# EFFICIENCY OF POLYCRYSTALLINE PHOTOVOLTAIC PARKS IN ROMANIA
## Possibility of Using Renewable Energy

by

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*The performance of photovoltaic panels and lifetime are determined to a large extent by the quality of photovoltaic cells, their soldering technology, the quality of ethyl vinyl acetate film in which they are encapsulated, the encapsulation technology and the back sheet. Depending on the manufacturing technology, photovoltaic panels can be made of monocrystalline, polycrystalline, and amorphous silicon cells.*

*This manuscript studies the main factors that influence the aging of photovoltaic panels in order to assess their effectiveness and sustainability in terms of energy, in order to establish the optimum conditions of photovoltaic panel's location, being a contribution to the attainment of the targets in terms of growth using renewable sources of energy. The main purpose of this research is to study the current state, in Romania, in the field of renewable energies by using solar panels.*

Key words*: efficiency, photovoltaic panels, renewable energy*

## Introduction

The fossil fuels needed to produce energy in thermoelectricaly power plants represent depleting sources in forthcoming, hence it is necessary the use of renewable electricity [1].

Renewable energy is now considered a more desirable source of fuel than nuclear power because there are not so many risks and disasters [2].

Solar energy is virtually inexhaustible. This energy is *clean*, meaning that there are no emissions of $CO_2$ or other pollutants and *sources* in the sense that it is not dependent on substances that need thousands or millions of years to be form from natural processes [3, 4]. Production of solar energy by solar panels or other means using solar energy is free of noise, unlike other sources [5].

Solar cells are manufactured as crystalline or thin film. Crystalline type photovoltaic (PV) cells are more efficiency than thin film, but some of the thin film (like cadmium-telluride) is also used, because they have lower cost [6, 7].

The performances and life span of photovoltaic panels are determined to a large extent by the quality of photovoltaic cells, their soldering technology, the quality of the EVA films in which they are encapsulated, the encapsulation technology and the back sheet [8, 9].

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Generating electricity with solar PV panels is a viable solution in all regions of Romania for both independent PV systems and for the realization of photoelectric power plants connected to the national energy system. Our country is privileged from the point of view of the solar energy level, the level of solar irradiation being higher than in the Western European countries with tradition in using these PV systems. The radiation level in Romania is very good compared to other countries with a temperate climate, and the differences, depending on the geographical area, are very low. That is why our country is in the European sunlight Area B, which offers real benefits for the exploitation of solar energy [10, 11].

The efficiency of PV panels has steadily increased over the last decade as a result of overall efforts to reduce energy dependence, reaching today at around 15-20% [12, 13]. The use of high technologies and increased production capacities have made them accessible for both industrial and domestic applications, and is now a solution that can be reached at a glance for the production of electricity in isolated areas [10]. The PV field has given rise to a global industry capable of producing many gigawatts of additional installed capacity per year [14].

Most PV parks in Romania were built in 2013. The increase in investment in such a short time was caused by the very attractive subsidy, regulated by Law 220/2008, with amended and supplemented, which aims to recover the investment in the next 4-5 years [14-16].

In this article are presented the specific characteristics of PV panels, used in Romanian production to determining the main factors that influence the aging of PV panels in order to assess their effectiveness and sustainability in terms of energy. Measurements were made in situ at two PV parks, A and B. Park A is located near city of Brasov and park B is located near city of Targu Mures.

## Location and description of PV panel

In order to analyse the level of degradation of PV panels, measurements were made in situ in two PV parks A and B. Both PV parks are located in hilly areas, with the same weather conditions, in quiet areas away from any source that could endanger their operation.

The PV parks from both destinations consists of polycrystalline PV panels.

In order to identify the type of the PV panels degradation, is made an assessment consists of visual inspection and I-V curve measurement in the fields (the whole plant or selected areas).

The I-V 400 multifunction instrument was used for verification the current-voltage characteristic of PV strings. The instrument also measures the values of its temperature and incident irradiation. By using this instrument the main parameters of both a single module and more PV modules were determined. From the measurements made with I-V 400 and the visual analysis of the two PV parks has been identified the problems arising from their exploitation to date.

Data obtain from measuring of current-voltage ( I-V) have been done to the standard test conditions (STC) of cell temperature of 25 °C and an irradiance of 1000 W/m$^2$ with an air mass 1.5 (AM 1.5) [17], in order to be compared with the nominal data declared by the manufacturer in the PV panel datasheet.

For data processing, it is necessaryerrft: solar radiation, temperature and the angle of fall of solar radiation on PV panels.

The necessary equipment for carrying out these determinations consist in:

– M304 – to determine the optimum period of measurements (determine the angle of fall of the solar radiation on the surface of PV panels),

- HT304N – reference cell for measuring solar radiation with monocrystalline and polycrystalline silicon,
- PT300N – PV panel temperature sensor, which is positioned on the back of the PV module to compensate for the modulus to drop in temperature.

## Results and interpretation

The analysed PV parks have an operating life of about 3 years. Park B from Targu Mures was put into use in 2013 and Park A in Brasov in March 2014. The two PV parks were analysed to assess efficiency in terms of aging, combined with their degradation [18, 19].

Construction and commissioning, for the most PV parks in Romania, has completed in 2013. Over 1000 MW of the total installed capacity of 1400 MW at that time.

The investments were made in the context of a lack of information and technical training in the field, on the Romanian market. The selection criterion for PV panels, given the very attractive supply of the Asian market, was the lowest price. In this way, PV panels with hidden defects have entered the market and this defects become visible after about 5-6 years of operation. The new defects may appear and grow when the module is into operation (named as hidden manufacturing defects). Usually some of these hidden defects that only appear in normal operation are not detected in reliability tests (EN 61215 or EN 61646) [20, 21] due to the different operational conditions of the module in the standard tests and in the field [22, 23]. We expect that starting this year and continuing with the next years, we will have a number of PV parks that will have serious problems caused by the premature degradation of the panels.

### *Visual analysis*

As a result of the analysis and measurements carried out in the field, no defects affecting the efficiency of the panels were visually identified in the PV park A in Brasov. They only showed normal exploitation patterns such as dust and poultry. The cells were observed to be in good condition.

In case of PV Park B in Targu Mures, the situation is quite opposed to Park A. Several types of degradation of the panels with significant impact on the efficiency and integrity of PV modules have been identified here.

The types of degradation encountered are:

- changing the colour in the central ribbon area (yellow-brown),
- hotspot with damage to the protective layer (due to bypass diode failure),
- hotspot with melting of PV cells (due to bypass diode failure), and
- damage to the distribution box / inverter.

Following observations and problems identified in the field, it can be concluded that PV panels in Park B have hidden manufacturing defects that affect their integrity.

### *Data analysis*

By interpreting the measured I-V characteristic, it can determine: degradation state of the panel (as compared to initial parameters), failure of a cell, an interrupted or degraded connection in connectors or cable, or more severely, the occurrence of potential induced degradation effect in modules.

On the interpretation of the measurement results, will be taken account of the fact that, in the first year of light exposure of PV panels, their power will suffered a reduction of up to 3% due to the effect of light induction deterioration (LID). An annual loss of 0.5% is also considered excellent, as the annual power loss is between 0.4% and 7% [8].

*Photovoltaic Park A – Brasov*

After measurements have been made on a PV module in Park A, the characteristic of current-voltage and power curves for single module in figs. 1(a) and 1(b) and multiple module in figs. 2(a) and 2(b).

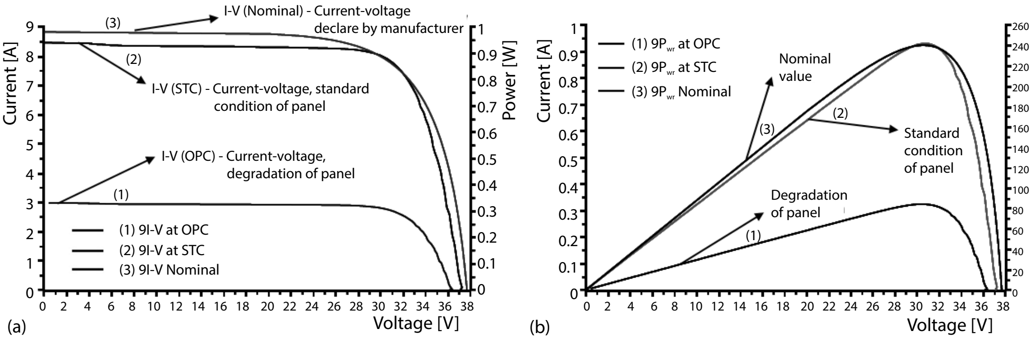


**Figure 1. Measurement in PV park A; current-voltage (a) and power (b) curve for single module**

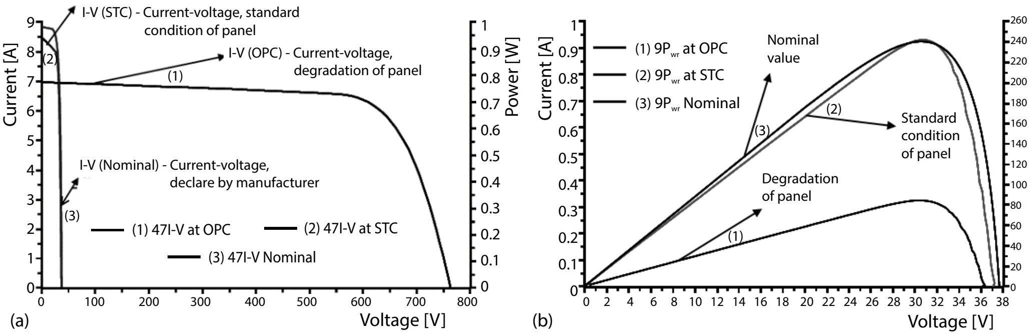


**Figure 2. Measurement in PV park A; current-voltage (a) and power (b) curve for multiple module**

In tab. 1 are presented the measured electrical parameters of PV module under working conditions (about 3 years), for Park A-Brasov.

**Table 1. Reference module parameters**

| Parameters | Unit | Value |
|---|---|---|
| Maximum power, $P_{\max}$ | [W] | 84.24 |
| Open circuit voltage, $V_{oc}$ | [V] | 36.28 |
| Short circuit current, $I_{sc}$ | [A] | 2.97 |
| Maximum power voltage, $V_{pm}$ | [V] | 30.29 |
| Maximum power current, $I_{pm}$ | [A] | 2.78 |

From tab. 1 it can be determinate the fill factor (FF), the FF is essentially a measure of quality of the solar cell. It is calculated by comparing the maximum power to the theoretical power (TP) that would be output at both the open circuit voltage and short circuit current together.

The FF can also be interpreted graphically as the ratio of the rectangular areas depicted [24] and it can be calculated with formula:

$$\text{FF} = \frac{I_{pm} \times V_{pm}}{I_{sc} \times V_{oc}} = \frac{P_{\max}}{A = P_T} = 0.78 \tag{1}$$

Using the electrical parameters declared by the manufacturer (nominal) the FF is 0.72. The FF factor means how percent from the TP generated within the solar cell ($I_{sc} \times V_{oc}$) can be utilized as a real power ($P_{max}$), it can never be more than 1, FF is always less than 1. Typical FF of contemporary silicon solar cells range from 0.70-0.80. In our case the FF is 0.78, falls within limits.

In tab. 2 are presented the measured electrical parameters of PV string (22 modules) under working conditions (about 3 years), for Park A-Brasov.

From tab. 2 it can be determinate the FF, in this case the value is 0.72. The FF value is within the range of 0.70-0.80. Using the electrical parameters declared by the manufacturer (nominal) the FF is 0.72.

**Table 2. Reference string parameters**

| Parameters | Unit | Value |
|---|---|---|
| Maximum power, $P_{max}$ | [W] | 3833.18 |
| Open circuit voltage, $V_{oc}$ | [V] | 763.90 |
| Short circuit current, $I_{sc}$ | [A] | 6.96 |
| Maximum power voltage, $V_{pm}$ | [V] | 609.70 |
| Maximum power current, $I_{pm}$ | [A] | 6.29 |

Measurements made on Parks A panels indicate that deviations from nominal sizes fall between 4-5%. This deviation is normal in the case of a 3-year PV park, indicating a loss of approximately 0.6% per year.

*Photovoltaic park B – Targu Mures*

After measurements have been made on a PV module in Park B, the characteristic of current-voltage and ,power curves was showed in figs. 3(a) and 3(b).

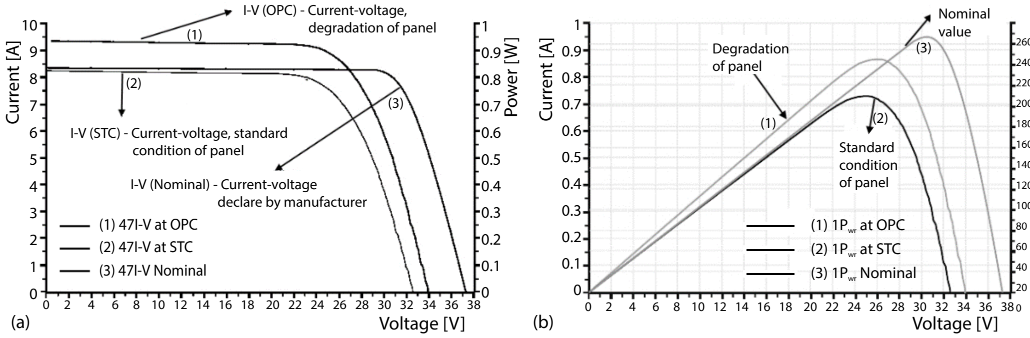


**Figure 3. Measurement in photovoltaic park B; current-voltage (a) and power (b) curve where bypass diode has yield**

In tab. 3 are presented the measured electrical parameters of PV module under working conditions, for Park B – Targu Mures.

From tab. 3 it can be determinate the FF, in this case the value is 0.70. Usually FF > 0.7. Using the electrical parameters declared by the manufacturer (nominal) the FF is 0.78, much bigger that our module.

**Table 3. Reference module parameters**

| Parameters | Unit | Value |
|---|---|---|
| Maximum power, $P_{max}$ | [W] | 217.78 |
| Open circuit voltage, $V_{oc}$ | [V] | 34.08 |
| *Short circuit current,* $I_{sc}$ | [A] | 8.96 |
| Maximum power voltage, $V_{pm}$ | [V] | 26.08 |
| Maximum power current, $I_{pm}$ | [A] | 8.35 |

By yielding the bypass diode, many hotspots are produced, which is an avalanche phenomenon, eventually ending out of production. The avalanche phenomenon in hotspot spots (brown spots, covered areas of cells) occurs as a result of opturating the light of action on the PV cell which leads to its heating (assuming the role of diode). This process accentuates the colour and automatically leads to a stronger cell heater. Thus, the PV panel is out of use, because the bypass diode remains permanently open and fast to creep.

## Conclusions

The analysis of the measurements made at the two parks resulted in the following conclusions.

- The PV park A, located in the Brasov area, is presented in a very good condition with its quality panels. The curves of the I-V (current-voltage) characteristic and the power determined on the modules indicate that the deviations from nominal sizes are between 4-5%, which means excellent panel behaviour after 3-4 years of commissioning. Considering that in the first months of light exposure of panels, their power drops by up to 3%, due to the LID, it turns out that the annual power loss of the panels is 0.4-0,7% $P_n$ (nominal power). A 0.5% annual power loss is considered excellent;
- The PV panel park B, near Targu Mures, is a 2.4 MW park. As a result of field measurements, it was found that there was a power loss of about 20%, which is abnormal for a 3-4 year old PV panel. The main phenomenon affecting about 40% of the total panels is changing the colour of the cells around the central ribbon. As expected, a hotspot appears in that area, which in turn develops cascade until, after the passage of the bypass diode, the encapsulating foil burns to carbonization, and can even generate fires.

As a result of the investigations we can conclude that the loss of efficiency of PV panels is in normal, even very good limits, with a minimum aging degree (0.5% per year), compared to their loss of efficiency due to the presence of hidden defects (20% after the first 4 years of operation and the loss of approximately 40% of the panels).

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