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Design and Analysis of Photovoltaic System for a Rural House in Bangladesh

Dr. Raton Kumar Nondy, Md. Turiqul Islam, Sumon Islam, Md. Sariful Islam

Abstract— A reliable, affordable and secure supply of electrical energy is important for the socio-economic development of any country. Bangladesh as a developing country is now looking forward to develop its renewable energy sources in addition to its traditional sources of fossil fuel. It has very limited nonrenewable energy sources of its own but it is endowed with renewable energy sources like solar, biomass, wind and hydro. Bangladesh is recognized to have excellent solar PV potential because of its geographical position. But little systematic quantitative investigation has been evaluated for PhotoVoltaic (PV) power generation with its economic and environmental impacts using scenario-based analysis. In this paper, possible implementations of solar technologies like PV cells and its implementations are discussed. Further, electrical demand of an isolated rural house in Bangladesh without connection to national grid, using day to day necessary appliances, by PV system is also presented as an example system. Primarily electrical consumption of a house was estimated using energy charts, by considering the working time, total daily energy consumption was also calculated. The last year registered data were obtained by using a pyranometer. From these data, time of radiations and least radiation intensities were also investigated in different seasons and in different places of Bangladesh.

Index Terms— PV cell, solar radiation, temperature, maximum power point tracking (MPPT), Solarex MSX120 performance parameter, renewable energy.

1 Introduction

The use of electricity is increasing all over the world with the increase of electronic equipment. All electronic devices run on this electrical energy. People use such devices in their daily life. To fulfill the power requirement from the consumers, enough sources of power are needed. Existing power plants cannot give enough electricity power, and the most part of the sources of energy is fossil fuel. Fossil fuel power plant generates massive amount of CO_2 and lots of other gases which are not suitable for the environment. This a major reason for global warming. It causes an increase in the temperature of the environment.

Solar PV is a key technology for capturing the benefits like having no waste, no moving parts, no emissions, less trans- portation costs, not requiring water during power production and has no adverse effects on the environment [1]. This is a sustainable solution to protect the atmosphere by reducing the greenhouse effect and control the rising temperature.

Bangladesh is a land of area 147,570sq km with its 180 million people and increasing every year, resulting in a considerably high electricity demand each year. As a result, Bangladesh experiences unmanageable shortage of electricity every year especially in summer. Over 70% of Bangladesh lies outside the national grid [2]. Bangladesh is situated between latitudes 24.20^{o} N and 25.35^{o} N and longitudes 88.20oE and 89.30oE which is an ideal location for solar energy utilization [3]. Daily average solar radiation varies between 4 to 6.5kWh per square meter [4]. So solar energy can be used as an alternative source not only to get rid of everyday load shedding miseries but also to reduce the power shortage.

2. Calculation of Load

2.1 Preparation for Degining

It is very important to have a proper understanding of the case of designing any solar system. The size of the components of the system depends on the electricity demand. So the whole system designing is dependent on the amount of load. If there is no correct information about the load, the initial cost will increase, the PV array or the battery size will be slashed, and the system will not work effectively. Therefore, the load type and size should be determined carefully so that the performance of the whole system is maximum. Before designing the system, we needed to calculate how much time it would run. For our study we use DC flood light and DC fan. So we avoid the difficulty of choosing any inverter. Total load of the house hs shown in Table 1.

Table 1: Total Load

SL NO	Bulb (Watt)		Fan (Watt)	TV (Watt)	
Room 1	10W	5W		-----	
Room 2	10W	5W	40W	25W	
Room 3	10W	5W		-----	
Kitchen	5W	-----	-----	-----	
Bathroom	5W	-----	-----	-----	

A security bulb is chosen in front of the house which is 10 Watt. All bulbs are as chosen LED bulb.

Total load, P=3×10W+5×5W+1×40W+1×25W+1×10W=130Watt

Table 2: Total Load (Watt-hour)

Bulb (W)	Fan (W)	TV (W)	Quantity	Rated power	Operating hour	Watt-Hour
10			4	10 x 4=40 watt	3	40 x 3= 120
5			5	5 x 5 =25 watt	2	25 x 2 = 50
	40		1	40 x 1=40 watt	6	40 x 6 = 240
		25	1	25 x 1=25 watt	2	25 x 2 = 50
			Total	=130 watt		= 460 watt-hour

Now in summer, autumn and spring for 460 watt-hour load for a 12-volt DC system, daily ampere-hour calculated as follows:

Watt- hour/voltage = (volt. x amp. x hr)/ voltage
= (460/12) amp-hr
=38.33 ampere-hour

Again, in winter, as people does not use fan, 220 watt-hours daily ampere-hour is calculated as follows for our system:

Watt- hour/voltage = (voltage x ampere x hour)/ voltage
= (220/12) ampere-hour
=18.33 ampere-hour

At this point load calculation is completed.

2.2 Designing of the PV Cell

This model is mathematically described by some equation which is an implicit equation where I and V can be solved by using the method of Newton-Raphson or analytically with approaches. This equation has five parameters I_L, I_{SAT}, R_S, R_{SH} and I_D.

A PV cell is initially a silicon semiconductor junction device that contains a p-n junction like a diode. It produces power relative to the occurrence daylight. At the point when light shines on the PV cell current flow from the p-type side to the n-type side over the p-n junction through a wire which is known as light generated or photocurrent I_L. The equivalent circuit of a basic PV cell can be modeled by a current source in parallel with a diode, a shunt resistance announcing a leakage current and a series resistance describing an internal resistance to the current flow as depicted in figure 2.1.[5]

The photocurrent IL of the PV cell is directly proportional to the solar illumination. The output current I_{OUTPUT} of the cell is $I_{OUTPUT} = I_L - I_D - I_{SH}$. As R_{SH} »μ, so I_{SH} » 0.

$I_{OUTPUT} = I_L – I_{ZD}$ ………………………………… (1)

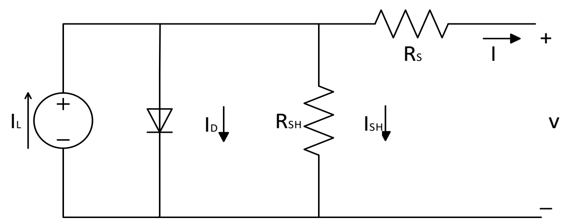

Figure 1: Electrical model of PV cell

If I_{SAT} is the saturation current of the diode then,

$I_D=I_{SAT} (e^{(q*(V+IRs)/nKT)}-1)$………………………….. (2)

Thus the equations for the I-V characteristics of the PV cell,

ar

$I_{OUTPUT} = I_L- I_{SAT} (e^{(q*(V+IRs)/nKT)}-1)$……………………(3)
$I_L= I_L(T_1)(1+ K_0 (T -T_1))$………………………….........(4)
$I_{L(T1)} = G * I_{SC(T1, nom)} / G_{(nom)}$ ……………………........(5)
$K_0 = (I_{SC(T2)} - I_{SC(T1)})/(T_2 -T_1)$ ……………………..…….. (6)
$I_{SAT} = I_{SAT (T1)}*(T / T_1)^{3/n} * e^{- qVg / nk * (1/T - 1/T1)}$ ….....(7)
$I_{SAT(T1)} = I_{SC(T1)} / (e^{qVoc (T1)/ nkT1} -1)$………………. (8)
$R_S = -dV / dI_{VOC} - 1/X_V$ …………………………....(9)
$X_V = I_{SAT(T1)}* q / nkT_1*e^{qVOC(T1) / nkT1}$ ……………..(10)

Here, n is known as diode quality factor which is 1 for ideal diode. Se R is a small resistance which represents internal losses due to current flow. The Boltzmann's constant,

$k =1.380658 * 10^{-23} JK^{-1}$ [6]

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

Short circuit current: 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.

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

$V_{OC} = nkT / q * \ln (I_L / I_{SAT} +1)$………………….. (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,

$P_{max} = V_{max}* I_{max}=V_{OC} * I_{SC} * FF$ ………………….. (12)

Here FF is the fill factor.

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

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

Parameter	Value
Maximum power (Pmax)2	120W
Voltage at Pmax, Vmax	33.7V
Current at Pmax, Imax	3.56A
Minimum Pmax	114W
Short-circuit current (Isc)	3.87A
Open-circuit voltage (Voc)	42.1V
Temperature coefficient of Isc	(0.065±0.015)%/°C
Temperature coefficient of Voc	-(80±10)mV/°C
Temperature coefficient of power	-(0.5±0.05)%/°C
NOCT3	47±2°C
Maximum system voltage	600V
Maximum series fuse rating	20A

Table 3: Typical Electrical characteristics of Solarex MSX120, 120W PV module.

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:

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

Fill factor is determined from measurement of the I-V curve and for good PV cells its value is greater than 0.7.

In this experiment, Solarex MSX120, a 120W PV module is utilized to examine the electrical performance parameters at a various natural place. This module comprises of 72 multi-crystalline silicon solar cells designed as four series strings of 18 cells each. At the point when light occurrences on it, it produce a photocurrent, IL 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. Average Solar Radiation and Temperature Data in Bangladesh:

The average solar radiation in the Bangladesh is sufficient enough to keep a significant contribution to the country's energy supply. Thirty years average solar radiation data according to NASA Surface Meteorology and Solar Energy website [8] is analyzed to find out the variation of solar radiation and average solar temperature in the Bangladesh. Figure 2, Figure 3, Figure 4, Figure 5 show the average solar radiation and Figure 6, Figure 7, Figure 8, Figure 9 show the average solar temperature during spring (March-April), summer (May-July), autumn (August-October) and winter (November-February) respectively in seven different cities in the Bangladesh. If we consolidate the four figures, we can see that the average solar radiation of Barisal, Chittagong, Comilla, Dhaka, Rajshahi, Rangpur and sylhet are 34.35MJ/m2/day, 34.35MJ/m2/day, 34.53 MJ/m2/day, 34.53MJ/m2/day, 33.95MJ/m2/day, 33.74 MJ/m2/day and 33.95MJ/m2/day respectively. The comparison between the maximum solar radiation throughout the country shows that Dhaka and Comilla have more solar radiation than the others city. But Rajshahi and Sylhet have less solar radiation variation throughout the whole year than the other city. Relatively less variation in solar radiation helps to design PV module with less battery storage capacity and hence the cost of the module reduces [7].

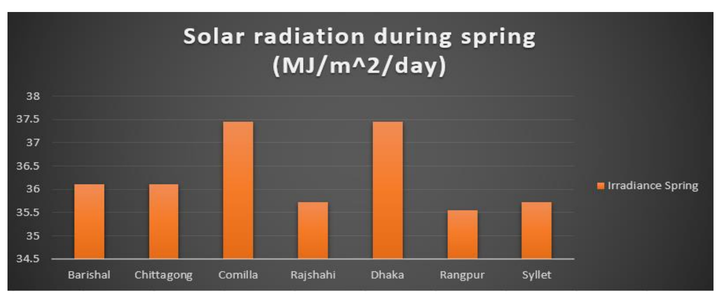

Figure 1: Solar Radiation during spring in Bangladesh

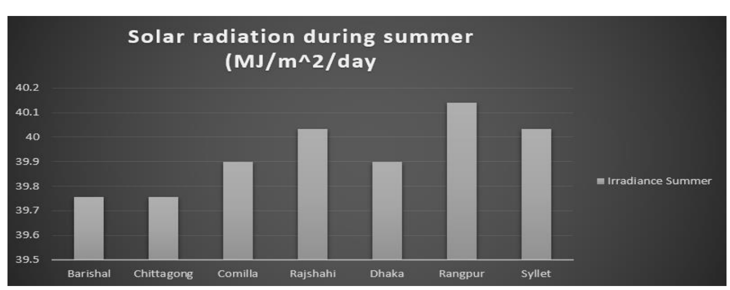

Figure 2: Solar Radiation during summer in Bangladesh

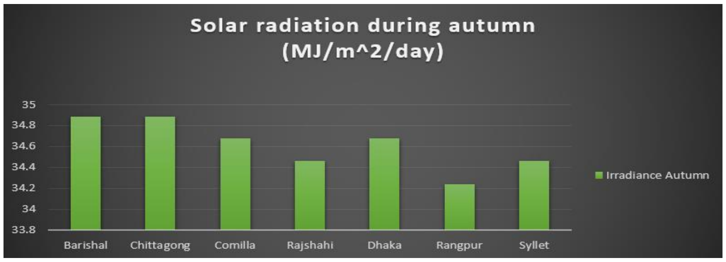

Figure 3: Solar Radiation during autumn in Bangladesh

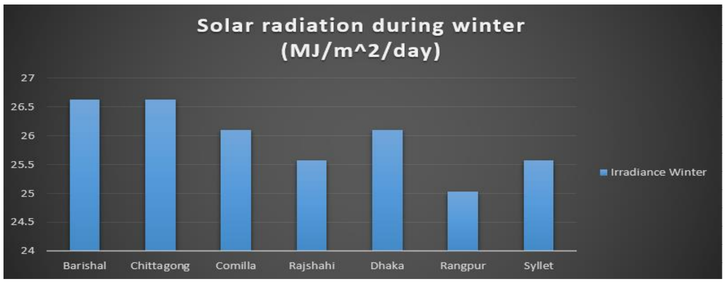

Figure 4: Solar Radiation during winter in Bangladesh

In Bangladesh, it has been observed that the solar radiation is at its highest values during summer and its lowest values during winter. The maximum values of radiation for Barisal, Comilla, Chittagong, Dhaka, Rajshahi, Rangpur and Sylhet are 39.756MJ/m²/day, 39.9MJ/m²/day, 39.76MJ/m²/day, 39.9MJ/m²/day, 40.032MJ/m²/day, 40.14MJ/m²/day and 40.04MJ/m²/day respectively and should be taken as the input of the PV cell during summer.

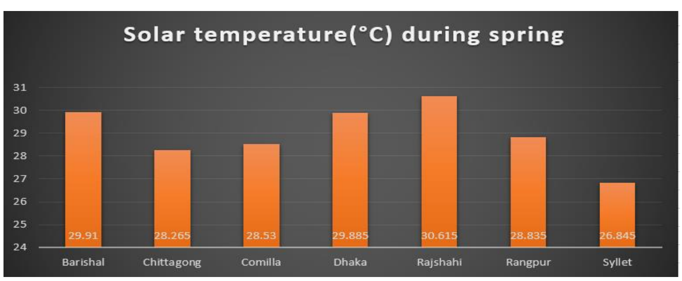

Figure 5: Solar Temperature during spring in Bangladesh

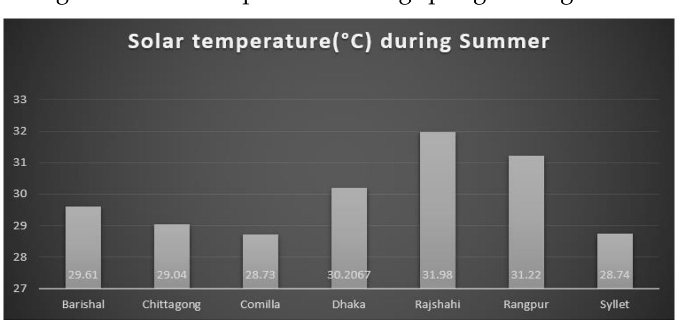

Figure 6: Solar Temperature during summer in Bangladesh

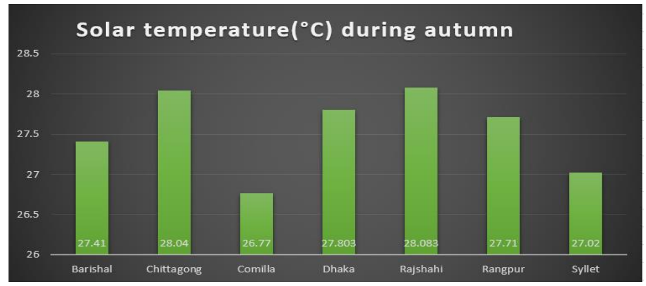

Figure 7: Solar Temperature during autumn in Bangladesh

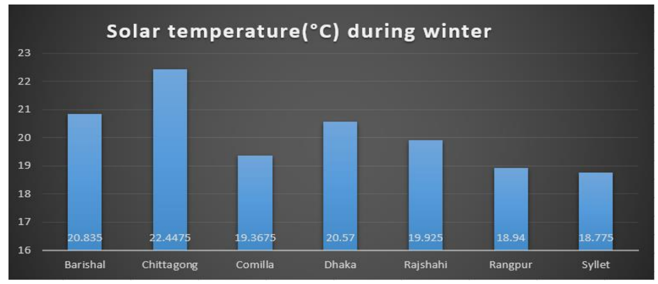

Figure 8: Solar Temperature during winter in Bangladesh

Similarly, the minimum values of radiation for Barisal, Comilla, Chittagong, Dhaka, Rajshahi, Rangpur and Sylhet are 26.63MJ/m²/day, 26.1MJ/m²/day, 26.63MJ/m²/day, 26.1MJ/m²/day, 25.58MJ/m²/day, 25.04MJ/m²/day and 25.58MJ/m2/day respectively and should be taken as the input of the PV cell during winter. Again the first middle values of the radiation for Barisal, Comilla, Chittagong, Dhaka, Rajshahi, Rangpur and Sylhet are 36.11MJ/m²/day, 37.45MJ/m²/day, 36.11MJ/m²/day, 37.45MJ/m²/day, 35.73MJ/m²/day, 35.55MJ/m²/day and 35.73MJ/m²/day respectively should be taken as the input of the PV cell during spring and at its second middle values of the radiation for Barisal, Comilla, Chittagong, Dhaka, Rajshahi, Rangpur and Sylhet are 37.88MJ/m²/day, 3.68MJ/m²/day, 34.884 MJ/m²/day, 34.68 MJ/m²/day, 34.463 MJ/m²/day, 34.237MJ/m²/day and 34.46MJ/m²/day respectively should be taken as the input of the PV cell during autumn.

4. Simulation and Experimental Results of PV Cell in Matlab

The output intensity of a PV changes with the solar irradiation variety when the temperature is constant and the normal for output control changes with the surrounding temperature's variety when the solar irradiation is consistent. For our research, we are interested to see the execution parameter of Solarex MSX120 in seven different cities for four unique seasons: Winter, spring, summer and autumn.

It has been found that the average temperature in Barisal is

20.84°C during winter, solar radiation is 0.308 kw/m² and 22.45°C and 0.308 kw/m² respectively in Chittagong. The average temperature and solar radiation are 19.37°C and 0.302 kw/m² respectively during winter in Comilla. The average temperature and solar radiation are 20.57°C and 0.302 kw/m² respectively during winter in Dhaka. The average temperature and solar radiation are 19.93°C and 0.296 kw/m² respectively during winter in Rajshahi. The average temperature and solar radiation are 18.94°C and 0.290 kw/m² respectively during winter in Rangpur.

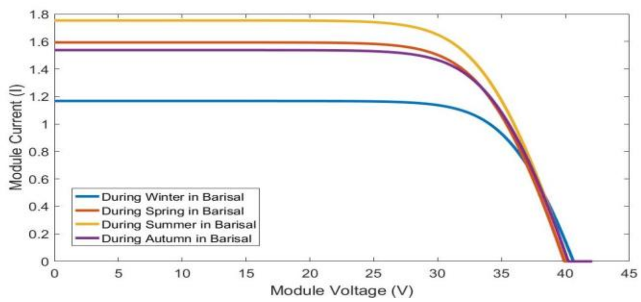

Figure 9: Simulated V-I curve of Solarex MSX120 for Barisal

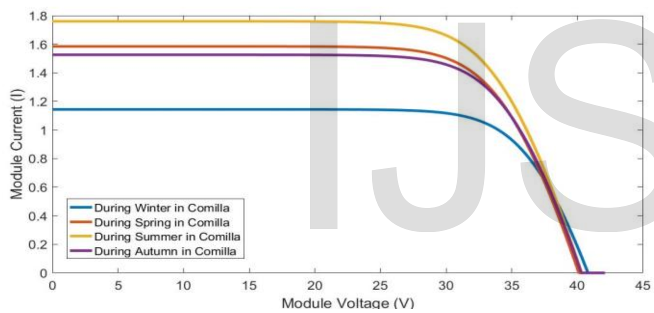

Figure 10: Simulated V-I curve of Solarex MSX120 for Comilla

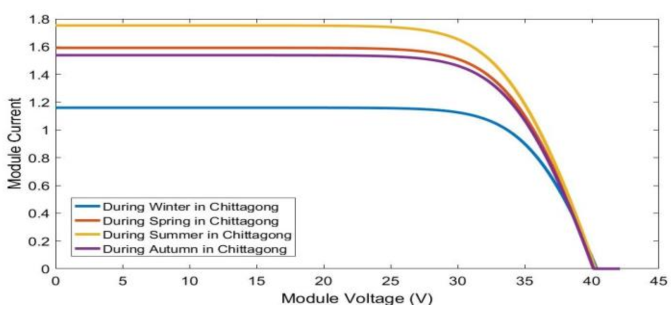

Figure 11: Simulated V-I curve of Solarex MSX120 for Chittagong

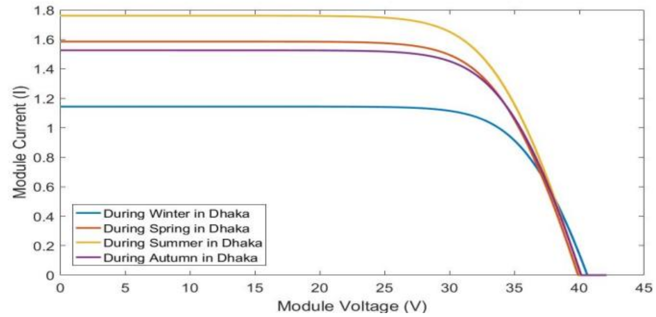

Figure 12: Simulated V-I curve of Solarex MSX120 for Dhaka

The average temperature and solar radiation are 18.76°C and 0.296 kw/m² respectively during winter in Sylhet. It has been found that the average temperature in Barisal is 29.91°C during spring and the average solar radiation is 0.418kw/m². The average temperature and the average solar radiation are 28.53°C and 0.416kw/m² respectively during spring in Comilla. Average temperature and the average solar radiation are 28.27°C and 0.418kw/m² respectively during spring in Chitagong.

The average temperature and solar radiation are 29.89°C and 0.416kw/m² respectively during spring in Dhaka. The average temperature and solar radiation are 30.62°C and 0.414kw/m² respectively during spring in Rajshahi. The average temperature and solar radiation are 28.84°C and 0.411kw/m² respectively during spring in Rangpur.

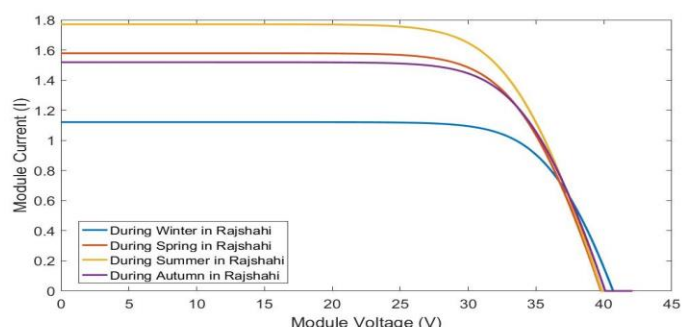

Figure 13: Simulated V-I curve of Solarex MSX120 for Rajshahi

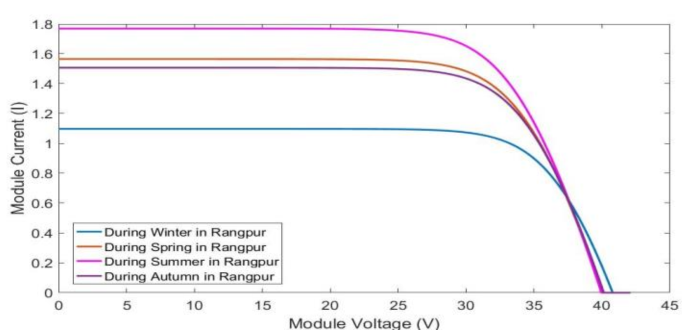

Figure 14: Simulated V-I curve of Solarex MSX120 for Rangpur

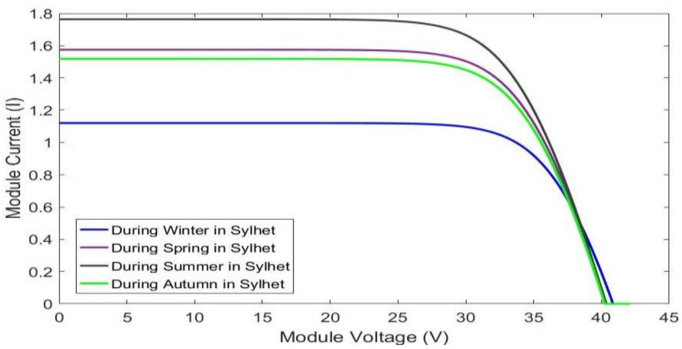

Figure 15: Simulated V-I curve of Solarex MSX120 for Sylhet

The average temperature and solar radiation are 26.85°C and 0.414kw/m² respectively during spring in Sylhet.

In summer, the average temperature in Barisal is 29.61°C and the average solar radiation is 0.460kw/m² and 28.73°C and 0.462kw/m² respectively in Comilla and 29.04°C and 0.460kw/m² respectively in Chittagong.

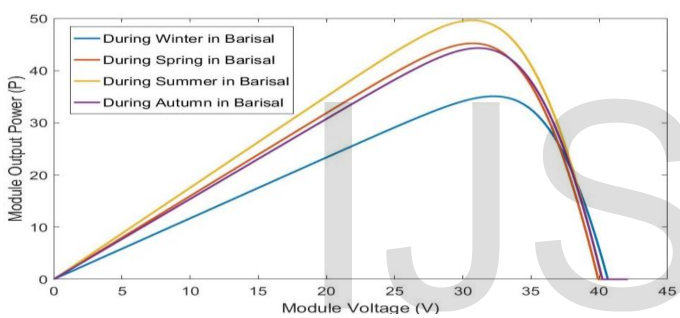

Figure 16: Simulated P-V curve of Solarex MSX120 for Barisal

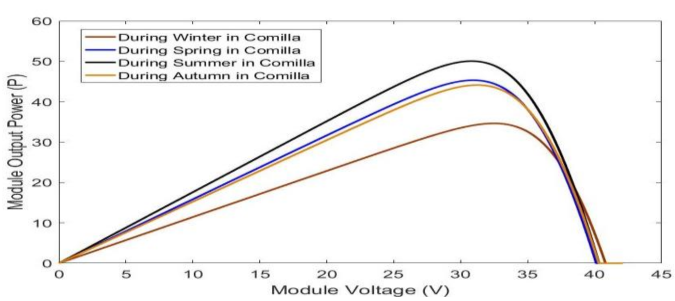

Figure 17: Simulated P-V curve of Solarex MSX120 for Comilla

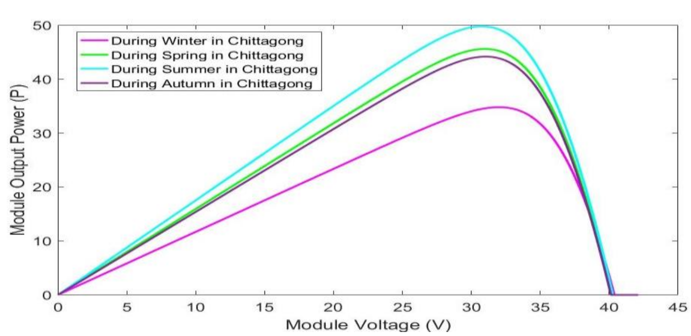

Figure 18: Simulated P-V curve of Solarex MSX120 for Chittagon

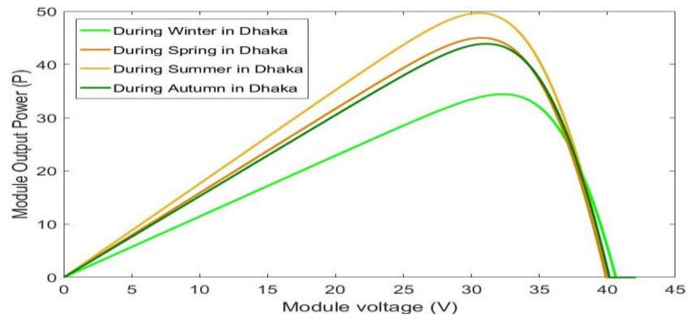

Figure 19: Simulated P-V curve of Solarex MSX120 for Dhaka

The average temperature and solar radiation are 30.21 °C and 0.462kw/m² respectively in Dhaka and 31.98°C and 0.463kw/m² respectively in Rajshahi. The average temperature and solar radiation are 31.22°C and 0.464kw/m² respectively in Rangpur and 28.74°C and 0.463kw/m² in Sylhet.

During autumn, it has been found that the average temperature in Barisal is 27.41°C and solar radiation is 0.404kw/m² and 26.77°C and 0.401kw/m² respectively in Comilla. The average temperature and solar radiation are 28.04°C and 0.404kw/m² respectively in Chittagong. The average temperature and solar radiation are 27.80°C and 0.401kw/m² respectively in Dhaka and 28.08°C and 0.399kw/m² respectively in Rajshahi. The average temperature and solar radiation are 27.71 °C and 0.396kw/m² respectively in Rangpur and 27.02°C and 0.399kw/m² respectively in Sylhet.

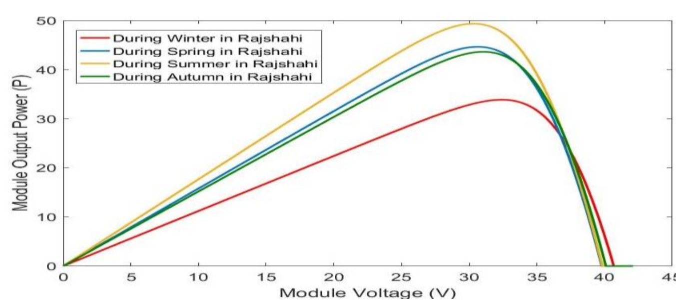

Figure 20: Simulated P-V curve of Solarex MSX120 for Rajshahi

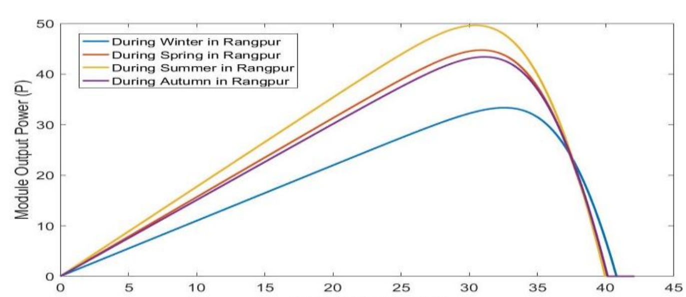

Figure 21: Simulated P-V curve of Solarex MSX120 for Rangpur

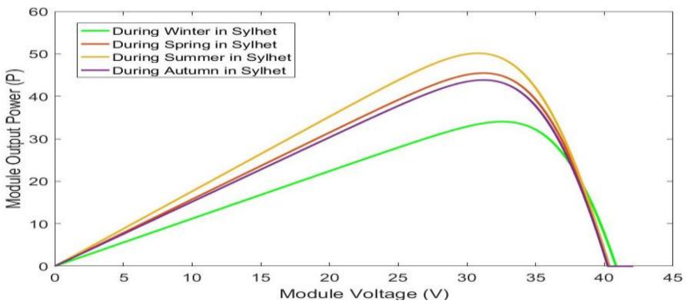

Figure 22: Simulated P-V curve of Solarex MSX120 for Sylhet

5. Discussion on the System Performance

From our experimental results, we analyze the sun oriented radiation and the temperature information for seven different divisions of Bangladesh during winter, spring, summer and autumn. For the maximum performance, we can take Comilla as the reference, where the maximum output of Solarex MSX120 is found when the module output voltage is around 30 V and the maximum output power is about 50.03watts during summer. Compared to Comilla, Barisal, Chittagong, Dhaka, Rajshahi, Rangpur and Sylhet have lower maximum power output estimated about 1 watt during summer. And the lowest power is found in Rajshahi and Rangpur having about 1 watt during summer.

During winter and autumn, the output power is lower than the summer and spring, it becomes the lowest. During winter the maximum power of Dhaka is about 34.7 watt. And the maximum power of Comilla and Barisal is 34.6watt and 33.9watt while the maximum power of Rajshahi, Chittagong, Sylhet and Rangpur are 33.82watt, 33.81watt, 33.75watt and 33.22watt during winter. Again, during spring the maximum power of Barisal is about 46.1watt. And the maximum power of Chittagong, Sylhet, and Comilla are 45.46watt, 45.09watt and 45.01watt while the maximum power of Dhaka, Rangpur and Rajshahi is 44.98watt, 44.96watt and 44.90watt during spring. Correspondingly, during autumn the maximum power of Barisal is about 43.30watt. And the maximum power of Chittagong, Comilla, and Sylhet are 44.12watt, 44.10watt and 43.92watt while the maximum power of Dhaka, Rajshahi and Rangpur is 43.9watt, 43.8watt and 43.64watt during autumn.

In this research the demand of energy for a rural area house is 130watt. But the 120watt module efficiency in Bangladesh is above 44 watt accept winter. In that case, we use 3 modules to fulfill our demand.

6. Limitation

The amount of sun energy that could be collected. The radiation of sun is nearly fixed; the place that can be used to pave solar panels are limited; we cannot exploit all of sunlight to electricity because biosphere needs it; the energy conversion efficiency has a theoretical limit. But even all these are considered, this limit is still well beyond the energy human needed.

7. Future Work

We can concentrate on the use of grid-connected solar-powered generators to replace conventional sources of electricity, particularly in the Rural Area in Bangladesh. As considered one of the most arousing energy growth nations, the cost of small-scale PV generation will help Bangladesh with the very high value of access to electricity for rural people.

8. Recomandation

From the analytical information and the simulated outcome, obviously, the variety of current and power is less in Rangpur and Rajshahi than different cities, which is most useful to design good storage of energy. So for presenting the large scale PV system, Comilla is recommended an area to get quality and effective power all through the entire year.

9. Conclusion

In that work, possible implementations of solar technologies like PV cells and its implementations are developed for a rural house in Bangladesh. The house assumed for study is not connected to grid system.

We further explore the performance of a typical 120W PV module of Solarex MSX120 throughout the Bangladesh. The V-I curve and maximum power output are resolved in various cities in Bangladesh. Each time the maximum power output is found in voltage around 30 V. Clearly, to get the greatest power at more often than not of the multi-day, Maximum Power Point Tracking (MPPT) framework ought to be introduced.

10. References

[1] V. Agarwal and A. Vishwakarma, A comparative study of PWM schemes for grid connected PV cell, in Power Electronics and Drive Systems, 2007. PEDS'07. 7th International Conference on, 2007, pp. 1769-1775.

[2] T.-u. SHAKIR-ul haque Khan and S. H. Rahman, A bri4 study of the pmlpect of solar energy in generation of electricity in Bangladesh, Cyber Journals: Multidisciplinary Journals in Science & Technology, Journal of Selected Areas of Renewable & Sustainable Energy (JRSE), June Edition,2012.

[3] A. S. Islam, M. Mondal, and M. Ahiduzzaman, Grid Connected Solar PV Irrigation System in Semi-Arid Region of Bangladesh, Int. J. of Sustainable Water & Environmental Systems, vol. 1, pp. 33-38,2010.

[4] A.K.M. Sadrul Islam, Mazharul Islam and Tazmilur Rahman, Effective renewable energy activities in Bangladesh, Renewable Energy, -Elsevier, 2006.

[5] N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, O"ptimization of perturb and observe maximum power point tracking method, " Power Electronics, IEEE Transactions on, vol. 20, pp. 963-973, 2005.

[6] F. M. Gonzlez-Longatt, "Model of photovoltaic module in Matlab," II CIBELEC, vol. 2005, pp. 1-5,2005

[7] R. Sagor and M. Abido, Study of solar energy for PV implementation in Saudi Arabia" in Energy Conference and Exhibition (EnergyCon), 2010 IEEE International, 20 I 0, pp. 830-834

[8] Charles H. Whitlock, Donald E. Brown, William S. Chandler and Roberta C. DiPasquale, RELEASE 3 NASA SURFACE METEOROLOGY AND SOLAR ENERGY DATA SET F OR RENEWABLE ENERGY INDUSTRY USE.

- *Dr. Raton Kumar Nondy is working as an Assocaite Professor in the department of EEE at IUBAT. His areas of interest are: Power system stability, Renewable Energy and FACT system.*
  Email: raton.nondy@iubat.edu.
- *Md. Turiqul Islam has completed Bachelor degree in Electrical & Electronics Engineering from International University of Business, Agriculture & Technology (IUBAT). He is working as a Senior Lecturer in the department of EEE at IUBAT. His areas of interest are: Wind energy, Renewable Energy, Nano Technology and Robotics.*
  Email: tonmoy11105063@gmail.com.
- *Sumon Islam is continuing his Bachelor in Electrical & Electronics Engineering form International University of Business Agriculture & Technology. His interest fields are Renewable Energy and Robotics.*

  Email: sumonislamiubat@gmail.com
- *Md Sariful Islam is continuing his Bachelor in Mechanical Engineering from International University of Business Agriculture & Technology.* His interest fields are Renewable *Energy, Applied Mechanics and Materails.*

  Email:sariful17107061iubat@gmail.com