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Comparison of the Efficiency of Polycrystalline and Thin-Film Photovoltaic Outdoors

M. Almadhhachi, I. Seres, I. Farkas

ABSTRACT

In this paper, a comparison was made between two types of PV modules widely used in the market: polycrystalline and thin-film (both of them are silicon-based manufacturing) to identify the variables and parameters affecting the efficiency of solar cells. The efficiency of polycrystalline is higher than thin-film, although the open circuit voltage is more affected by solar radiation. The comparison was made in Gödöllő in Hungary, characterized by a moderate climate temperature and humidity on a partly cloudy day to study the effect of clouds and the change in the amount of solar radiation on solar cells. The flexible feature of thin-film cells can be used in many applications, especially those related to covering surfaces, as it is considered thin-layer and does not require an expensive metal structure to install. All these variables were calculated and discussed. The difference between the efficiency of polycrystalline and thin-film modules was a small percentage ranging between (-0.2% to 0.5%). This difference comes from the manufacturing technology method and the manufacturing quality itself.

Keywords: Solar cell, polycrystalline, PV module, PV technology, thin-film.

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I. Introduction

When fossil fuels are in constant decline with a continuous change in world oil prices, it is necessary to search for a suitable and alternative energy source. Traditional fuels are becoming scarce, and environmental concerns and global warming are becoming significant issues that must be addressed [1]. From the previous research that dealt with a review of sustainable energy, it seems that it has a real possibility of generating electrical energy. Moreover, it can be said that solar energy is the most suitable source, followed by biomass, and then comes hydro and wind energy, respectively [2].

Techniques and methods for obtaining solar energy have varied, and there is a race to get higher efficiency and broader applications around the world. Each type of solar energy production is characterized by several techniques to reach the ideal [3], [4].

Photovoltaic technology has been characterized by its spread worldwide because it outfits a wide range of applications and can be applied in different atmospheric conditions as it depends on sunlight [5].

Within the sunlight absorption technology, three basic types can be found within most applications that use this technology, which is (monocrystalline, polycrystalline, and thin-film), it is worth noting that there are some differences in manufacturing and efficiency between them [6].

The manufacture procedure necessitates two things: first, a material in which light absorption raises an electron's energy state, and second, the passage of that higher energy electron from the solar cell onto an external circuit. After dissipating its energy in the external circuit, the electron returns to the solar cell. The requirements for photovoltaic energy conversion can be met using several materials and technologies. Still, in reality, practically all photovoltaic energy conversion uses semiconductor materials in the form of a p-n junction [7].

Thin-film modules peak power at STC (Standard Test Conditions) varies throughout the year. In amorphous silicon modules, this variance is even more noticeable. According to the comparison, the performance of thin-film modules is superior to polycrystalline silicon modules for this location. However, during the winter months, cadmium telluride and polycrystalline silicon modules perform better, with greater daily yield values and lower total losses. Still, amorphous silicon and microcrystalline silicon modules perform better in the summer [8].

Numerous PV testing techniques and MPP tracker algorithms have been developed to discover the genuine MPP. However, the consistency and reproducibility of testing settings such as solar irradiation and PV module temperature are issues connected to comparing maximum-power point tracking (MPPT) algorithms, evaluation, and comparison of PV testing system performances [9].

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Previous studies dealt with the study and analysis of solar cells under standard conditions and to know more about the performance of solar cells in actual weather conditions to define those interested in the solar energy sector. Monocrystalline silicon, polycrystalline silicon, and thin-film have shown higher efficiency among all PV technologies. However, the efficiency is low when the module temperature is high and vice versa [10], [11].

Polycrystalline solar cells are the most widely used technology for PV power plants, as evidenced by their better performance and the fact that they have a strong market position and a big active research community. When comparing thin-film based technologies to wafer-based technologies, all thin-film based technologies exhibit substantial advantages. Thin-film based methods may be more appropriate if cost or efficiency are not the primary considerations. Still, specific cell criteria such as form, electrical parameters, or aesthetics must be addressed [12].

This paper aims to focus on the performance of solar cells under non-ideal weather conditions and compare two main types, which are polycrystalline and thin-film.

II. Procedure and Methodology

The main goal of this project is to compare the efficiency of two types of solar modules on a clawed day. Most previous projects used laboratory trials to investigate the differences in inefficiency. On the other hand, experiments under real-world situations can provide more secure and trustworthy data. Therefore, this project planned and processed an actual investigation under natural settings.

A. Site Description

Data is supplied for Gödöllő, located in Pest County, Hungary, about 30 kilometers northeast of Budapest. (As shown in Fig. 1), the location is 47.5944254 North, 19.3670737 East. Install the modules in a south direction, with an inclination angle of 20 degrees for both modules.

The foundation of the climate is the Sun's energy that reaches the Earth's surface. Therefore, the latitude and cloud cover determine the irradiation's spatial distribution. Because Hungary has a short latitude range, cloud cover impacts [13], [14].

Fig. 1. Hungary map, Gödöllő location

B. Solar Cells

Polycrystalline wafer-based solar cells and thin-film (Amorphous silicon) module ware compared and analyses. In this study, two pieces of PV modules were evaluated, as shown in Fig. 2. The PV modules are new, and Table 1 lists the parameters of the PV modules.

TABLE I: The Parameters of the PV Modules

Channels	Voltage(V)	Current (mA)	Area (m^2)	Power (W)
Polycrystalline	12	250	0.1776	3
Thin-film	12	50	0.0384	0.6

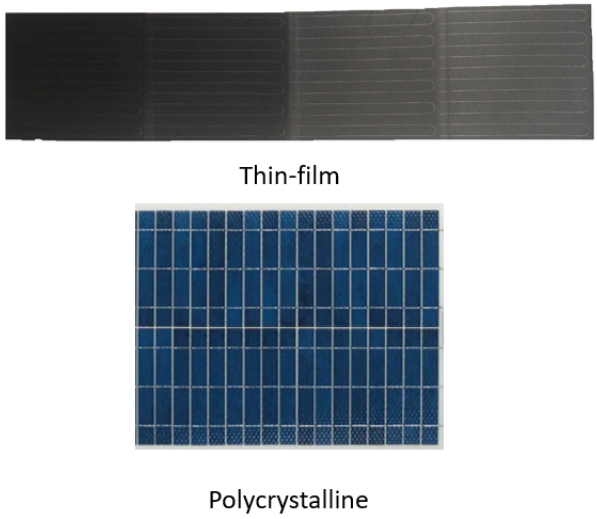

Fig. 2. Thin-film and Polycrystalline modules

C. Measuring Devices

The output efficiency of the PV module was estimated by:

$$E = \frac{Output\ Power}{Input\ Solar\ Power} = \frac{Voc*Isc}{G*A} \quad (1)$$

here Voc is the open-circuit voltage, Isc is the short circuit current, G is the reference irradiation, and A is the solar module area. The short-cut circuit current can be calculated as:

$$Isc = I_0 \left(\frac{eq*Voc}{Ad*K*T-1}\right). \quad (2)$$

where T is the module temperature, I_0 is dark current, Ad is diode quality factor, K is Boltzmann constant, eq is the electronic charge [15].

Fig. 3. OWON B35T+ multimeter.

The short-circuit current fluctuates non - linearly with irradiation and has a minor variation with temperature depending on the temperature coefficient. According to several prediction methods, the photocurrent's fluctuations with irradiation and temperature are similar to those of the short-circuit current [16], [17].

The OWON B35T+ multimeters measured the voltage and current for each 10 minutes, as shown in Fig. 3.

III. Results and Discussions

To identify the importance of atmospheric influences on the efficiency of solar cells by measuring the performance of solar cells according to the atmospheric condition.

On a partly cloudy day, the solar radiation was fluctuating Fig. 4. The readings of the solar cells were taken to calculate the efficiency of the modules, compare them, and study the behaviour of each module separately. The comparison between the photovoltaic modules showed that it depends on the amount of solar radiation and the effect of clouds. The voltage behaviour of the two modules was almost equal, as in Fig. 5. The open-circuit voltage appeared slightly high due to the low temperature of the atmosphere and this is due to the inverse proportion to the temperature, that is, the lower the temperature, the higher the open-circuit voltage [15].

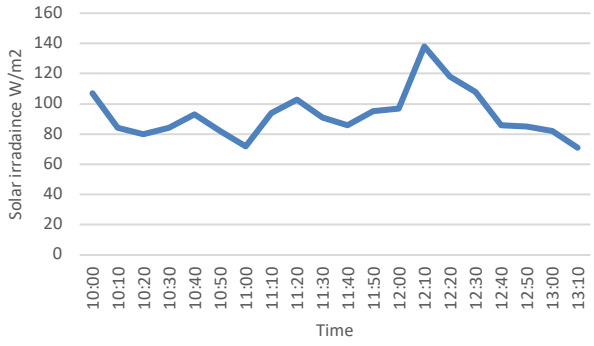

Fig. 4. Solar radiation on a cloudy day.

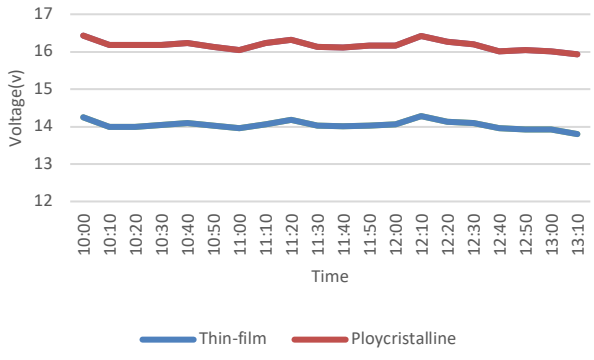

Fig. 5. The voltage produced during the time for both modules.

From (1) the output power of each module can be calculated, Fig. 6. there was a different behaviour of each solar cell type, where the variety power of polycrystalline was more influential due to the difference in solar radiation value.

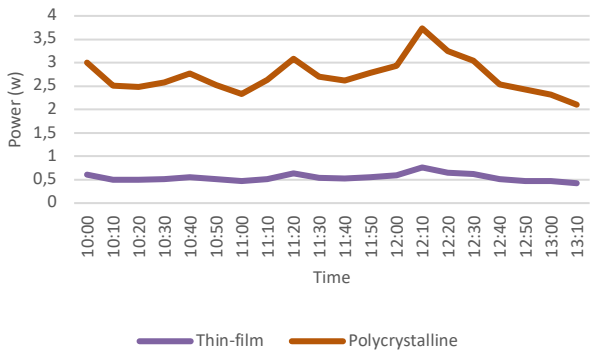

Fig. 6. The power produced during the time for both modules.

By applying the efficiency equation and calculating it for both types, as shown in Fig. 7, there is a direct relationship between solar radiation and the solar module efficiency, especially since the ambient temperature was low and the weather was partly cloudy. This feature is essential for temperate regions to maintain electricity production.

Certainly, the results that appeared in this study can be compared with previous studies [18] mentioned in reviews that the efficiency of the thin-film 13% was obtained in 1995. It is in continuous development [19], got an efficiency of more than 13.6 in In 2004 [20], [21], and an efficiency of more than 17.3 was obtained [18].

The efficiency results were acceptable because the efficiency of the polyurethane ranged between 13% to 17% [22].

The difference is minimal and almost identical between the curves, indicating the efficiency of solar modules and modern technologies for manufacturing modules to maintain their efficiency. Although there is a difference in Fig. 6. which shows the open-circuit voltage, this change is considered not to be measured and does not affect the production process.

The difference between polycrystalline and thin-film efficiency is illustrated in Fig. 8. The difference between the efficiency ranges between (-0.2% to 0.5%), at an average rate of less than 0.2%, which is a meagre rate due to the relatively low solar radiation. The efficiency difference increases with the increase in the rate of solar radiation and electricity production.

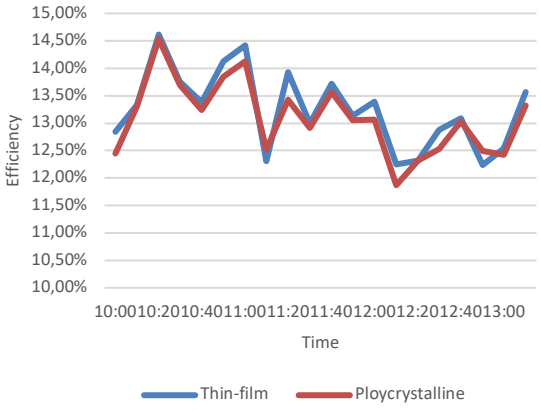

Fig. 7. The efficiency for both modules.

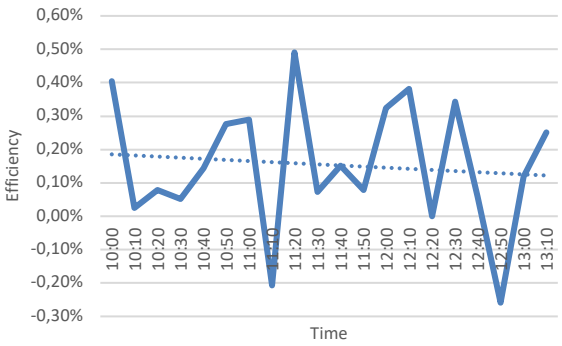

Fig. 8. The efficiency difference of modules.

IV. Conclusion

The test was carried out under normal weather conditions. All the readings were studied to determine the differences between the two types of solar cells to provide precise results for anyone who wants to acquire these modules under the same weather conditions.

Polycrystalline is more efficient than the thin-film solar module. However, both polycrystalline and thin-film have the same behaviour production depending on the solar radiation ratio. Statistical analysis was made to state the relationship between efficiency and performance ratios of module types, environmental temperature, module temperature and amount of radiation. Moderate regions in weather conditions are more efficient in photovoltaic technology.

Reliance on the open-circuit voltage gives accurate and reliable results because there is no noticeable effect on the temperature of the solar module in moderate or cold weather. Instead, the most significant impact is on the amount of solar radiation and the module's surface area directly exposed to radiation.

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Conflict of Interest

Authors declare that they do not have any conflict of interest.

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