Experimental Research on the Influence of Factors on the Electricity Production of Thin-Film Photovoltaic Panels

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Abstract: *Given the current context regarding environmental pollution, in which conventional installations also participate, the aim of this article is to analyse whether photovoltaic systems are a viable solution to help solve this problem. Thus, the article analyses the way in which the electricity production of photovoltaic installations is influenced by the aging of the photovoltaic cells that make it up, but also by certain natural factors (water droplets, shading caused by clouds). Experimental measurements were performed on a new ZY-S100 thin-film photovoltaic panel and then on an aged one (7 years of operation) using an MI 3109 EurotestPV Lite METREL. When it comes to the main problem addressed in the paper, the influence of the aging of photovoltaic cells on the efficiency of the photovoltaic panels, the measurements indicated that the aged panel suffered a 25% decrease in efficiency in the seven years of operation, which comes to a decrease of 3.57% for each year.*

Keywords: *Electricity, photovoltaic panels, thin-film, aging, natural factors influence*

1. Introduction

The utilisation of renewable energy sources (RES), together with the improvement of energy efficiency (EE), can contribute to the energy consumption reduction, greenhouse gas emission reduction and in consequence, to the prevention of dangerous climate changes. The advantages of using solar energy emerge from the fact that it is an endless energy source that is also non-polluting. The disadvantages of using solar energy are that the caption technology is yet insufficiently performant. Another disadvantage is solar panels have a low efficiency, and the solar energy varies depending on the time of the day, or year, the angle of incidence of the solar panels or the atmospheric conditions [1, 2, 3, 4].

The last decades had brought a radical change in the concept plan by becoming aware of the necessity to durably develop social and economic life and to promote renewable energy sources that are considered a key element. From all these sources, electricity that is obtained by converting solar energy seems one of the most promising energy sources, that in the present is based on the technology of three generations of photovoltaic panels built to resist a wide range of exterior temperature (-40ºC…80ºC) and can also withstand various environmental factors (rain, hail or snow). On the flip side, the shade from clouds and the low levels of radiation, due to cloudy skies, has up until this moment a considerable effect on the capacity of the panels to generate electrical energy due to their low efficient in these conditions [5, 6, 7, 8, 9, 10].

The article proposes an assessment of the production of energy when exposed to solar radiation and an estimation of the decreasing efficiency of electrical energy production of 7-year-old panels, but also of the effects made by clouds and rain droplets.

2. The evolution of photovoltaic panels

Currently, photovoltaic generators are a reality, functioning all around the globe, and even more, being the only energy source of energy for satellites and the International Orbital Station. Also, in many countries extensive programmes of research and subsidy to determine attractive prices for the selling electrical energy from solar panels. Both the problem of the availability of energy, it's cost and the negative influence of the energetic industry on the environment stimulated research and innovation in the renewable domain [11]. Lately, the conversion of solar energy with the help of

photovoltaic technology was often addressed by researchers under various aspects [12, 13, 14]. Thus, photovoltaic panels are built in a various range, starting from crystalline silicon panels (the first generation of cells) [15, 16, 17, 18], , panels with Thin Film photovoltaic cells made by applying a thin layer (thick of about several μm, in comparison with crystalline silicon panels that have a thickness of several hundreds of μm) of semiconductor material(amorphous silicon, cadmium telluride- Cadmium sulphide (CdTeS), gallium arsenide (GaAs)) and up to copper, indium and selenite (CIS) modules, copper, indium, gallium and selenite (CIGS) and copper, indium, gallium, selenite and sulphur (CIGSS) modules, technologies under study and development, in which silicon is replaced with special alloys [8, 9, 10].
The research and development of photovoltaic cells in the last 2 decades have led to the appearance on the market of third generation panels / modules, the technologies used being promising. Examples are organic photovoltaic (OPV) and hybrid pigmented sensitized (DSSC) cells. The third generation can be classified as follows: advanced inorganic thin film such as (CIS), organic solar cells that include fully organic and hybrid cells; and thermo-photovoltaic (POS) cells with low bandwidth potential but which can be used for both heat and power (CHP) systems [11].

3. The influence of the aging of thin-film photovoltaic panels and environmental factors upon the electrical energy production. CASE STUDY

3.1 Description of the experimental installation

The experimental arrangement was located in the courtyard of the Faculty of Constructions of the Polytechnic University of Timișoara. The stand that was used to perform the measurements consisted of: a metal support to position at a 45° inclination a new thin-film photovoltaic panel (module) ZY-S100 and later an aged one (that was operating for 7 years) of the same type and a test apparatus MI 3109 EurotestPV Lite METREL (from the LE laboratory, specializing in CONSTRUCTION INSTALLATIONS). To perform the experimental measurements, an ammeter clamp was used to measure current (cc / ac), a test probe, a probe for measuring the temperature of photovoltaic cells and a probe for measuring solar radiation, a resistance and two multimeters to be able to measure voltage, current and resistance when the installation is under load. The orientation of the stand used was towards the east (the only option available for the placement of the panels for a concrete installation).
The ZY-S100 thin-film photovoltaic panel can deliver a maximum power of 100W ± 3%, and the characteristics are presented in ANNEX 1. The type of panel for which the measurements were made, the preparation of the installation and the equipment used are shown in Fig.1, and the measurement diagram and connections is represented in Fig. 2 [19].

Fig. 1. Preparation of the test installation

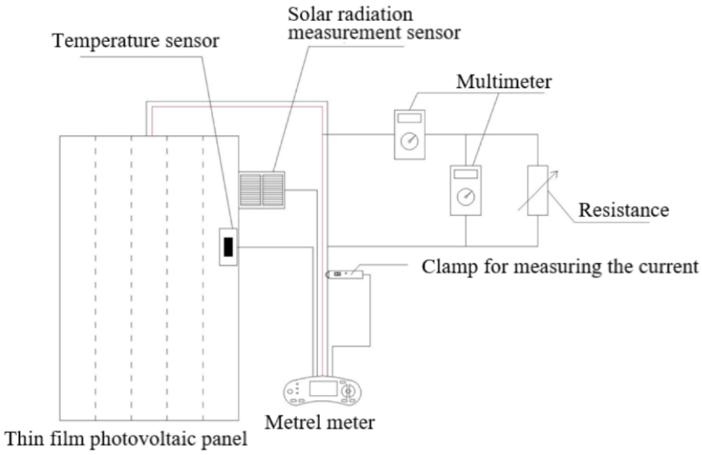

Fig. 2. The measurement and connection scheme

Thus, to obtain the experimental results was used a test device MI 3109 EurotestPV Lite METREL, two multimeters and a resistance that allowed the following measurements of the following parameters: direct current in photovoltaic installations, insulation resistance, continuity of PE conductors, open circuit voltage Uoc and current short circuit Isc, plotting the current-voltage curve IU of photovoltaic modules, irradiation, temperature of photovoltaic module, measurement of alternating current in photovoltaic installations, voltage, current and power, efficiency of photovoltaic modules [19].

3.2 The influence of environmental factors on efficiency

Two thin-film photovoltaic modules were tested for outdoor conditions for 4 days and the output power was monitored every hour. One of these modules was previously cleaned, having a free surface, without obstruction factors, and the other was affected by water droplets on its surface.
Temperature is a significant determining factor that affects the speed of electric flows through any given electric circuit. The daily power output, short circuit current and open circuit voltage of each studied module exposed to water droplets are illustrated in Fig. 3 showing the effects of raindrops on the output power, comparatively, between a new panel and an aged panel [19].

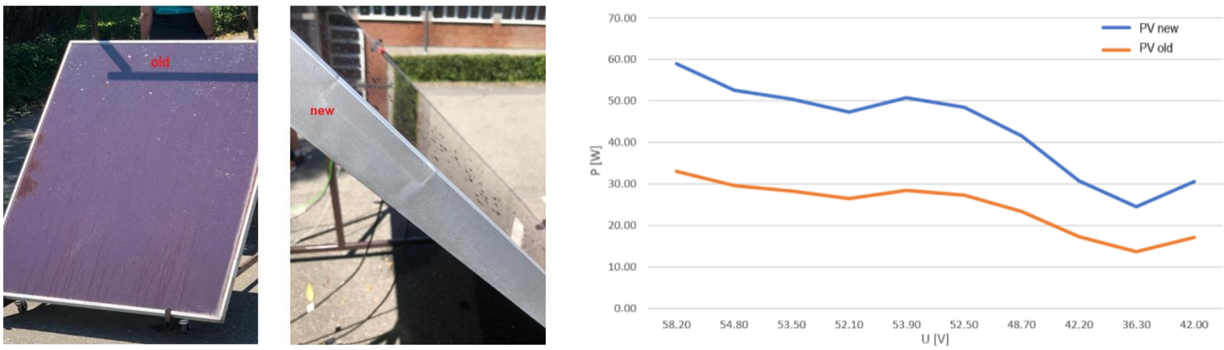

Fig. 3. The output power of a new panel and an old one both covered with water droplets

The water droplets lower the temperature of the photovoltaic module, which in turn increases the potential difference, thus improving the output power. To describe the impact of temperature on the efficiency of a photovoltaic module, the output voltage of a photovoltaic module can be estimated at a given temperature using the relation (1) [19]:

$$U_{oc,amb} = T_{coef} \cdot [(T_{STC} - T_{amb})] + U_{OC,STC} \tag{1}$$

where:

$U_{oc,amb}$ - open circuit voltage at the ambient temperature T_{amb}
$U_{oc,STC}$ - open circuit voltage at STC(standard testing conditions)

T_{STC}- temperature of the open circuit at STC

If $U_{oc,amb} = 0.33 \cdot (25 - T_{amb}) + 22.06$, the relation shows that, for the low ambient temperature, a high voltage would be obtained. There are two advantages to running water on the surface of the panel, namely: cooling and cleaning the panel. The cooling rate for photovoltaic cells is 2 °C / min, depending on the operating conditions. It can be seen that, regardless of the condition of the panel, new or old, the effects of the water droplets are the same [19].

3.3 The influence of the aging of photovoltaic cell on the efficiency

Azidi et al. [20] points out that in order to take into account the aging of photovoltaic modules, the effects of optical and electric degradation are taken into account. The degradation rate of αopt transmissivity (optical glass loss and encapsulation loss) and series resistance (damage of electric parts) αRs are defined with accelerated test results. Optical losses for both EVA encapsulant and glass are assessed by measuring the spectral hemispheric transmittance after 10 years of exposure with an annular sample extracted from outdated field modules. The transmittance reduction is calculated with spectral values in the wavelength range of 450-1200 nm. The rate of degradation of series strength is determined by taking into account a linear variation of the measured values obtained every 500 hours for an accelerated test at 85 ° C heat / 85% humidity performed on encapsulated silicon cells, assuming that 1000 hours of testing are equivalent to 20 years of use. The dispersion of the experimental values is ± 10% [19].

$$\tau(T) = \tau_0\left(-\alpha_{opt} \cdot T + 100\%\right) \quad (2)$$

$$R_S(T) = R_{S0}\left(+\alpha_{R_S} \cdot T + 100\%\right) \quad (3)$$

It should be noted that aging is a long-term phenomenon, and the laws of aging are defined on a large scale compared to the instant detection of MPP: ΔT >> Δt. The lifespan of a photovoltaic module is between 20 and 25 years, and that of an inverter is around 10 years. The results between the initial time and T = 20 years are compared. The DC / DC converter and the inverter should keep their properties constant over time to appreciate the effect of the degraded photovoltaic module [20].
As for the resistance of the photovoltaic module, it is increased due to the aging effect, and then it limits the output power. The decrease in power as a function of voltage is shown in Fig. 4 for a panel that operated for a period of t = 7 years.

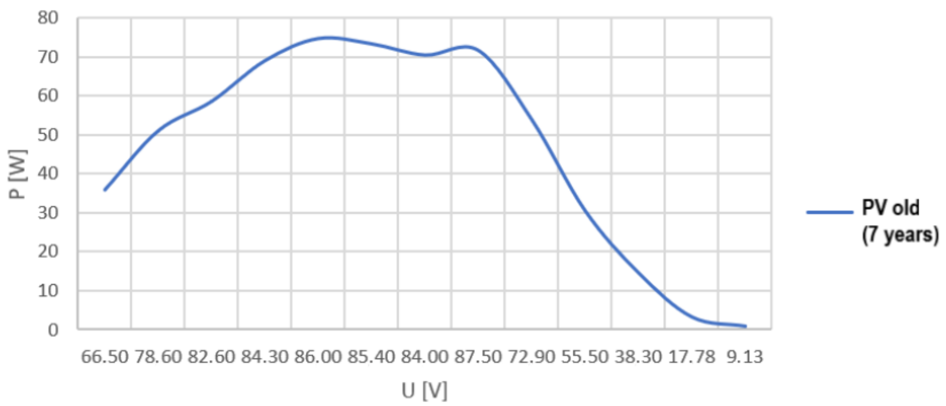

Fig. 4. Power in relation to voltage (t=7 year)

The temperature of the cells was also monitored, which led to the conclusion that the decrease in power is influenced when the module temperatures are higher. Temperatures measured at the surface of the panel are up to 50.8 ℃. The specialized literature indicates as a percentage the decrease of the efficiency of 1% / year for photovoltaic panels [20]. The appearance of the curves drawn for the period in which the recordings were made (4 days) is approximately the same, being comparable to the specialized literature, and for this reason it was represented in Fig. 4 power curve in relation to the voltage for a high degree of sunshine (cloudless sky).

3.4 The influence of clouds on the efficiency

During the days when the measurements took place, there were also periods when the sky was covered by clouds, which influenced the efficiency of the photovoltaic panels, which can be seen in Fig. 5. The measurements were performed hourly on a new photovoltaic panel.

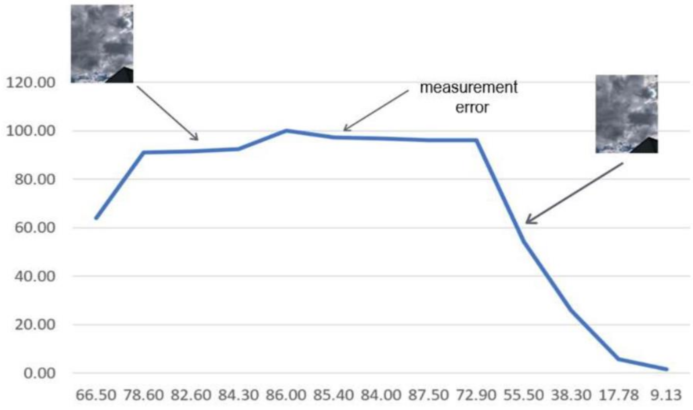

Fig. 5. The influence of clouds on the efficiency of a new photovoltaic panel

Cloud shading tends to be detrimental to the performance of photovoltaic modules. The cloud shading condition was considered one of the most significant sources of loss for photovoltaic installations. The best solution to this problem is to avoid shading as much as possible. The impact that shading has on the performance of the photovoltaic module depends on certain parameters such as the level of solar radiation and the distribution of shadows on the surface of the panel. The obtained results indicate that the output voltage of the photovoltaic panel decreases as the shaded surface increases. The maximum voltage value for the photovoltaic panel without shading was 86 V, and in the presence of shade due to clouds, the maximum voltage was 82.6 V, which indicates a decrease of 3.95% (Fig. 5.). The effects of clouds on the power curve are highlighted by images in Fig. 5 at the time they occurred [19].

3.5 The comparative analysis between the efficiency of old and new thin-film photovoltaic panels

Fig.6 compares the voltage variation and the voltage for a new panel and an old panel.

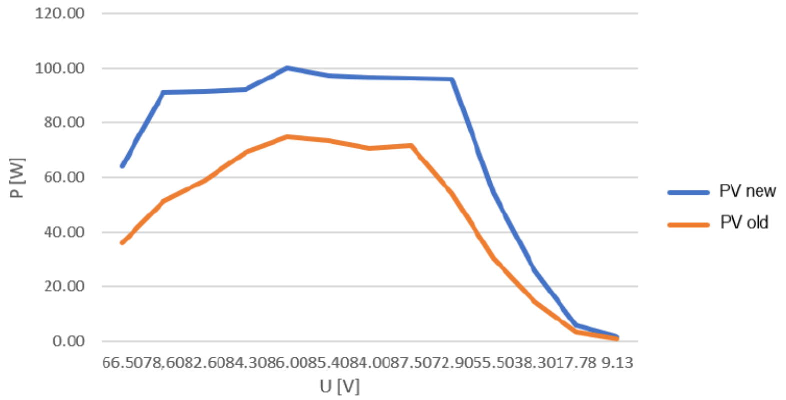

Fig. 6. The output power for a new and old panel

A decrease in the efficiency of the ZY-S100 thin-film panel of 25% can be observed, which means a decrease of 3.57 % for each year of operation [19].
Although the literature indicates a 1% decrease in yield per year for photovoltaic panels, the study shows that it is important to specify the type of panel and photovoltaic cells for which experimental measurements were performed.

4. Conclusions

In this paper, the impact of the aging of photovoltaic cells, the impact of clouds and the impact of water droplets on the surface of the panel on the electricity production of photovoltaic panels were studied. In order to achieve this goal, measurements were made regarding the output power of a new ZY-S100 thin-film photovoltaic panel and later on an identical (7 years) aged panel. Measurements and calculations have taken into account both the laws of aging and the uncertainty of the data.
Regarding the impact of water droplets on the surface of the panel, it was concluded that water droplets lower the temperature of the photovoltaic module, which in turn increases the potential difference, thus improving the output power. It has also been observed that regardless of the condition of the panel, new or old, the effects of water droplets are the same.
Measurements on the photovoltaic panel when the sky was overcast indicated that cloud shading tends to be detrimental to the performance of photovoltaic modules, with the panel's output voltage decreasing as the shaded area increases. At the same time, from measurements and calculations it was observed that, for the panels used in the presence of clouds, there was a decrease of the output voltage of 3.95%.
The test results regarding the impact of the aging of photovoltaic cells on the electricity production of ZY-S100 thin-film panels show a 25% decrease in panel efficiency in the 7 years of operation, which means a decrease of 3.57% for each year of operation. Although the literature indicates a 1% decrease in efficiency per year for photovoltaic panels, the study shows that it is important to specify the type of panel and photovoltaic cells for which experimental measurements were performed.

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