

Solar Photovoltaic Electricity for Irrigation under Bangladeshi Climate

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Abstract

In order to optimize the performance of SPV (Solar Photovoltaic) systems, one must first define what the system to be optimized is and what performance indicators should be used. Various indicators are used in the industry including Fill Factor (FF), Conversion Efficiency (η_c), specific yield (kWh/kWp), performance ratio (actual performance/theoretical performance), Levelized Cost of Energy (LCOE), Payback Period (PP) and internal rate of return (IRR). The fundamentals of SPV systems and how their performance can be measured are described throughout this chapter. Solar cells may be manufactured using a number of different semiconductors and techniques. The cell types used in this project were selected on the basis of being widely commercially available for terrestrial installations.

Keywords: SPV, Crystalline Cell, Climatic condition, Conversion efficiency (η_c), Practical applications, Irrigation, Maximum power point (MPP)

I Introduction

There are two main types of solar photovoltaic (PV) cell - thin film and crystalline. Crystalline cells make up over 90% of grid connected PV systems worldwide (including solar farms and building mounted systems) [30,65]. Whilst crystalline cells are more expensive than thin films, they are generally more efficient and have longer performance warranties. Silicon cells are mostly produced by doping a thin top layer with Boron and the thicker lower layer with Phosphorous (Fig. 1). These doped layers create an intermediate 'depletion zone' between them and a resulting electric field. When photons falling on the device transfer their energy to electrons, the latter are promoted to the conduction band and gain mobility.

II. Methods and Materials

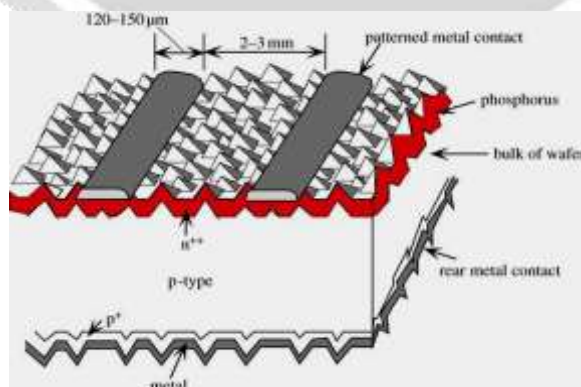


Fig.1: Cutaway section of a solar PV cell, showing doped layers, courtesy of [35].

Diffusing to the depletion zone, the field causes a net movement of electrons from the p-type layer to the n-type layer; if the cell is connected in a circuit power can then be extracted [31-34].

II. A. Define different Parameters:

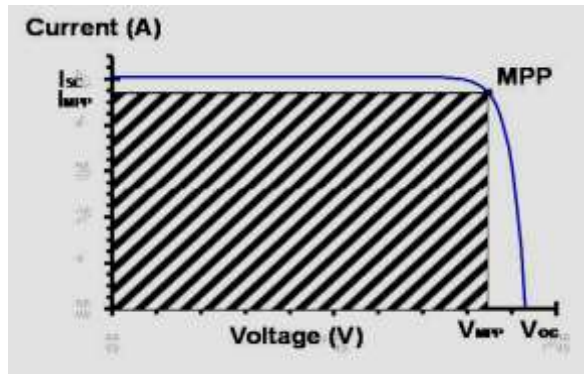


Fig.2 IV curve for a solar PV cell

The key points on the IV curve are:

(i) Open circuit voltage V_{oc} : The maximum voltage of the cell or module, Connected to an infinite resistance, with no current flowing. The voltage of a solar cell Varies inversely with temperature.

(ii) Short Circuit Current (I_{sc}): The maximum current of the cell or module at zero volts. Current varies proportionally with solar irradiance, but in datasheets is usually given for 1000W/m^2 (STC1).

(iii) Maximum power point (MPP):

Note that at I_{sc} and V_{oc} no power can be generated because $P=IV$. On a graph of current against voltage, power is represented by the area under the box formed by the operating point. The 'Maximum Power Point (MPP)' is at the 'knee' of the IV curve where this is greatest. To maximize the output from a solar cell or an array of cells, a Maximum Power Point Tracking (MPPT) circuit is employed in the inverter or battery charger to optimize the current draw to operate the system at MPP.

(iv) Maximum power point voltage (V_{MPP}):

Maximum power point voltage (V_{MPP}) is the voltage corresponding to the MPP.

(v) Maximum power point current (I_{MPP}):

Maximum power point current (I_{MPP}) is the current corresponding to the MPP.

(vi) Crystalline silicon cells:

Crystalline (as opposed to thin film) silicon cells were historically believed to have better longevity than thin film, however recent research has found that this may not be the case [36]

(vii) Poly-crystalline silicon (mcSi):

The silicon is grown into multiple crystals, giving it a crazed appearance, like galvanized steel. Molten silicon is cooled in moulds to form ingots from which wafers are cut.

(vii) Mono-crystalline (scSi):

The silicon is grown into a large single crystal from a seed crystal. This crystal is sawn into an ingot from which wafers are cut. The mcSi or mSi wafers are doped, etched, and screen printed to create a working solar cell.

II.B. [46-49]: Description of solar module:

A module is consists of more than one unit of solar cell. The unit cells are fabricated by connecting silicon or germanium diode through series connection. But in a module, the solar cells are connected both in series and in parallel as per requirement. Generally, the solar cells are imported from other countries. Because, there is no industry in our country for making solar cell. Production of solar cell needs a furnace where it produces high temperature. So, modules are fabricated in our country by those imported solar cells. In Fig.3 shown below:



Fig.3 Solar Panel set up for irrigation at Savar, Dhaka, Bangladesh

II.C Connecting materials for producing solar module [24, 50-58]:

The Fig.4 shows the wafers for connecting solar cells to form solar modules. It is very sensitive to form a module by thin wafers. In the figure, it is not connected properly, then the I-V characteristics of the curve will not be ideal. The fill-factor (FF) will be less than the ideal value e.g. 0.7. Due to this reason, it is very important to use this wafer to form a module.



Fig.5 Method of measurement of I-V characteristics

The environmental conditions vary from time to time during the day period of the sun. That is why the efficiency and fill factor varies with the same change of environment [66,67]. Solar cell tester helps us to measure the performance of the solar cell instantly. Generally, solar cell is set up on the solar tester connecting with a calibrated computer. Finally, we get the value of all parameters with time including I-V curves. Before constructing a solar module, solar cell tester is very important whether those cells are ideal or not.

II D: I-V characteristics of a solar cell:

The solar cell is made by semi-conductor materials. These solar cells have I-V characteristics diode, transistors, FED and SCR. For any solar cell, firstly it has to measure the I-V characteristics. Because the I-V characteristics is wide different between ideal and non-ideal cell. The I-V characteristics is drawn by collecting the current and the voltage, we change the load resistor. Now it has to draw the variation of useful power with the variation of time in presence of sunlight. The following solar light also varies with time. So, the efficiency and FF also varies with time. From the I-V curve, it has to measure two important parameters, efficiency and FF of any solar cell. In that sense, I-V is the heart of a solar cell.

II E Standard solar cell condition:

The climatic condition of any country varies with their longitudinal and latitudinal earth location. That is why, the climatic condition of the countries are not the same. Bangladesh is a tropical country. The solar radiation here, during the consecutive eight months of the year remain sunlight favorable for solar cell for electricity production. Because for those eight months of the year, the sky condition remains clear. And the rest four months, the sky condition sometimes remains sunlight favorable, sometimes semi-favorable and sometimes cloudy, sometimes semi-cloudy and sometimes foggy or hazy. So, the performance during these four months (July, August, September and October) are low in comparison of the eight months. So, scientists determine the standard state condition for the solar cell, $V_{oc} = 0.5$ volt and $I_{sc} = 0.5$ amp. The state conditions are, solar radiation is 1000 watt/m^2 , cell temperature is 25°C and atmospheric pressure is 760 mmHg .

II F Practical application of solar cell for irrigation:

For the practical application of the solar cell electricity, research was conducted at Savar in Dhaka. The Fig.6 shows the stand alone photovoltaic system for solar irrigation. The solar pump system is used during the season of paddy

cultivation. Besides this, the local farmers are supposed to use the solar pump for the cultivation of various vegetables, greens after the end of the paddy cultivation.



Fig.6 Application of solar electricity for irrigation purposes using water pump collecting water from the lake.

III. Results and Discussion with Graphical Analysis:

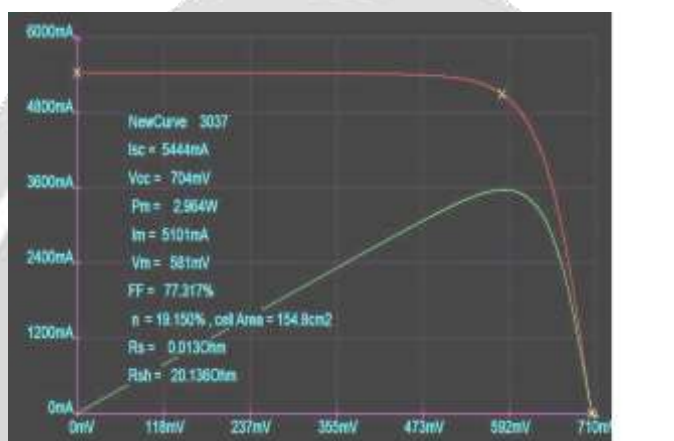


Fig.7 Ideal I-V curve for ideal solar cell-1

Fig.7 shows the I-V curve for a solar cell under Bangladeshi climatic condition. It is shown the following experimental result:

- Short circuit current, $I_{sc} = 5444$ mA,
- Open circuit voltage, $V_{oc} = 704$ mV,
- Maximum useful power, $P_m = 2.964$ W,
- Maximum useful current, $I_m = 5101$ mA,
- Maximum useful voltage, $V_m = 581$ mV,
- Fill Factor, $FF = 77.317\%$,
- Conversion efficiency, $\eta_c = 19.15\%$,
- Cell Area = 154.8 cm²,
- Diode Series resistance, $R_s = 0.013$ ohm,
- Shunt resistance, $R_{sh} = 20.136$ ohm.

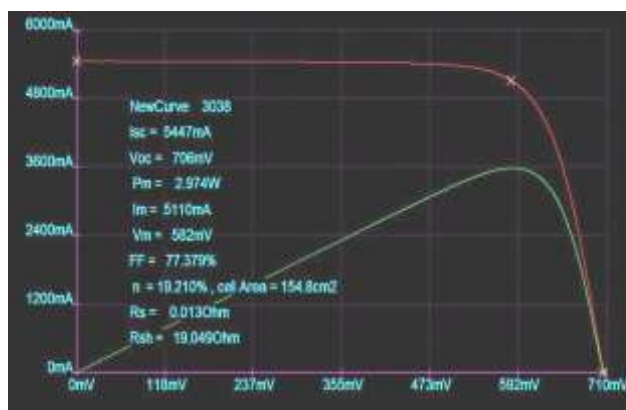


Fig.8 Ideal I-V curve for ideal solar cell-2

Fig.8 shows the I-V curve for a solar cell under Bangladeshi climatic condition. It is shown the following experimental result:

Short circuit current, $I_{sc} = 5447\text{mA}$,
 Open circuit voltage, $V_{oc} = 706\text{ mV}$,
 Maximum useful power, $P_m = 2.974\text{ W}$, Maximum useful current, $I_m = 5110\text{ mA}$, Maximum useful voltage, $V_m = 582\text{ mV}$,
 Fill Factor, $FF = 77.379\%$,
 Conversion efficiency, $\eta_c = 19.210\%$,
 Cell Area = 154.8cm^2 ,
 Diode Series resistance, $R_s = 0.013\text{ ohm}$,
 Shunt resistance, $R_{sh} = 19.049\text{ ohm}$.

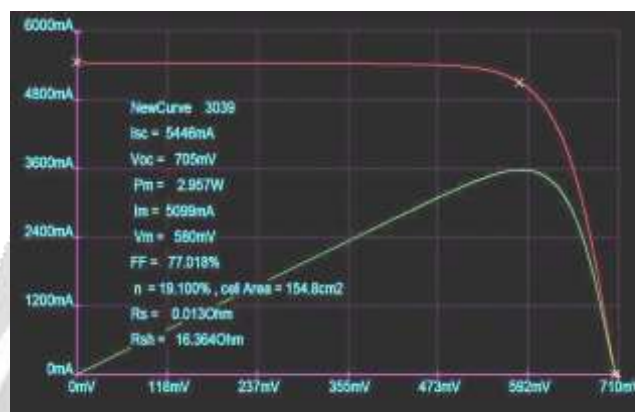


Fig.9 Ideal I-V curve for ideal solar cell-2

Fig.9 shows the I-V curve for a solar cell under Bangladeshi climatic condition. It is shown the following experimental result:

Short circuit current, $I_{sc} = 5446\text{ mA}$,
 Open circuit voltage, $V_{oc} = 705\text{ mV}$,
 Maximum useful power, $P_m = 2.957\text{ W}$, Maximum useful current, $I_m = 5099\text{ mA}$, Maximum useful voltage, $V_m = 580\text{ mV}$,
 Fill Factor, $FF = 77.379\%$,
 Conversion efficiency, $\eta_c = 19.100\%$,
 Cell Area = 154.8cm^2 ,
 Diode Series resistance, $R_s = 0.013\text{ ohm}$,
 Shunt resistance, $R_{sh} = 16.364\text{ ohm}$.

Finally, it is shown that where FF increases, the conversion efficiency also increases. Therefore it can be said that FF and conversion efficiency (η_c) is almost proportional.

IV. Conclusion

The Fig.6 shows that the water is extracted from a river which meets up the demands for cultivation in the whole months of the year. So, the farmers are very happy for having this solar irrigation pumping system. It is mentioned that this solar pumping irrigation project is installed by BADC to help the farmers when there is no water in the dry season as well to enhance paddy production. It is very happy system that in solar pumping system, no oil/fuel is required. It saves the environment and cost simultaneously which we may call environment friendly cheap cultivation system for Bangladesh and this is one of the main objective of my research work.

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