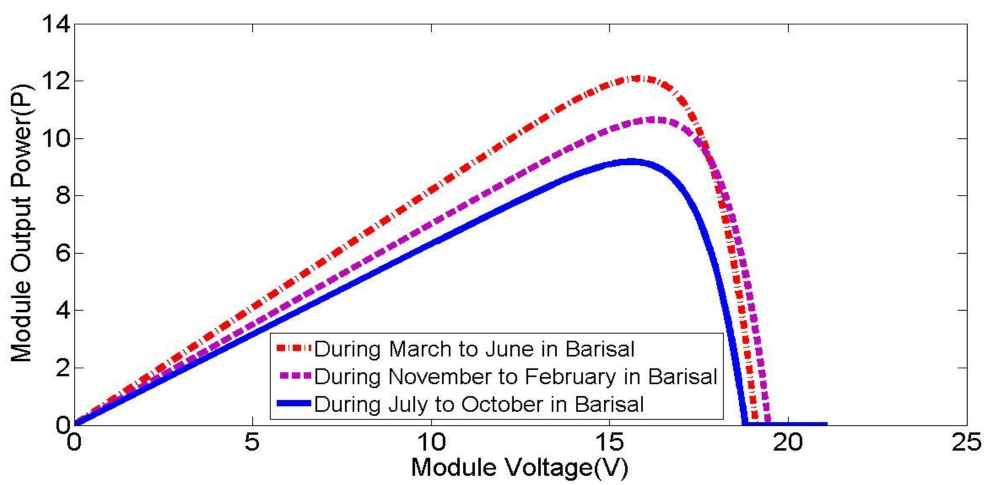

Fig 5.15: Simulated P-V curve of MSX60 for Barisal.

5.7-Sylhet division:

The average temperature and the average solar radiation are 27°C and 211 watt/m² (from figure 5.1) respectively during summer in Sylhet. The average temperature and the average solar radiation are 28°C and 166 watt/m² (from figure 5.2) respectively during monsoon in Sylhet. The average temperature and the average solar radiation are 21°C and 186 watt/m² (from figure 5.3) respectively during winter in Sylhet.

Figure 5.16 and Figure 5.17demonstrate the current-voltage curve and power-voltage curve of MSX60 influenced by solar radiation and temperature of Sylhet.

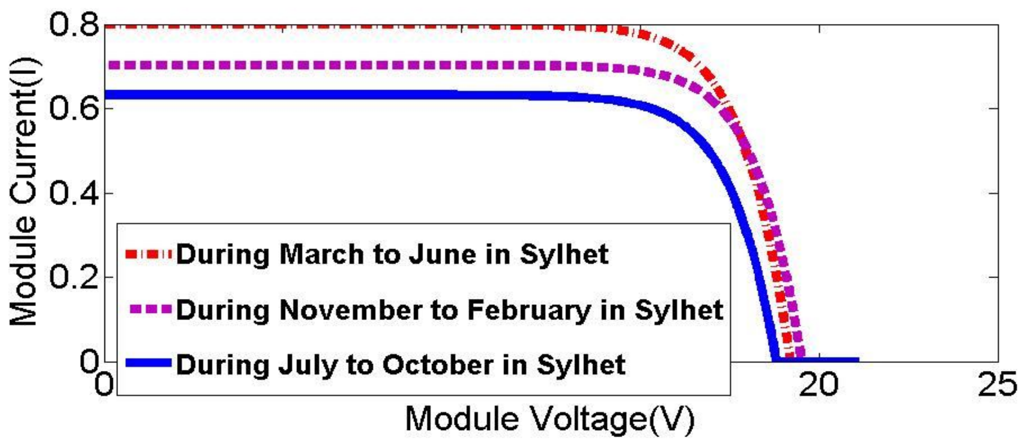

Fig 5.16: Simulated P-V curve of MSX60 for Sylhet.

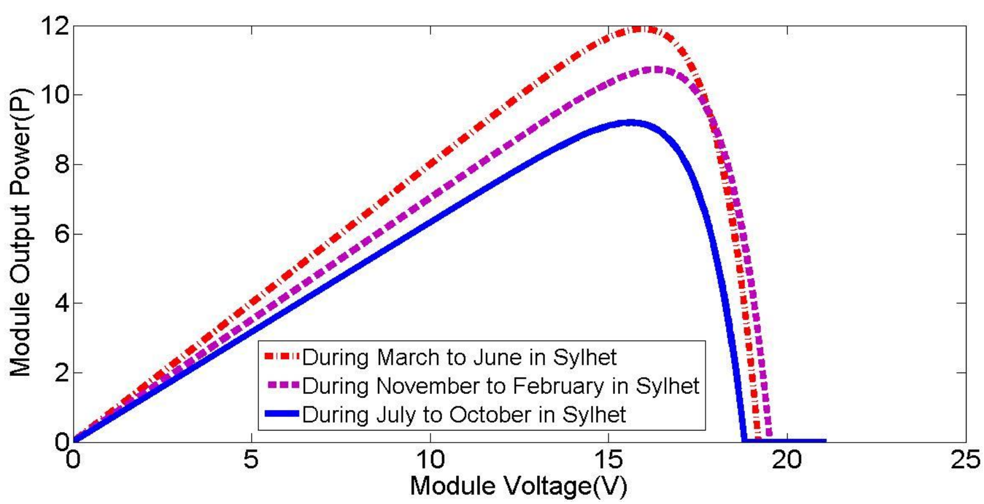

Fig 5.17: Simulated P-V curve of MSX60 for Sylhet.

Chapter 6- Performance Analysis

6.1 Parameters considered:

We analyze the performance of the output considering different condition of the system. As the source of energy that means the sun is not in our control the performance should vary sometimes. Considering all the environmental effects we try to take our decision.

The performance of the solar module varies due to different parameters. Performance of the module varies due to environmental parameters such as solar radiation, temperature and weather conditions. These parameters are nit constant for different times in the year or even it changes throughout a single day. Solar radiation varies throughout the day and is maximum at mid day and is minimum at the afternoon. Also the weather condition can change during any time of consideration.

For our case we considered the average solar radiation of day and night. If we consider only the day time then the performance of the PV cell will increase significantly as the average solar intensity become higher at the day time. So considering the night time when there is no radiation is affecting the result as well as the decision. The maximum average solar radiation of day and night is 203.67watt/m^2 but if we consider only day time then it will be about 1100watt/m^2. So the output power of the PV cell will be maximum at that time, but the average output power will be lesser than that.

Here we do not consider the unusual change of weather during any seasons. But when we consider practical life implementation then we also have to consider any kind of unusual behavior of the weather.

6.2 Performance of our system:

From our experimental results, we analyze the solar insolation and the temperature data for seven divisions of Bangladesh during summer (March-June), monsoon (July-October) and winter (November-February).

For the maximum performance we can take Rangpur and Rajshahi division as the reference, where the maximum output of MSX60 is found when the module output voltage is around 16V and the maximum output power is about 14 watt during summer. Compared to Rangpur & Rajshahi; Dhaka, Chittagong and Khulna have lower maximum power output estimated about 13 watt during summer. And the lowest power is found in Sylhet and Barisal having about 12watt during summer.

During winter the output power is lower than the summer and during monsoon it becomes the lowest. During winter the maximum power of Rangpur and Rajshahi is about 12.5 watt. And the maximum power of Dhaka, Chittagong and Khulna are about 11.5 watt while the maximum power of Sylhet and Barisal is about 10.5watt during winter.

Again, during monsoon the maximum power of Rangpur and Rajshahi divisions is about 11watt. And the maximum power of Dhaka, Chittagong and Khulna are about 10watt while the maximum power of Sylhet and Barisal is around 8.5watt during monsoon.

Here it is observed that the variation of maximum output power is less in Dhaka and Chittagong divisions throughout the year which is very helpful to design PV module with good battery storage capacity. But we get maximum power output in Rangpur division and Rajshahi division during March-June. Thus if we can maintain good battery storage capacity of PV modules then both Rangpur and Rajshahi division are recommended places to implement large numbers of solar PV modules.

Chapter 7- Conclusion

We analyze the performance of a typical 60W PV module of MSX60 throughout Bangladesh. The V-I curves and maximum power output is determined in different divisions of Bangladesh. Every time the maximum power output is found in voltage around 16V. Also the output power varies due to the variation of solar radiation and temperature. We should mention that for maximum power at most of the time of the day the Maximum Power Point Tracking (MPPT) system should be introduced [9].

For large scale PV system the variation of the performance parameters, that means the variation in temperature and solar radiation should be as less as possible. But if we have variation then we need to maintain good storage system.

From the output result we can see that the variation of current and power is less in Dhaka and Chittagong divisions. So large scale PV system can be introduced in these two regions as less variation in current and power is helpful for good storage design. Also Rangpur and Rajshahi divisions are preferable if we can maintain good storage system.

This paper analyzes the performance of a typical 60W PV module of MSX60 throughout Bangladesh. This paper is an important step to install a complete Photovoltaic system in Bangladesh. A good PV system will provide clean energy as well as it will lessen the power crisis in Bangladesh.

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