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Analysis of Noise with Curve Fitting Method of a PV cell

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Abstract

Solar photovoltaic technology is a major contender in the race for renewable, sustainable and green energy. This paper introduces the characteristics of different PV cell equivalent circuit and its output behaviour. It describes and implements the proposed characterization method by using a selected model. It generates I-V and P-V curve using iterative method. Noise analysis and observation of curve fitting are briefly described here. The white noise effect and its related output characteristics are explained too. To introduce and implement the generalized method, a photovoltaic electrical equivalent circuit is used here. The fundamental equation of a PV cell is used to study the model and to analyze the best fit of observed data. The values of ideal parameters are used to study the model's behaviour. The main objective is to measure the noise in data approximation and on the polynomial curve fitting method for both the I-V and P-V curve.

Keywords: Photovoltaic cell, model, noise, Fitting.

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1. Introduction

The world is moving towards sustainable and green energy technologies like solar energy, wind power, hydro power, bio gas etc due to the environmental pollution and global warming problems. Solar powered energy is becoming more popular and fastest growing energy source due to its availability of constant source means sunlight consistency, renewability, inexhaustibility and non-polluting capacity [1]. Significant photovoltaic deployment has occurred in recent years especially in the developed countries with different capacities and configurations. The impacts of photovoltaic technology on the environment have made it as a well accepting and promising source of electric energy. Researchers all around the world are looking for the solar PV cell with reliability, low cost, low wastage and maximum output. The single diode solar cell model consists of five parameters [2]-[3]. And it is an efficient tool to predict and analyze the behaviour of a PV cell under the variation of external and internal parameters [1]. Furthermore they are analyzed using the ideal values given by the industry. The considered parameters are solar irradiance, cell temperature, shunt resistance, series resistance and diode reverse saturation current [2].

2. PV Cell Model

The single diode solar cell model is considered the most used and efficient electrical equivalent model of a PV cell. In this work, the single diode five parameters model is used to characterize the PV module. The PV cell equivalent circuit consists of a diode D, a series resistor R_s [1]-[3], a photo current source I_{ph}, and a shunt resistance R_{sh} [3].

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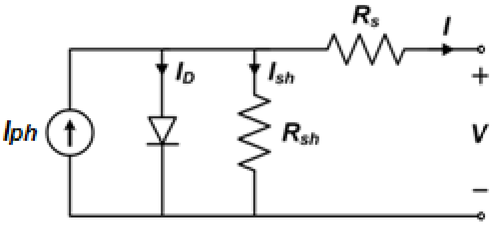

Figure 1. PV cell equivalent circuit.

From the above equivalent circuit we can find the load current (I) of the following equation [1] [4] [5]:

$$I = I_{ph} - I_s\left(\exp\left(\frac{qV+qR_sI}{NKT}\right) - 1\right) - \frac{V+R\ I}{R_{sh}} \quad (1)$$

The Shockley diode equation is:

$$I_d = I_s\left(\exp\left(\frac{qV+qR_sI}{NKT}\right) - 1\right) \quad (2)$$

And, the current across the shunt resistor is:

$$I_{sh} = \left(\frac{V+R_sI}{R_{sh}}\right) \quad (3)$$

Equation (1) can be written in the simplified form,

$$I = I_{ph} - I_d - I_{sh} \quad (4)$$

So, it is the simplified equation of load current (I) of a photovoltaic cell.

From (1) we have,

$$I = I_{ph} - I_s\left(\exp\left(\frac{qV+qR_sI}{NKT}\right) - 1\right) - \left(\frac{V}{R_{sh}}\right) - \left(\frac{R\ I}{R_{sh}}\right) \quad (5)$$

Finally we obtain,

$$I = \left(\frac{R_{sh} \times I_s}{R_{sh}}\right)\left(1 - \left(\frac{V}{R_{sh} \times I_s}\right) - \exp\left(\frac{qV}{NKT}\right) + I_{ph}\right) \quad (6)$$

Here, it is considered as the analytical solution of the fundamental equation for the load current (I) under certain $(R_s=0)$ condition [4].

3. Method

It is impossible to find directly analytical solution of the equation (1) with all parameters, so we considered the numerical one in here [3]. Among all of the numerical methods we worked with 'Bisection Method' to solve the equation of a PV cell as it is found more reliable and suitable.

In order to simulate real data to the generated ones from the equation (1) white noise with two percent of maximum of current value is added. In the PV systems the origins of the real noise occurs due to the uncertainty of measurements and random changing of external parameters. The external parameters considered here are solar radiation and temperature. There are signal noise due to electrical and data acquisitions also. In data acquisitions signal noise is mainly due to analog to digital conversion (ADC) and it is known as quantification noise. In this paper it is just considered the white noise due mainly to measurement uncertainties. The signal noise created due to electrical and data acquisition causes is an ongoing work. For the curve fitting fourth order polynomial method is used.

4. Simulation Result

In this section the different analysis and the related output figures are shown.

The typical current-voltage (I-V) curve of a PV cell is obtained by simulation is:

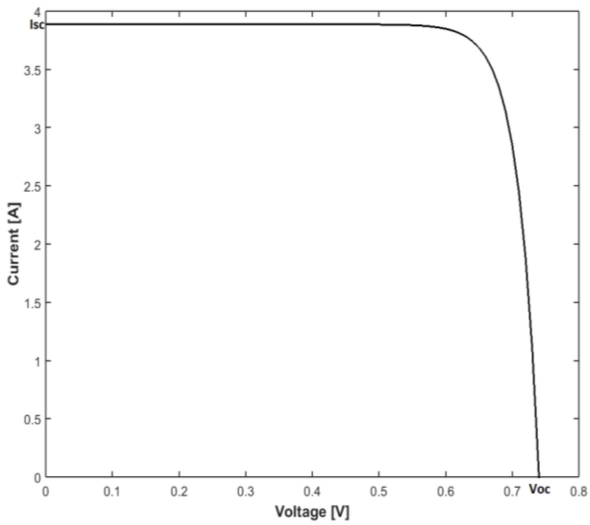

Figure 2. I-V curve of photovoltaic Cell.

In the I-V curve of a PV cell, there is short circuit current where the current has its maximum value. And the maximum value of voltage is open circuit voltage [6]. The curve plotted in figure 2 shows the behaviour of the current with respect to its voltage.

In the next part it is shown the power-voltage (P-V) typical curve of a PV cell. In that curve there is a point where power is maximum is called maximum power point (MPP) [2]. Maximum power point is calculated at the highest point of power-voltage curve and at the knee point of a current-voltage curve.

The typical power-voltage (P-V) curve of a PV cell is obtained by simulation is presented in figure 3.

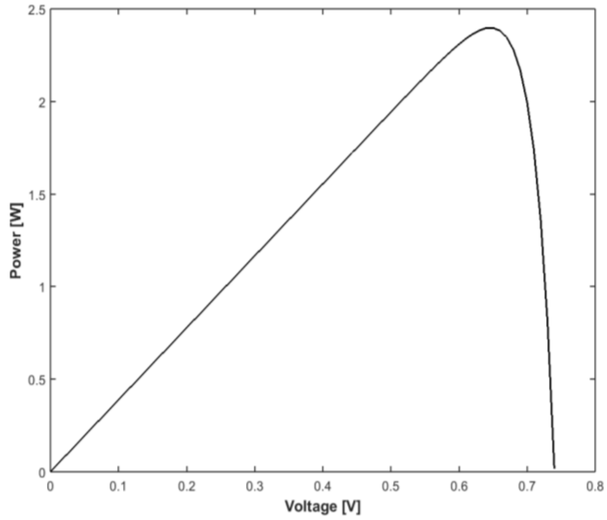

Figure 3. P-V curve of photovoltaic Cell.

In the next it is shown the produced I-V and P-V curve obtained from experimental data. The obtained I-V curve by experimentation is presented in the figure 4.

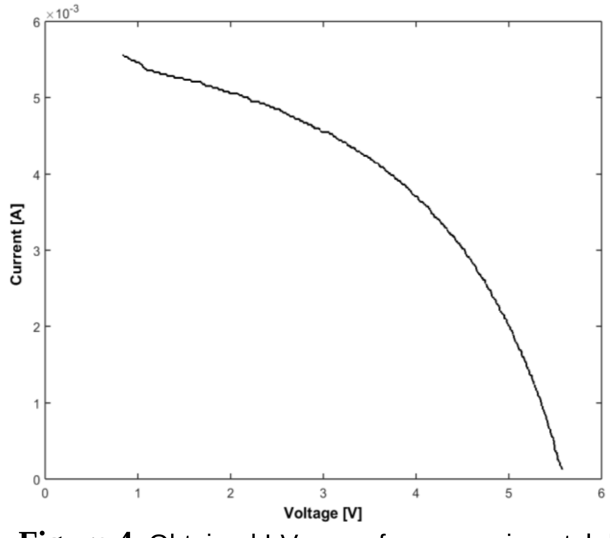

Figure 4. Obtained I-V curve from experimental data.

Figure 4 presents the current-voltage (I-V) curve obtained from the measured data. From the current-voltage (I-V) curve we find that the measured short circuit current (Isc) is 5.5564 mA and open circuit voltage (Voc) is 5.595172 V.

The power-voltage curve (P-V) is also obtained from the measured data. And from the P-V curve we obtained the maximum power point (MPP) is 15.18 mW.

The obtained typical power-voltage (P-V) curve by experimentation is shown below:

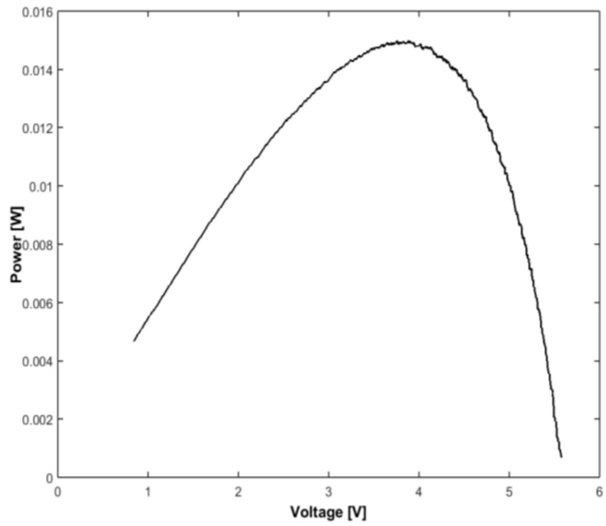

Figure 5. The P-V curve from experimental data.

4.1. Noise Data Approximation

Obtained I-V curve with noise is presented in figure 6 [7]:

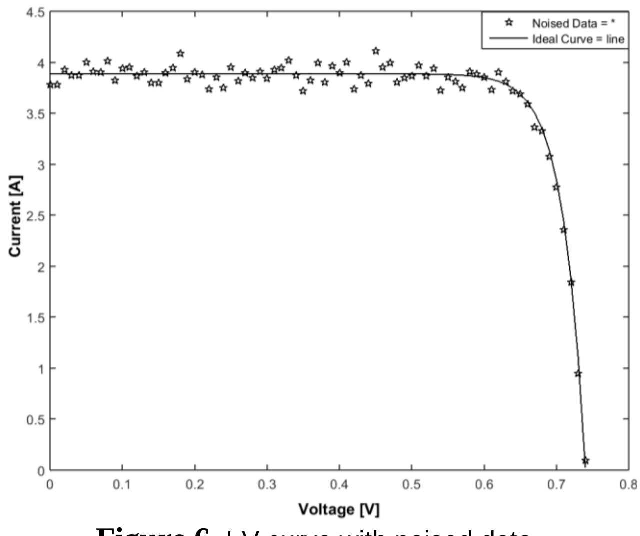

Figure 6. I-V curve with noised data.

Figure 6 presents the current-voltage (I-V) curve with noised data. The standard deviation considered here is two percent of the maximum of current value. By adding white noise we can be able to see the difference between the simulated data and real data. Because of adding noise in the curve we can see that there is deviation or fluctuation in the I-V curve. But, the curve without noise is very smooth and there is no deviation except in MPPT point.

Before, we discussed the simulation part with white noise and its I-V characteristics. Now, we will see the characteristics of I-V curve with noise by using measured data.

The obtained I-V curve by measured data with noise is presented in the figure 7.

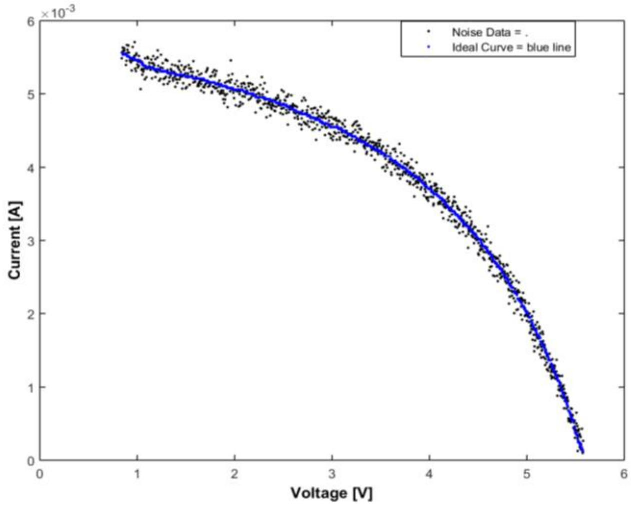

Figure 7. I-V curve with noise measured data.

Figure 7 represents the obtained current-voltage (I-V) curve with white noise. The curve is produced by the set of measured data. The blue curve in the figure is the ideal curve obtained by the measured data. And, the curve obtained by the scattered values is the curve with white noise data. For the white noise we have used two percent of maximum of current. The main objective of adding noise is to see how the ideal curve deviates from its ideal position. Though we know that there is noise in real data already, but we used other certain value of white noise in it. The purpose is to show the current-voltage (I-V) curve characteristics and behaviour after adding white noise.

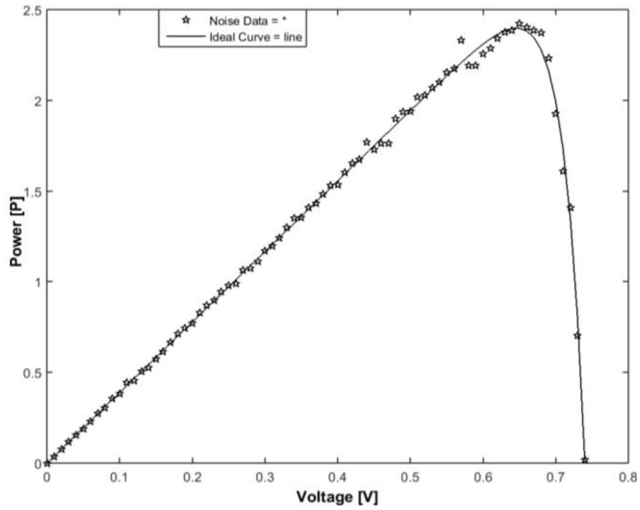

Figure 8. P-V curve of noise data.

The power-voltage curve with noise experimental data is obtained here [8]. The curve in blue is the ideal curve from measured data. And the curve obtained by scattered data sets is obtained by adding white noise in measured data.

The obtained P-V curve by measured data with noise is presented in figure 9.

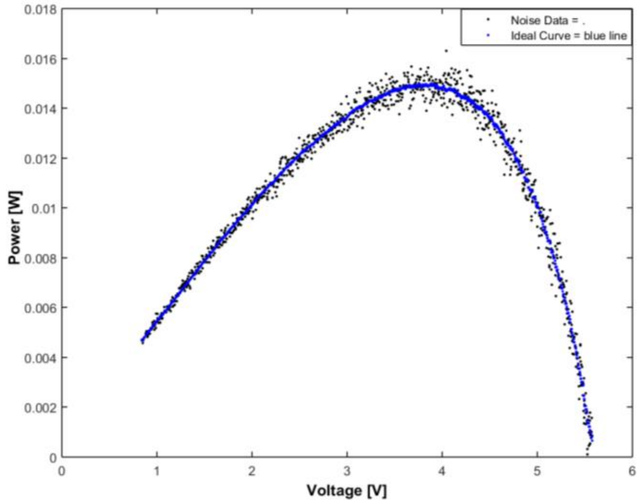

Figure 9. P-V curve with noise measured data.

From figure 9, we can see that the ideal curve is smoother than the noised curve. The purpose of using noise in the simulation is to observe the curve in real situation. And to see the deviation of noise curve with ideal curve also.

We used the standard deviation of two percent of maximum of current value in the previous simulation. In future, we will use standard deviation of five percent of maximum of current value in order to see how it affects in both I-V and P-V curve.

4.2. Curve Fitting Approximation

The action of establishing a mathematical function or a curve by the best fit to a series of data points by giving the constraints is the curve fitting method. In here we are going to use the curve fitting approximation for both the ideal I-V and P-V curve and I-V and P-V curve with white noised data.

The obtained figure shows the fitted curve from standard values of I-V curve by using fourth order polynomial curve fitting method. The main objective is to observe the fitted curve and make comparison between ideal curve and fitted curve.

The obtained current-voltage curve by using polynomial is presented in figure 10 [7]-[9].

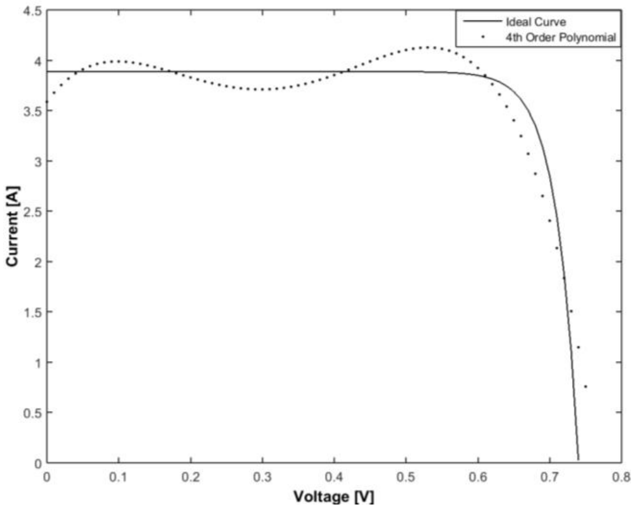

Figure 10. I-V curve with 4th order polynomial fitting.

If we look at the figure, we can see that there are differences between the two curves. The curve obtained by ideal value looks smoother than the curve obtained by polynomial fitting. The curve obtained by polynomial fitting method has deviations in the curve as the fitting occurs.

The obtained I-V curve from measured data by using 4th order polynomial is presented in figure 11.

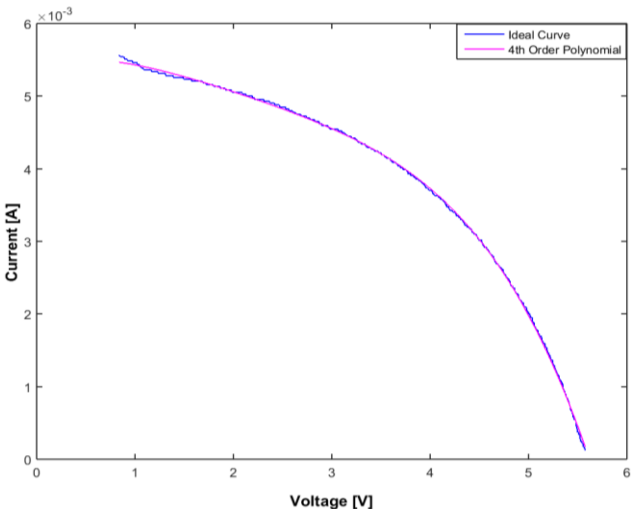

Figure 11. I-V curve with 4th order polynomial fitting.

Figure 11 presents the current-voltage (I-V) curve fitting with fourth order polynomial method. Here the I-V curve of blue colour is obtained from the ideal measured values. And the other I-V curve is the curve obtained by fourth order polynomial fitting on the ideal value. From the figure we can see that the curve obtained by polynomial fitting is almost in line with the curve of ideal measured value.

Obtained P-V curve is presented in the figure 12. [7]

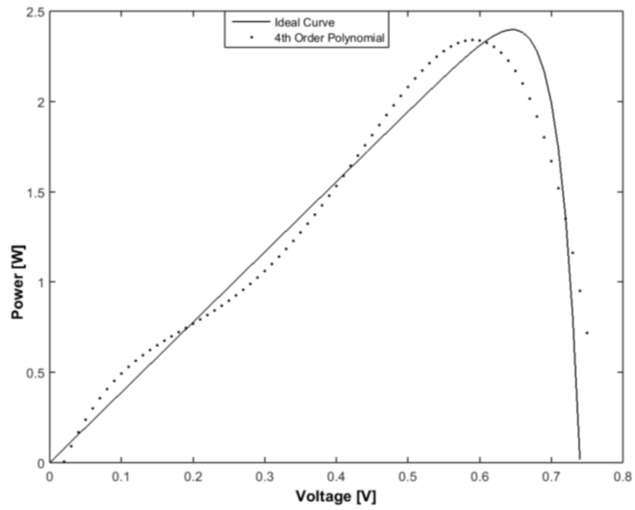

Figure 12. P-V curve with 4th order polynomial fitting.

The above figure shows the power-voltage curve for fourth order polynomial fitting. There are two figures we can see here one is the smoother which is P-V curve with ideal data and another is P-V curve with fitted data. The fourth order polynomial fitting method is considered here in order to fit the curve.

The obtained P-V curve from measured data by using 4th order polynomial is:

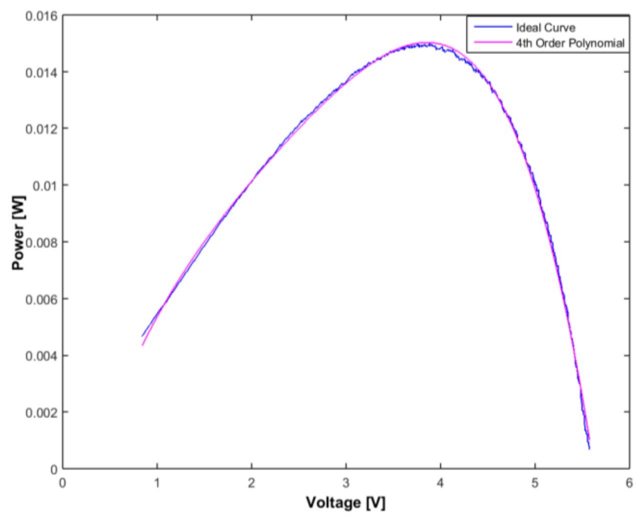

Figure 13. P-V curve with 4th order polynomial fitting.

The above figure is the power-voltage (P-V) curve obtained from measured data. The curve in blue is the ideal power-voltage curve obtained from measured data. And, the other is the fitted curve by using fourth order polynomial fitting.

In the next figure we are going to see the curve fitting for the noise I-V curve of PV module. The figure is:

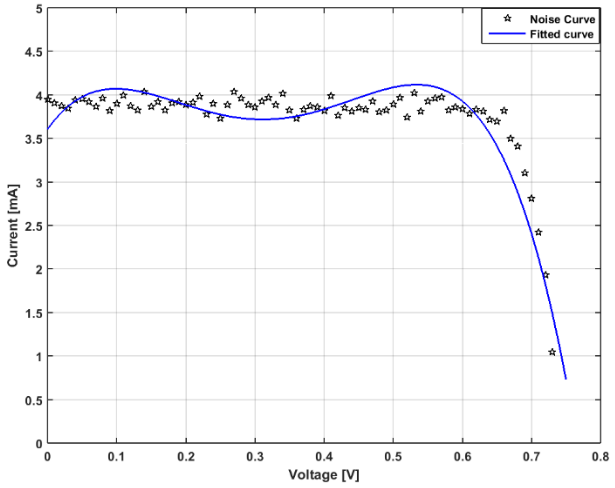

Figure 13: I-V curve with noise fitted data.

Conclusion

This paper has analyzed the method for the mathematical modeling of a PV cell with different behaviors like noise analysis and curve fitting. It is based on a MATLAB simulation by using the fundamental circuit equations of a solar photovoltaic cell. First, we analyzed the current-voltage (I-V) and power-voltage (P-V) curve from the equivalent circuit equation by using a numerical method. In here we observed the noise approximated data for I-V curve and P-V curve. We observed also how the approximated values differ from its ideal value. And then we used the fitting curve method to fit the curve in accordance with the method. The forth order polynomial method is used to analyze the data. This paper gives the clear idea about the data with noise and the data with fourth order polynomial method approximation. By those given observations we can characterize the PV cell. The characterization can increase the efficiency of the PV cell and it is seen as gain of electric energy production. Good characterization is a substantial contribution to the environment by producing more clean energy and better use of solar resource.

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