

Comparative Study On The Performance Of Mono-Crystalline And Poly-Crystalline Photovoltaic Cell Configurations Under ANNABA Weather Conditions

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Abstract: In coastal areas, the behaviour of solar panels changes significantly compared to the data sheets provided by the manufacturer. In this study, we aim to evaluate the performance and efficiency of polycrystalline and monocrystalline solar panels installed in the Sidi Amar region of Annaba, Algeria. This region has the significant solar potential and moderate temperatures throughout most of the year. We evaluated how external factors in this region, such as solar radiation and temperature, influence the production and efficiency of each solar panel module. By analysing the I-V and P-V electrical properties, we compared the performance of each module (monocrystalline and polycrystalline) based on the weather conditions of this locality. Additionally, we conducted a theoretical analysis using the MATLAB/Simulink model of the PV module to complement our experimental results.

Keywords: Photovoltaic module; Mono-crystalline; Poly-crystalline; Annaba weather; Characteristics (I-V & P-V).

INTRODUCTION

The development of renewable energy sources, such as solar energy, wind energy, and biomass energy, to produce electricity is becoming increasingly necessary today. The significant depletion of fossil fuel stocks is the reason for this orientation, as it is due to the rising demand of manufacturers in developed countries. Because solar energy is almost always present and available throughout the year, it is one of the most significant renewable energy sources. Algeria has a lot of potential for solar energy due of its advantageous geographic location. The average annual solar energy in Algeria is estimated by the Centre for the Development of Renewable Energies to be 2,650 hours in the north, 3,000 hours in the highlands, and 3,500 hours in the southern desert. Due to its ability to generate approximately 168.971 TWh of power annually more than 100 times that of Spain and twice that of Egypt, Algeria is given preference in the utilization of this renewable energy source [1]. There are two technologies are used in the utilization of solar energy.

The first technology transforms the photon energy into thermal energy known as a thermal module. The second technology, known as a photovoltaic cell (PV cell), uses this process to transform photo-energy into electrical energy, but this is not enough to supply household appliances and public areas [1]. To produce the required quantity of power, the solar cells are arranged in series or series/parallel to manufacture a PV module or panel [2].

The performance of a photovoltaic system is influenced by various factors, including dust, filth, sunlight, temperature, shade, degradation, and more [3, 4]. Studying the characteristics (I-V & P-V) of PV modules is the most practical approach to assess the performance of PV systems [2]. Several researchers are studying this field and have proposed several simulation models that delineate the behaviour of the PV module, and PV field. Thus, equations are given to calculate the parameters of these models [5, 6]. However, an experimental study is necessary to confirm the effectiveness of the proposed simulation model.

This work proposes a simple model that describes the behaviour of any type of PV module, using Matlab/Simulink software. This can predict current-voltage and power-voltage characteristic of PV module depending on the influence of several factors.

An experimental study was carried out using the Mono-crystalline (Dimel 130W) and Poly-crystalline (Dimel 135W) PV module model, which presented the effects of climatic conditions at "SIDI AMAR", Annaba city (Algeria), on their characteristics (I-V and P-V).

1 THEORETICAL STUDY

1.1 Photovoltaic Module Modelling

The model a single diode for solar module (Fig. 1) is a suitable model for this investigation. This is due to two factors: the model's simplicity, ease of implementation, and ease of result analysis; and first, the produced findings typically exhibit a high degree of consistency with experimental data [7].

According to Fig. 1 [8, 9], the equivalent circuit is made up of a photocurrent, a diode, a parallel resistor that expresses a leakage current, and a series resistor that describes an internal resistance to the current flow.

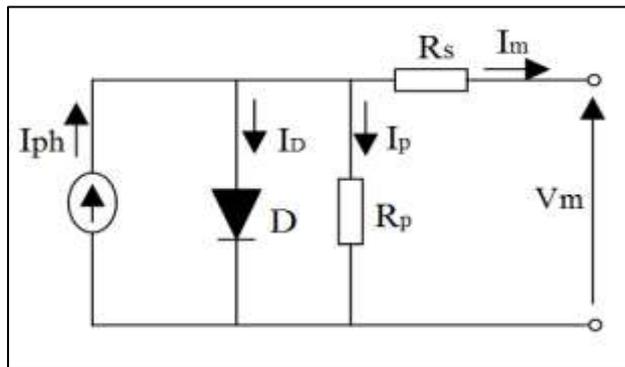


Fig.1 Equivalent electrical circuit of PV module

The Equivalent electrical circuit of PV module can be described in Eq. (1).

$$I = I_{ph} - I_0 \cdot \left[\exp\left(\frac{V + I \cdot R_s}{a \cdot V_t}\right) \right] - \left(\frac{V + I \cdot R_s}{R_p} \right) \quad (1)$$

Where:

I is the output current of PV module (A);

I_{ph} is the photovoltaic current (A);

I_0 is the saturation current of diode;

V is the output voltage of PV module;

V_t is the thermal voltage;

a is the diode ideality factor;

R_s and R_p are series resistance and shunt resistance, respectively.

The photovoltaic current mainly depends on the radiation intensity and cell operating temperature as follows [10, 11]:

$$I_{ph} = \left[I_{sc} + k_i \cdot (T - T_{ref}) \right] \cdot \frac{S}{S_{ref}} \quad (2)$$

Where:

I_{sc} is the short-circuit current (A);

k_i is the short-circuit current coefficient (A/°C);

T is the temperature of the p-n junction solar cell in K;

T_{ref} is the temperature at standard test conditions STC (25 °C, 1000 W/m²).

S is the solar radiation (W/m²);

S_{ref} is solar radiation at standard test conditions STC (25 °C, 1000 W/m²);

The saturation current of PV module is expressed in the following equation:

$$I_0 = I_{r0} \cdot \left[\left(\frac{T}{T_{ref}} \right)^3 \cdot \exp \left(\left(\frac{q \cdot E_g}{a \cdot k} \right) \cdot \left(\frac{1}{T_{ref}} - \frac{1}{T} \right) \right) \right] \quad (3)$$

where

- I_{r0} is the reverse saturation current (A);
- K is the Boltzmann constant ($1.38 \cdot 10^{-23}$ J/K);
- q is the electron charge ($1.6 \cdot 10^{-19}$ °C);
- $E_g=1.12$, is the Silicon Gap Energy (eV).

2 Experimental Setup

The experimental characteristics (I-V and P-V) were measured by an experimental bench study as shown in Fig. 2. Additionally, simulation was accomplished in MATLAB/Simulink software (Fig. 3). The entire system was simulated under different solar energy conditions to test the proposed system under specific conditions [12].



Fig. 2 Experimental setup and measurement devices

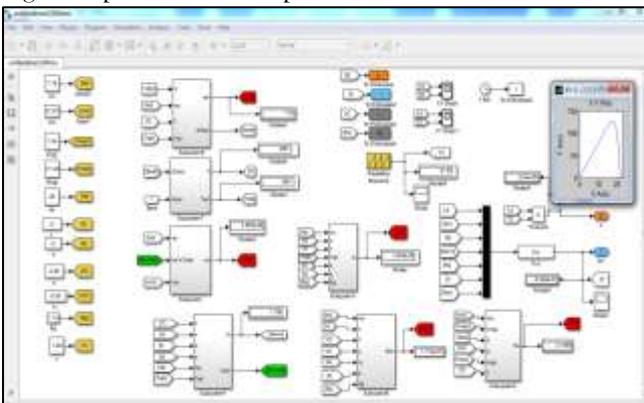


Fig.3 Simulation model of PV module

Table 1 presents specific electrical parameters of PV module used in this study.

Table 1 - Specific electrical parameters of PV modules used in this study.

PV modules	Monocrystalline Dimel 130 W	Monocrystalline Dimel 135 W
Maximum power (Pmax)	130 W	135 W
Maximum power voltage (Vmpp)	17.45 V	17.9 V
Maximum power current (Impp)	7.44 A	7.55 A
Open circuit voltage (Voc)	21.87 V	21.9 V
Short-circuit current (Isc)	7.78 A	8.2 A
Max system voltage	1000 V	1000 V
Number of cells per module	36	36

3 RESULTS AND DISCUSSION

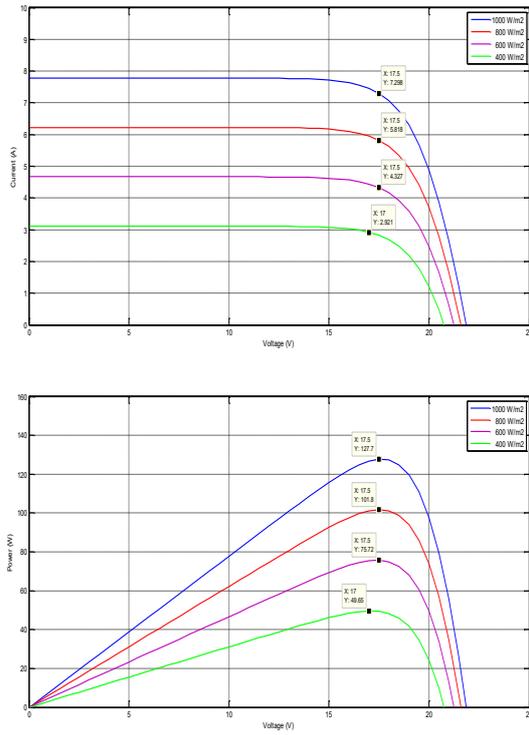


Fig.4 (I-V & P-V) curves of PV module (130 W) at different solar illumination values

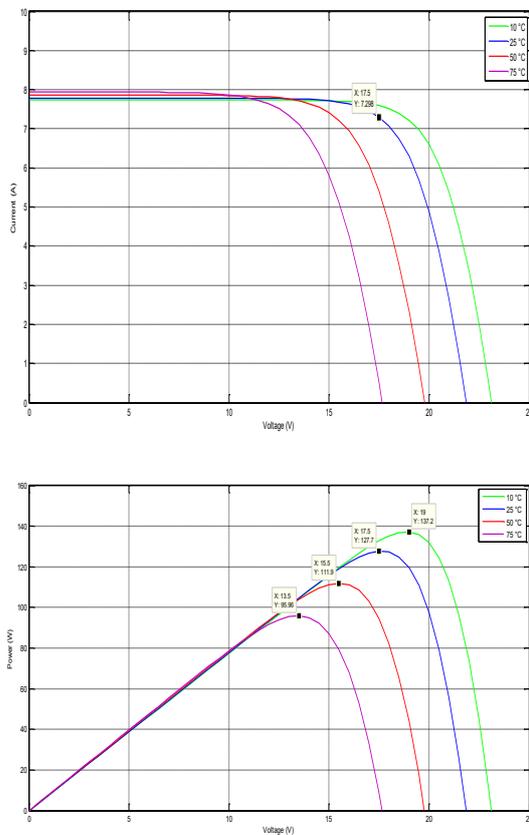


Fig.5 (I-V & P-V) curves of PV module (130 W) at different temperature values

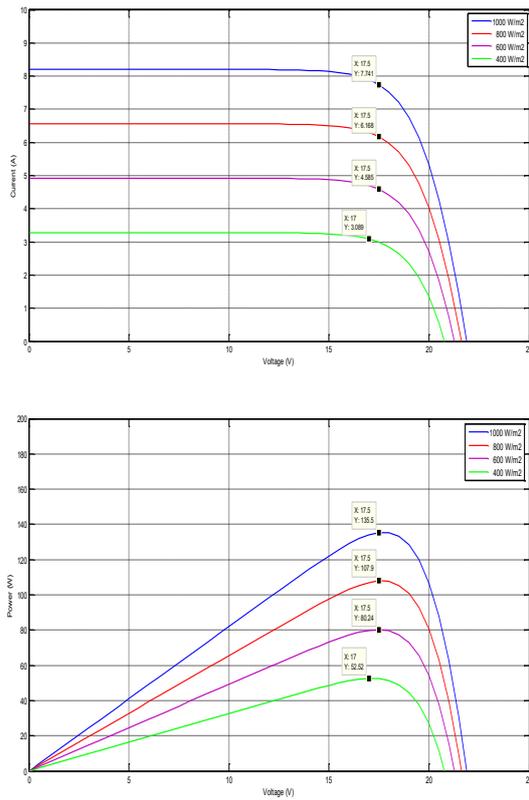


Fig.6 (I-V & P-V) curves of PV module (135 W) at different solar illumination values

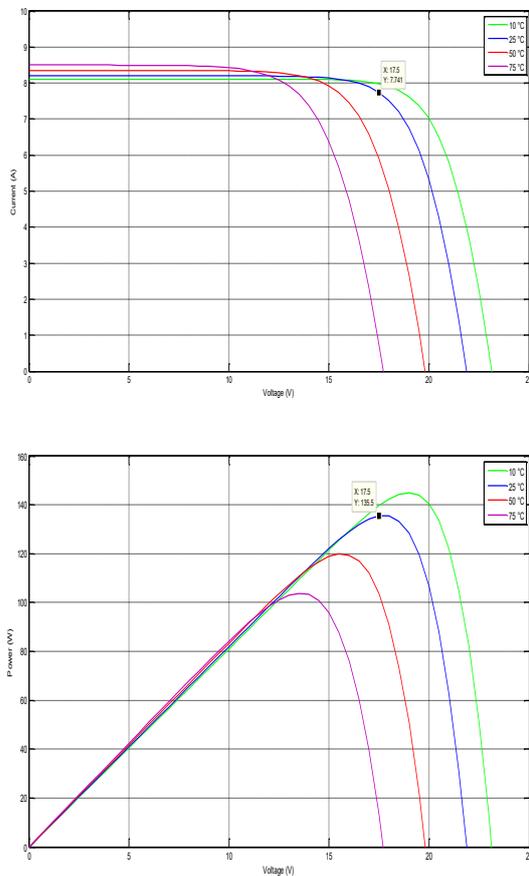


Fig.7 (I-V & P-V) curves of PV module (135 W) at different temperature values

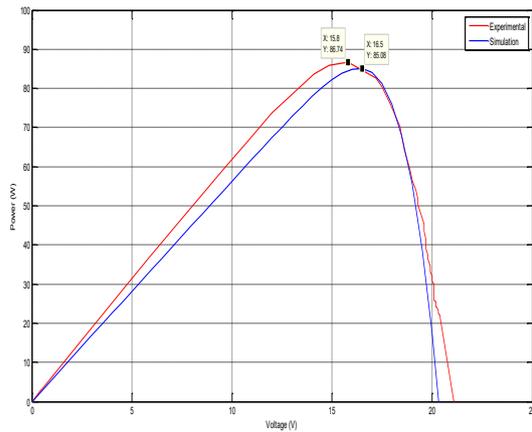


Fig.8 (P-V) curve of PV module (130 W) in outdoor (Annaba)

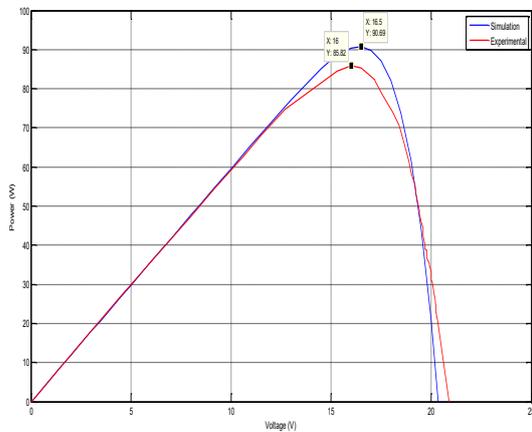


Fig.9 (P-V) curve of PV module (135 W) in outdoor (Annaba)

The current and power curves of PV modules at various solar irradiance levels (400 W/m² to 1000 W/m²) and constant temperature (25°C), are shown in Figures 4 and 6. These curves were obtained by simulating the PV modules: 130 W and 135 W, respectively.

We observe that rising of solar irradiance values; leads to rising of PV module short-circuit current values, which in turn raise maximum power values. The opposite is also true. On the other hand, the open-circuit voltage value increases less when the solar irradiance value increases.

PV module I-V and P-V characteristic curves, Dimel 130 W and Dimel 135 W, respectively, are shown in Figures 5 and 7. These curves were produced by a constant solar irradiation value of 1 KW/m² and at varied PV module temperatures ranging from 10 °C to 75 °C.

We notice from curves, that the increase in the module temperature value leads to the decrease in the open-circuit voltage value, which results in a decrease in the maximum power point of PV modules, while the short-circuit current values stays almost constant.

Figure 8 and 9 illustrates the Power-Voltage curves, respectively, of PV modules taken under outside conditions in Annaba (red curves), while the simulation results are shown in the blue curves.

We notice that the maximum power produced by the mono-crystalline PV module (Dimel 130), was about 86.74 W on 04 Thursday 2018 at 15:08 H (S = 720 W/m² and T = 38.5 °C) (see Fig. 8), while the poly-crystalline PV module Dimel 135, was about 85.82 W corresponding to the maximum voltage (16 V) (fig. 9).

Moreover, the results of the simulation model and the experimental measurements are almost identical, as shown by the red and blue curves in Figure.8 and 9.

4 CONCLUSION

In this work, we presented an experimental study on the performance of two types of PV modules (mono-crystalline and poly-crystalline), which are installed in the city of Annaba in Algeria. The experiment was conducted under normal climatic conditions, with emphasis on the effects of external factors such as solar irradiance and PV cell temperature.

We observed that the power produced by the mono-crystalline module is slightly higher than the poly-crystalline type PV module, found in the same climatic condition, although the latter in standard conditions is more powerful than mono-crystalline (see table 1).

A simple simulation model has been provided to estimate the parameters and predict the characteristics of any photovoltaic module. The results of our investigation allow us to conclude that the comparison seems to show that the simulation and experimental results are almost identical, demonstrating the validity of the model.

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