Photovoltaic panels cost optimization with flexible polymer semiconductor cells using fuzzy logic

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Abstract. This paper presents the research undertaken by the authors to determine the parameters of electric power produced by a photovoltaic panel using flexible semiconductor polymer cells, aiming a comparative study between this panel and other types of conventional photovoltaic panels, with monocristalline, polycristalline and amorphous silicon, based on technical and economic indicators, established under uncertainty conditions. We will also present the variation of these dimensions according to the incidence angle of solar radiation. Thus, researches will show that for its value between 36-38 degrees, you get very good conversion yields. The economic study presented also reveals that under uncertainty there is a correspondence between the panel type and its physical and economic characteristics.

1. Introduction

The energy economy and its production of renewable resources is a major concern of researchers lately [1-8] and the use of solar energy as a polluting and virtually inexhaustible energy by capturing it with different methods is a the current topic that responds specifically to the development requirements of the CE mentioned in Directive 2010/31 and transposed in the concept of E4 house [9-11]. In this paper we accomplished a comparative study on the electricity production of four types of photovoltaic panels, for 1 KW installed power, as follows: monocristalline silicium-PVGIS panels; polycristalline silicium-PVGIS simulation panels; amorphous silicium-PVGIS simulation panels; semiconductor polymer-PVGIS simulation panels and semiconductor polymer panels-experimental research. PVGIS (Figure 1) is an application for geographic assessment of solar energy resources and simulation of photovoltaic system performance. It provides an estimation of daily and monthly average solar irradiation, as well as simulations of the daily average electricity production, monthly and annual average of photovoltaic systems according to their type, geographic position, inclination angle and orientation. For using the program the geographic coordinates of the position of the simulated panel will be introduced and also
the functional characteristics of the simulated photovoltaic panel (Figure 1). Also, you can also choose the file type where to save the calculated data.

**Figure 1. Photovoltaic Geographical Information System (PVGIS) - application**

2. Materials and methods

2.1. *Flexible photovoltaic cells with semiconductor polymers*

Significant advances have been made in the field of photovoltaic energy over the last few years by using cells based on organic semiconductor materials. Conventional solar cells are made of inorganic materials such as silicium. Although the conversion efficiency of these cells is relatively high, they require expensive materials and energy-intensive manufacturing technologies. The main reasons for the increased interest in organic semiconductor materials are:

- ease of manufacturing and low cost of processing
- flexibility due to their ability to mold on any type of surface
- ability to be produced from recyclable materials and using renewable energy sources.
- keeps the solar energy conversion capacity regardless of the amount of solar radiation transmitted.

Conjugated polymers are particularly attractive in comparison with silicium because they are powerful light dampers visible and can be deposited in flexible substrates on large surfaces using wet processing technologies such as printing or layer coating.

In recent years, several types of organic photovoltaic cells have emerged, including: solar polymer cells, polymer-fullerene solar cells, small molecule cells and hybrid solar cells.

3. Results and discussions

This paper presents the research undertaken by the authors to determine the parameters of electric power produced by a photovoltaic panel using flexible semiconductor polymer cells, aiming a comparative study between this panel and other types of conventional photovoltaic panels, with monocrystalline,
polycrystalline and amorphous silicon, based on technical and economic indicators, established under uncertainty conditions.

The application (PVGIS) used performs simulation and provides tabular results in the specified file format. Average daily electricity production Ed, average monthly production Em, average daily sum of total solar irradiation per square meter of the studied panels (Figures 2-5).

The analysis of the results presented above confirms that there is a dependence between the solar radiation absorption capacity and the orientation angle of this panel being optimal for a value in the range 36-38 depending on the nature of the photo absorbent material used. The experimental data were obtained on a panel made up of organic semiconductor photovoltaic cells [14].

### 3.1. Economic comparisons between the four types of photovoltaic panels under uncertainty conditions

An economic study was also carried out using an expert system for uncertainty decision based on fuzzy logic [12-14] methods for the four types of photovoltaic panels (figures 6 - 9) using a technical and economical specific indicators. The four indicators considered were the following:

- Specific price in two
- Specific power in and

In order to make management decisions under uncertainty, we can use the following techniques that use the decision matrix \{Rij\}:

- Decision technique Max-Min or pessimistic method:
  \[ V_{optimal} = \text{Max}_i \min_j \{R_{ij}\} \]  (1)
• Decision technique Max-Max or optimistic method:

\[ V_{optim} = \max_i \max_j \{R_{ij}\} \]  

(2)

• The optimality technique or Hurwicz method:

\[ H_i = \alpha \times A_i + (1 - \alpha) \times a_i \]  

(3)

where:

\(\alpha\) – optimist coefficient (\(0 < \alpha < 1\));

\(A_i\) – the most favorable element of the line \(i\);

\(a_i\) – the worst element of the line \(i\);

In this case the optimal alternative is:

\[ V_{optim} = \max_i \{H_i\} \]  

(4)

• Proportionality technique or Bayes-Laplace method:

\[ V_{optim} = \max_i \frac{1}{n} \sum_{j=1}^{n} \{R_{ij}\} \]  

(5)

• The technique of minimizing regrets or Savage method:

The regrets matrix is determined:

\[ \{r_{ij}\} = \max_i \{R_{ij} - \max_i R_{ij}\} \]  

(6)

\[ V_{optim} = \min_i \max_j \{r_{ij}\} \]  

(7)

The specific price and annual output per unit of power are relevant when a certain installed power is required and the specific square matrix price and specific power per square meter are relevant for estimating a certain amount of available panels.

**Figure 6.** Specific prices in euro per watt for the four types of photovoltaic panels

**Figure 7.** Specific power per square meter for the four types of photovoltaic panels
We also present a comparison between simulation results and experiments resulting in a good fit (figures 10, 11).

The economic study shows that monocrystalline and polycrystalline silicium panels, although expensive the energy production and the specific power are high. Compared to the organic semiconductor panels and amorphous silicium that can reach up to 25% of the above-mentioned value and their power output exceeds 50%. It is found that the optimal option in most cases is that of semiconductor polymer panels.

4. Conclusions

The paper presented confirms the attractiveness of the development of technologies based on semiconductor polymer in photovoltaic energy production and has the following advantages:
- low production costs due to manufacturing technology at low temperatures
- ease of application to support surfaces.

The economic studies presented reveal the market value of the new semiconductor polymer panels and the correspondence between their type and the energy performance that converge to a clear conclusion that they provide a viable alternative to quality.

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