

ANALYTICAL COMPARATIVE STUDY OF EFFICIENCIES AMONG MONO-CRYSTALLINE, POLY -CRYSTALLINE AND THIN FILM (CdTe, CIGS) SOLAR CELL USING FILL FACTOR CALCULATION METHOD

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Abstract

This paper describes the effective utilization of solar power through photovoltaic cell in an urban area in Bangladesh. Using solar power in solar panel as an alternative power source, the main limitation is which one should have the better performances. Most widely used solar Cells are Mono-crystalline, Poly-crystalline, Thin film (especially CdTe, CIGS). In this paper we are focusing on the efficiency level of different types of solar cell using fill factor calculation (FFC) method. If we use Solar PV array in a combined power system then Fill Factor (FF) would play a vital role. In this (Indo-Pak Sub continent) region Solar PV doesn't capitalized as power generation in a conventional system. But if we look at the present scenario of power generation then we found scarcity of fossil fuels (Coal, Gas, Natural Gas, and Diesel) cause an alarming situation of electricity. The area of field study that we select for this aspect is Jhenaidah an urban area in Bangladesh located at 23° 33' north east latitude and 89° 10' East longitude.

Keywords: Solar PV, Thin Film, Fill Factor, Renewable Energy.

1. INTRODUCTION

Solar energy is an essential input for sustainable improvement of the society. There is a vast amount of potential regarding solar energy which it can provide quality power supply to remote areas. The abundant energy available in nature can be reformed to electricity in a sustainable way to prolong living standards of the people without access to the electricity grid. Solar energy is one of the purest energy which can be converted to electrical energy. Combining two or more renewable energies (such as Bio-Diesel and Solar PV) as a combined power system makes more feasible and reliable power system than conventional power system. Such combined power system gives the higher efficiency level based on their operating characteristics than that of single power source system. For choosing one of the solar cells among mono, poly crystalline and thin film (CdTe, CIGS) we have to focus on their efficiencies and efficiency depends on their fill factor (FF). Fill factor of a solar cell is the ratio of the open circuit voltage and short circuit current of maximum obtained power of the product. This paper elaborates the fill factor method. FF method is the way to find the best efficient solar cell. Result of this method is mono-crystalline which efficiency level is around 21% [1].

1.1 Overview of Solar Energy in Bangladesh

Bangladesh a very small country of South Asia region situated on the Bay of Bengal located at 23° 07' North latitude and 90° 35' East longitude. Existing power

generation scenario of Bangladesh solar energy is only 5% of their total generation. By 2020 Government of Bangladesh has set up a goal to provide electricity to all and make sure the price per unit must be in affordable price for this particular sustainable, reliable and quality supply of electricity. The main obligation of achieving this goal is an immense amount of unused renewable resources such as solar power. By 2015 it is our goal to achieve 10% of total energy generation is done by solar system and by 2020 it is our aim to achieve 20% [2]. Our government is placing priority on developing renewable energy resources to improve energy sector and establish a sustainable energy engine. In government approach Bangladesh Power development board formed the "Directorate of renewable energy and research & Development in 2010". GOB has taken several steps & project for achieving the goal. Electricity is the most important source of power for the country's economic activities. The installed capacity in January 2014 [3] is 10289 MW. As a matter of fact we use only three fourth of our power generation around (7716 MW). Only 62% of our total population has access to electricity with a very limited per capita availability of 321 kWh per annum [4].

2. METHODOLOGY

For calculating the efficiency level of a solar cell we must have to consider several parameters such as I-V curve, Short circuit current (ISC), Open circuit Voltage (VOC) & Fill Factor (FF) [5-9]. All the parameter's characteristics are

giving the final result to the efficiency. At first we measure the current using the equation –

$$I = I_L - I_0 [\exp(qv/nKT) - 1] \quad \text{----- (1)}$$

But in equation (1) the -1 term can easily neglected due to exponential term is usually $\gg 1$ except for voltage below 100 mv. Now Equation (1) turns to ---

$$I = I_L - I_0 [\exp(qv/nKT)] \quad \text{----- (2)}$$

Here, Dark Saturation $I_0 = 1E^{-10}$ A,
Light generated current, $I_L = 0.5$ A
Ideality Factor, $n = 1$
Temperature, $T = 300$ K, Voltage, $V = 0.5$ V

q is charge, k is Boltzman constant. [7]

By putting this value in equation (2) we obtain, $I = 0.4753$ A using light based IV curve calculator.

Using Open circuit voltage equation –

$$V_{OC} = (nKT/q) \ln (I_L / I_0 + 1) \quad \text{----- (3)}$$

Using the same parameters from equation (2) we have $V_{OC} = 0.5778$ V.

For finding the value of Fill Factor (FF) for efficiency at first we have to find normalized V_{OC} using the equation –

$$\text{Normalized } V_{OC} = (q/nKT) V_{OC} \text{ (open circuit)} \quad \text{----- (4)}$$

From equation (4) we get normalized $V_{OC} = 22.3304$ V. Now we'll use this value to measure Fill Factor (FF). [8]

$$FF = [V_{oc} - \{ \ln(V_{oc} + 0.72) \}] / (V_{oc} + 1) \quad \text{----- (5)}$$

Finally after getting all the values of FF, I_{SC} , V_{oc} & P_{in} . Then we use them in efficiency equation which is –

$$\eta = [(VOC * ISC * FF) / Pin] \quad \text{----- (6)}$$

3. PARAMETERS USED FOR FINDING EFFICIENCY

3.1 Open Circuit Voltage

V_{OC} is the open circuit voltage which is the maximum available voltage from a solar cell occurs at zero current. We can calculate open circuit voltage by using the equation (3) and finally obtained the result $V_{OC} = 0.578$ V.

3.2 Fill Factor

The short circuit current (I_{SC}) is the maximum current and open circuit voltage (V_{OC}) is the maximum voltage of a solar cell. Fill factor (FF) is defined as the ratio of maximum power of the product generated by V_{OC} & I_{SC} and it is measured in squariness of solar cell and also it reflects the largest rectangle area in IV curves as shown in Fig.1.

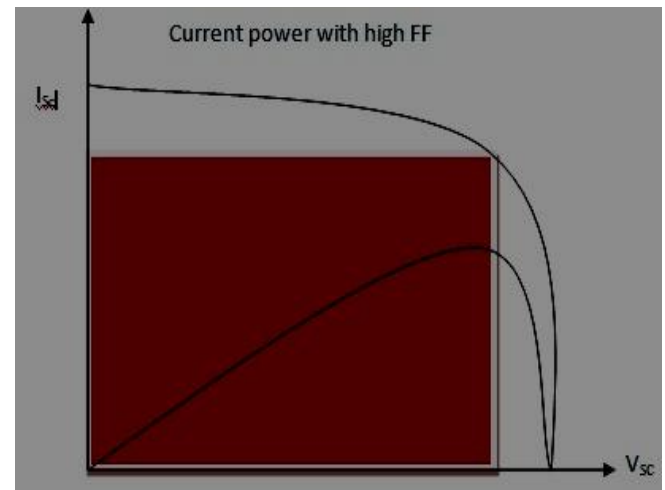


Fig – 1: I-V curve of solar cell indicating Fill Factor

Using equation (5) we obtain the FF = 0.8226. And Finally we have to use value of FF, V_{OC} , I_{SC} , & P_{in} to the equation (6) and got efficiency, $\eta = 17.27\%$.

4. CALCULATION

4.1 For Mono-Crystalline Solar Cell

For calculation the required equation and respective values are given in methodology part of this paper (E^{qn} 1 to E^{qn} 6). Calculations of Voltage open Circuit,

$$\begin{aligned} V_{OC} &= (nKT/q) \ln (I_L / I_0 + 1) \\ &= (1 * 300 * 1.38E^{-23} / 1.6E^{-19}) \times \ln \{ (0.5 / 1E^{-10}) + 1 \} \\ &= 0.025875 \times 22.332703 \\ &= 0.57785 \text{ Volt} \end{aligned}$$

But when we go for normalized V_{OC} the equation turns into $V_{OC} = (q/nKT) V_{OC}$ (open circuit)

$$\begin{aligned} &= (1.6E^{-19} / 1 * 300 * 1.38E^{-23}) \times 0.57785 \\ &= 22.3304 \text{ Volt} \end{aligned}$$

$$\begin{aligned} \text{Fill factor, } FF &= [V_{oc} - \{ \ln(V_{oc} + 0.72) \}] / (V_{oc} + 1) \\ &= \{ 22.3304 - \ln(22.3304 + 0.72) \} / (22.3304 + 1) \\ &= 0.8226 \end{aligned}$$

Finally we can measure the efficiency of a solar cell by using the equation –

$$\begin{aligned} \text{Efficiency, } \eta &= (Voc * Isc * FF) / Pin \\ &= (0.6 * 3.5 * 0.8226) / 10 \\ &= 17.27 \% \end{aligned}$$

Here for calculating efficiency we consider input power $1Kw/m^2$. ie $100mW/cm^2$. And for input power $100 \times 100 \text{ mm}^2$ cell = 10 Watt.

We will use the same effective equations for calculating Fill Factor (FF) for poly crystalline solar cell, then cadmium telluride (CdTe) and then (CIGS). The only difference we'll go down to up word process.

4.2 For Poly-Crystalline Solar Cell

If we consider open circuit voltage (V_{OC}), and short circuit current (I_{SC}), and input power (P_{IN}) would be same identical value that we use previous equation then from equation no (6) we have –

$$\begin{aligned} \text{Efficiency, } \eta &= (V_{oc} * I_{sc} * FF) / P_{in} \\ \Rightarrow 0.135 &= \{(0.6 * 3.5) / 10\} * FF \\ \Rightarrow FF &= 0.6428 \end{aligned}$$

Here efficiency level of Poly-Crystalline is considered 13.5 %. [10]

4.3 For CIGS Solar Cell

$$\begin{aligned} \text{Efficiency, } \eta &= (V_{oc} * I_{sc} * FF) / P_{in} \\ \Rightarrow 0.11 &= \{(0.6 * 3.5) / 10\} * FF \\ \Rightarrow FF &= 0.5238 \end{aligned}$$

Here efficiency level of CIGS is considered 11 %. [10]

4.4 For CdTe Solar Cell

$$\begin{aligned} \text{Efficiency, } \eta &= (V_{oc} * I_{sc} * FF) / P_{in} \\ \Rightarrow 0.1 &= \{(0.6 * 3.5) / 10\} * FF \\ \Rightarrow FF &= 0.47619 \\ \Rightarrow & \end{aligned}$$

Here efficiency level of CdTe is considered 10 %. [10]

5. RESULT & DISCUSSION

From this analytical calculation we have disclosed that the Mono-Crystalline Solar cell has the highest level of efficiency and as well as Fill Factor (FF) which is 17.27% and 0.8226 respectively. On the other hand for Poly Crystalline, CIGS & CdTe solar cell we have comparatively small value of Fill factor (FF) i.e. 0.6428, 0.5238 & 0.47619. It is well proven for a solar cell that the efficiency level is depending upon Fill Factor (FF).

6. CONCLUSION

The purpose of this paper is to draw a border line between different types of solar cells used as an alternative power source in an urban area in Bangladesh and successfully we have reached to our goal. Mono crystalline Solar cell has the better performance in course of efficiency which is calculated through Fill factor method (FF). FF is nothing but the squareness of open circuit voltage (VOC) and short circuit current (ISC). Higher value of 'FF' indicates that more area of maximum power is generated by the product. In this regard it reveals that for using Solar PV array as a combined power system in a bulk amount we should go for Mono-crystalline Solar cell.

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BIOGRAPHIES



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