Journal of Optoelectronics Engineering, 2014, Vol. 2, No. 2, 46-49
Available online at http://pubs.sciepub.com/joe/2/2/5

DOI:10.12691/joe-2-2-5

Solar Power Potentiality Analysis in Some Regions of Bangladesh in the Case of Solar Irradiance

Suman Chowdhury*

Department of Electrical and Electronics Engineering, IUBAT-International University of Business Agriculture and Technology
*Corresponding author: suman@iubat.edu

Received November 28, 2014; Revised December 16, 2014; Accepted December 28, 2014

Abstract This paper analyzes the power characteristics of the PV cell in the case of solar irradiance. And it is also seen that a significant power change is occurred if the level of the series resistance is varied. Finally it is observed that Dinajpur is 9.67% more potential than Khulna and Chittagong in respect of solar irradiance. Also it is found that Dinajpur is 7.47% more potential than Dhaka.

Keywords: *solar energy, solar irradiance, fill factor, PV cell, series resistance*

Cite This Article: Suman Chowdhury, "Solar Power Potentiality Analysis in Some Regions of Bangladesh in the Case of Solar Irradiance." *Journal of Optoelectronics Engineering*, vol. 2, no. 2 (2014): 46-49. doi: 10.12691/joe-2-2-5.

1. Introduction

Solar energy is the most promising source of clean, renewable energy and it has the greatest potential of any power source to solve the world's energy problems [1,2].Today more than 90% of the world market of PV cells is dominated by crystalline silicon in its multi-crystalline and mono-crystalline form. The most important things about PV cells are efficiency, long-term stability and lowest possible cost. PV cell made by mono-crystalline has been normally used because of its high efficiency. Recently, however, amorphous PV cell has its fixed place in consumer applications with the benefits of flexibility of usage and good aesthetic reason [3,4]. After partly solving the problems of light induced degradation, amorphous silicon begins to enter the power market. The visual appearance of thin film modules makes them attractive for facade applications [5,6].

Global radiation is the most important solar characteristics to be investigated to explore the potential of solar power generation. Global radiation in a specific location may be defined as the sum of direct and diffuse radiation throughout the day. The generated solar power is generally a global radiation on a horizontal PV panel surface. Also fixed panel receive solar radiation at angle that reduces the amount of energy considerably [7,8]. Furthermore inclination angle and azimuth angle play a vital role in radiation surface. Azimuth angle is generated by the earth rotation with its own axis and inclination angle is produced due to rotation of the earth around the sun.

This paper tried to investigate the power performance of PV cell in the case of solar irradiance and series resistance. Realizing the importance of solar irradiance, four locations of Bangladesh are investigated for finding the solar potentiality taking solar irradiance as an active influencing factor.

2. Solar Radiation

The solar irradiation exposed to the PV array for fixed position is calculated by equation 1 [9].

$$G_s = G_d + G_r \tag{1}$$

Where G_s is total solar irradiation in kW/m^2, G_d is direct component of solar irradiation in kW/m^2 and G_r is diffuse component of Solar Irradiation in kW/m^2.

$$\begin{aligned} G_d &= (H\cos\theta - \sin\theta\cos\alpha\sin\delta\cos\varphi_n + \\ &\sin\theta\cos\alpha\sin\varphi_n\cos\omega \\ &+ \sin\theta\sin\alpha\cos\delta\sin\omega)\times G_{od} \end{aligned} \tag{2}$$

Where H is sun elevation, θ is oblique angle of the sun in radian, α is azimuth angle, δ is declination of the sun in radian, φ_n is north latitude, ω is hour angle in degree, G_{od} is direct irradiation in radian.

$$G_r = \frac{G_{or}(1+\cos\theta)}{2} + 0.2G_o\frac{1-\cos\theta}{2} \tag{3}$$

Where G_{or} is diffuse (horizontal) irradiation in radian, G_o is global horizontal irradiation in kW/m^2.

The sun elevation is given by the equation 4 [9].

$$H = \sin^{-1}(\cos L\cos D\cos T + \sin D\sin L) \tag{4}$$

Where L is latitude in degree, D is declination of the sun in degree; T is hour angle in degree [9].

3. Fill Factor

Fill factor is a very important factor to measure the degree of performance. It can be defined as the closeness of the I-V curve to a square wave. Again it can be defined as the ratio of the maximum power that can be supplied to the load and product of short circuit current and open circuit voltage. The fill factor is given by (5) [10].

$$FF = \frac{P_{\max}}{V_{oc} I_{sc}} = \frac{V_{mp} I_{mp}}{V_{oc} I_{sc}} \quad (5)$$

Where V_{mp} is maximum power point voltage, I_{mp} is maximum power point current.

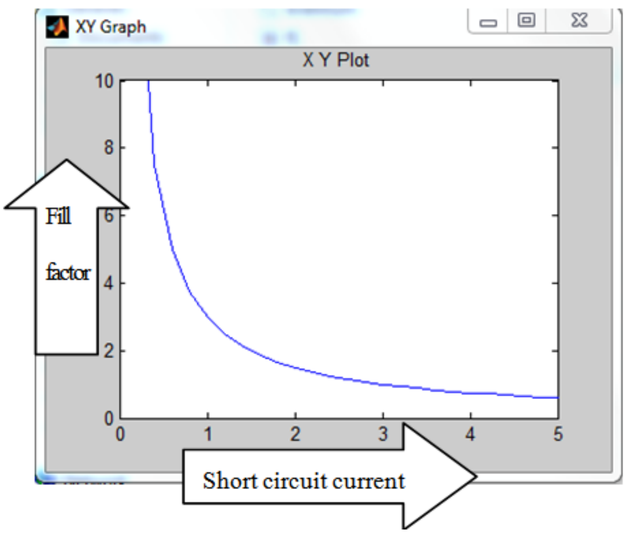

Figure 1. Fill factor effect on various levels of short circuit current

From figure 1, it is seen that fill factor value is rapidly decreasing with the increment of short circuit current element taking consideration of constant maximum power and open circuit voltage.

4. Modeling of Pv Cell

Figure 2 shows the equivalent circuit of the PV cell. The basic equation that mathematically explains the I-V characteristics of the PV cell is shown in (6) [11].

$$I = I_{ph} - I_S[\exp(\frac{q(V + IR_S)}{kT_C A}) - 1] - \frac{V + IR_S}{R_{sh}} \quad (6)$$

Where I_{ph} is a light generated current, I_S is cell saturation of dark current saturation, q (1.6×10^{-19}C) is electron charge, k is a Boltzmann's constant (1.38×10^{-23}J/k), T_C is the cell's working temperature, A is an ideality factor, R_{sh} is a shunt resistance and R_S is a series resistance. The light generated current mainly depends on the solar irradiance and cell's working temperature which is described by mathematical expression shown by (7) [11].

$$I_{ph} = [I_{SC} + K_I(T_C - T_{ref})]\frac{G}{G_n} \quad (7)$$

Where I_{SC} is the cell's short circuit current at 25°C, K_I is the cell's short circuit current temperature coefficient, T_{ref} is the cell's reference temperature and G is the solar irradiation in kW/m^2 and G_n is nominal solar irradiation at STC (Standard test condition) in kW/m^2. Again the cell's saturation current varies with cell temperature which is expressed in (8) [11].

$$I_S = I_{RS}(\frac{T_C}{T_{ref}})^3 \exp[\frac{qE_G(\frac{1}{T_{ref}} - \frac{1}{T_C})}{kA}] \quad (8)$$

Where I_{RS} is the cell's reverse saturation current at reference temperature, E_G is the band-gap energy of semiconductor material utilized in the PV cell.

The cell's reverse saturation current which is related to open circuit voltage and short circuit current is given by (9) [12].

$$I_{RS} = \frac{I_{SC} + K_I \Delta_T}{\exp(\frac{V_{OC} + K_V \Delta_T}{AV_t}) - 1} \quad (9)$$

Where Δ_T is the temperature difference between the actual and nominal temperature (°C), V_{OC} is the open circuit voltage of the PV cell, K_V is voltage coefficient and V_t is the thermal voltage of PV cell. The thermal voltage is given by (10).

$$V_t = \frac{kT_C}{q} \quad (10)$$

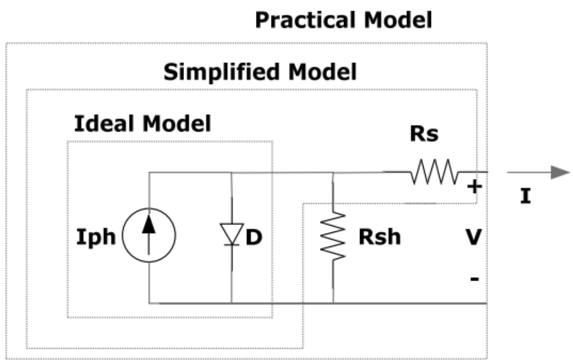

Figure 2. Equivalent circuit of PV cell [13]

5. Modeling of PV Array

The PV array is the series or parallel combination of the modules. To obtain power at desired voltage and current, the series and parallel combination of the PV modules should be analyzed properly. The current and voltage relationship of the PV array having N_S series and N_P parallel is given by (11) [7].

$$I = N_P I_{ph} - N_P I_S[\exp(\frac{q(\frac{V}{N_S} + \frac{IR_S}{N_P})}{kT_C A}) - 1] - \frac{\frac{N_P V}{N_S} + IR_S}{R_{sh}} \quad (11)$$

6. Simulation of the PV CELL and Solar Irradiance Data Analysis

To simulate the PV cell a solar model is taken known as BP MSX 64. The short circuit current and open circuit voltage of the MSX 64 solar module is 4A and 21.3V respectively. The basic simulink model for the PV cell is shown in Figure 3. Figure 4 shows the significant effect of solar irradiance on power of solar cell. From figure, it is spontaneously clear that power level is rising up significantly with the increment of incident solar irradiance. And from Figure 5, it is seen that maximum power is obtained when the series resistance value is minimum. So it can be said that solar power could be optimum if the least value of series resistance is maintained.

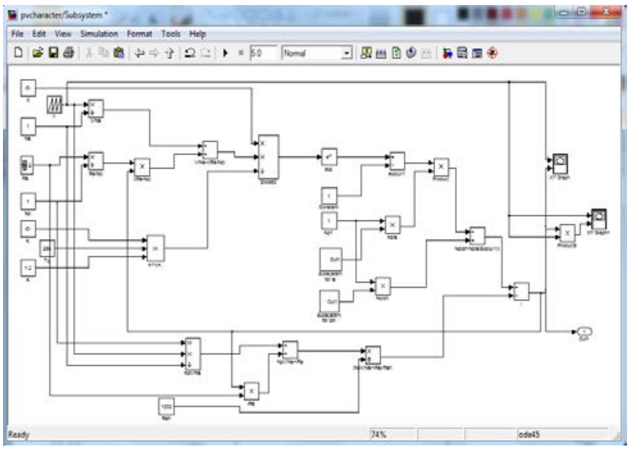

Figure 3. Simulink model of PV Cell

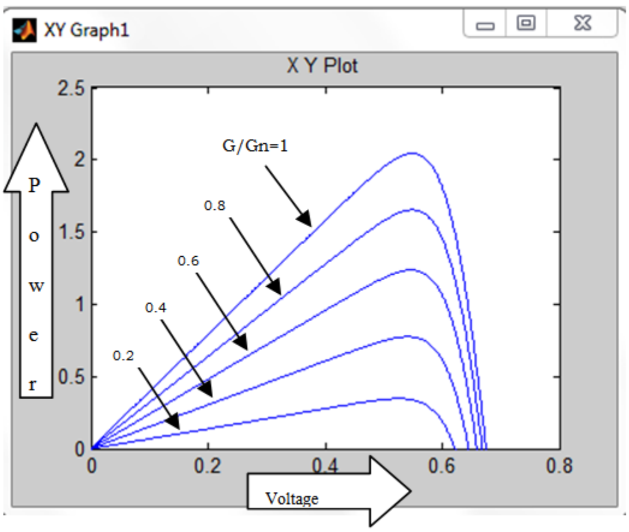

Figure 4. P-V characteristics of the cell for variation of the solar irradiance

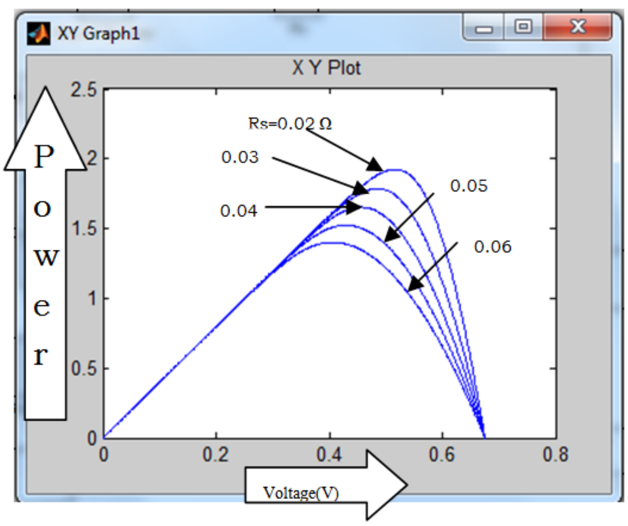

Figure 5. P-V characteristics of the cell for variation of the series resistance

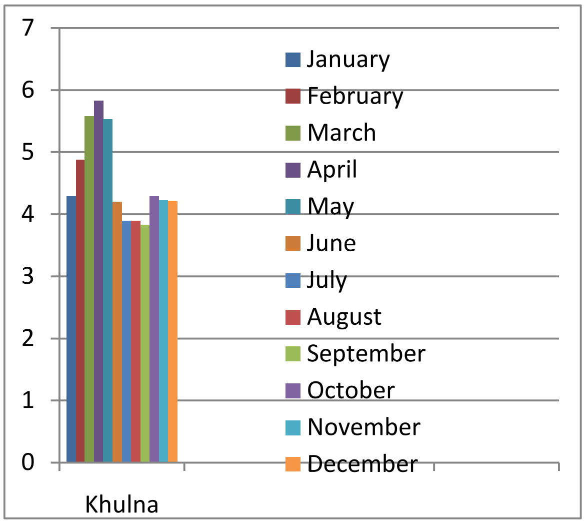

Figure 6. Monthly average irradiance incident (KWh/m^2/day) data

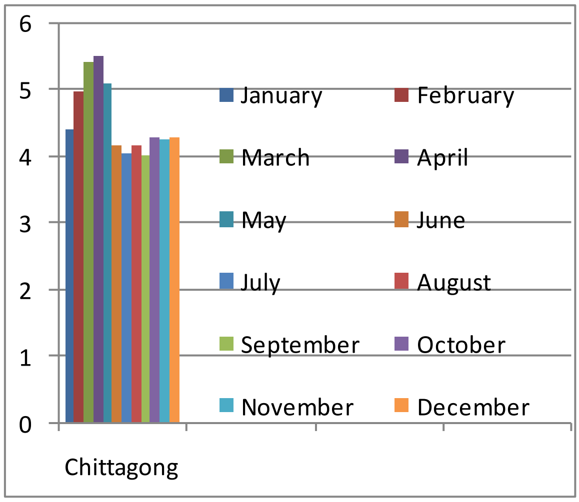

Figure 7. Monthly average irradiance incident (KWh/m^2/day) data

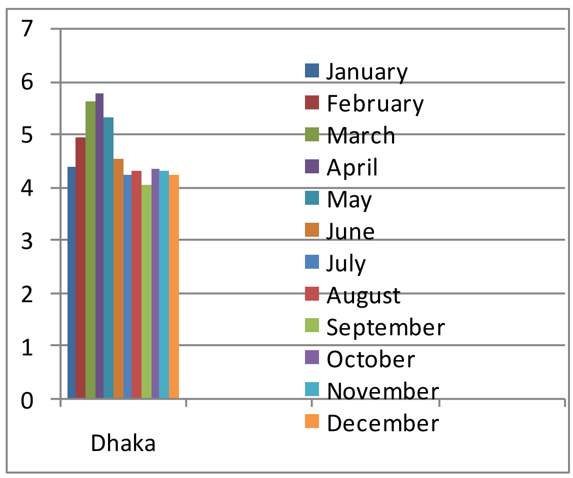

Figure 8. Monthly average irradiance incident (KWh/m^2/day) data

In addition to this, solar irradiance data has been analyzed for some particular locations in Bangladesh. The data has been taken from NASA website. Figure 6, Figure 7, Figure 8 and Figure 9 represent monthly averaged (22 year data) solar irradiance data for Khulna, Chittagong, Dhaka and Dinajpur respectively. The maximum solar irradiance observed is 5.83 KWh/m^2-day in Khulna region whether it is 5.51, 5.76 and 6.47 KWh/m^2-day in Chittagong, Dhaka and Dinajpur respectively in April. And the minimum solar irradiances observed are 3.83, 4.01, 4.01 and 3.99KWh/m^2-day in Khulna, Chittagong, Dhaka and Dinajpur respectively in September month.

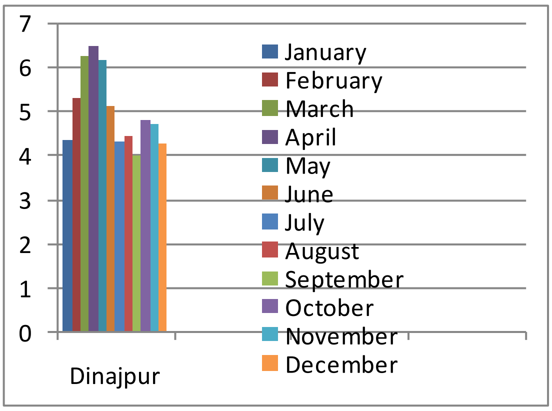

Figure 9. Monthly average irradiance incident (KWh/m^2/day) data

7. Conclusion

The power performance of the PV cell has been analyzed using the simulink of MATLAB software. The influencing factors considered are solar irradiance and series resistance. For the significant of the solar irradiance on solar power of PV cell, solar irradiance data has been analyzed in some particular regions of Bangladesh. From the respect of solar irradiance, it is found that Dinajpur is more potential than the other three regions. From the solar irradiance data, it is seen that maximum annual averaged solar irradiance is occurred in Dinajpur region which is around 4.99 KWh/m^2-day.

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