TOPIC 6: PV Systems - Performance, Applications and Integration
6.4 Building, Infrastructure, Landscape and Other Applications of PV

ENERGY PERFORMANCE EVALUATION OF A PHOTOVOLTAIC WINDOW

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ABSTRACT

The energy sector is in a process of radical and unstoppable transformation, motivated by two reasons: the fight against climate change and renewable energies. The two factors are decisive and go hand in hand, in line with the social demands and decisions of the European Union to comply with the emission reduction agreements.
The growing increase in energy consumption in developed and developing countries is an important task that must be addressed by the economic policies of these countries. The percentage of energy consumption of buildings relative to the overall energy use has grown in the last years due to the increasing amount of electrical devices.
The photovoltaic windows as an integrated system in the building façades can contribute to generate clean energy to meet needs of the inhabitants of these buildings.
A photovoltaic window specially built by a manufacturer has been studied. An amorphous silicon photovoltaic module encapsulated between two transparent glass sheets, an air chamber and a second double glass sheet with an air chamber forms the photovoltaic window. Everything is framed in a PVC structure. The effective dimensions of the a-Si photovoltaic module are 0.57x1.17 m^2, equivalent to a standard measurement of 0.60x1.20 m^2.
To know the electrical characteristics of PV window in standard test conditions, a test in accordance with IEC standard 61646 it has carried out. A peak power of 50.74 W_p was obtained.
Measurements of energy production in real sunlight were carried out. The window was placed vertically facing south on a test bench. Measurements of the energy produced by the photovoltaic window were made in several sunny days of August and September 2016 from sunrise to sunset. On average, the irradiance received on the plane of the photovoltaic window was 4114 Wh/m^2 and the energy produced 71.2 Wh each day. These results match those obtained using the Malaga radiation databases.
For one square meter of the window studied, 79.868 kWh/m^2/year are obtained, when an overall efficiency of 0.8 is considered. Integrating this PV window in a building in Malaga (Spain), an annual electric production of 345030 kWh is obtained when a glazing surface of 4320 m^2 is considered. This energy is enough to meet the annual electricity needs of the 68 household of the building.

EXPLANATORY PAGES

The aim of this work is to evaluate the energy performance of a photovoltaic window specially built and to estimate the electricity production potential along with the energy needs of urban buildings in Malaga (Spain).
An amorphous silicon photovoltaic module encapsulated between two transparent glass sheets, an air chamber and a second double glass sheet with an air chamber forms the photovoltaic window. The effective dimensions of the a-Si photovoltaic module are 0.57x1.17 m^2, equivalent to a standard measurement of 0.60x1.20 m^2. The frame of the window is a PVC structure.
The IV characteristic in standard test conditions obtained according to 61646 IEC standard [1] is shown in Table 1. A power uncertainty of ± 6.78% was found.

Table 1. Characteristic parameters of the a-Si module

I_{sc} (A)	V_{oc} (V)	V_{max} (V)	I_{max} (A)	Peak power (W_p)
0,71	113,19	87,18	0,58	50,74

The photovoltaic window has been placed in a photovoltaic test bench on the roof of a building of University of Malaga, in vertical position facing South. A protocol for data collection that allows knowing the instantaneous power generated by the photovoltaic window has been developed.
To know the energy produced, the voltage and current generated by the photovoltaic window in a sunny day as well as the solar irradiance, module temperature and ambient temperature are collected every ten minutes from sunrise to sunset. The measurements of the energy supplied by the photovoltaic window have been compared with those obtained with an IV photovoltaic meter. Figure 1 shows the experimental arrangement.

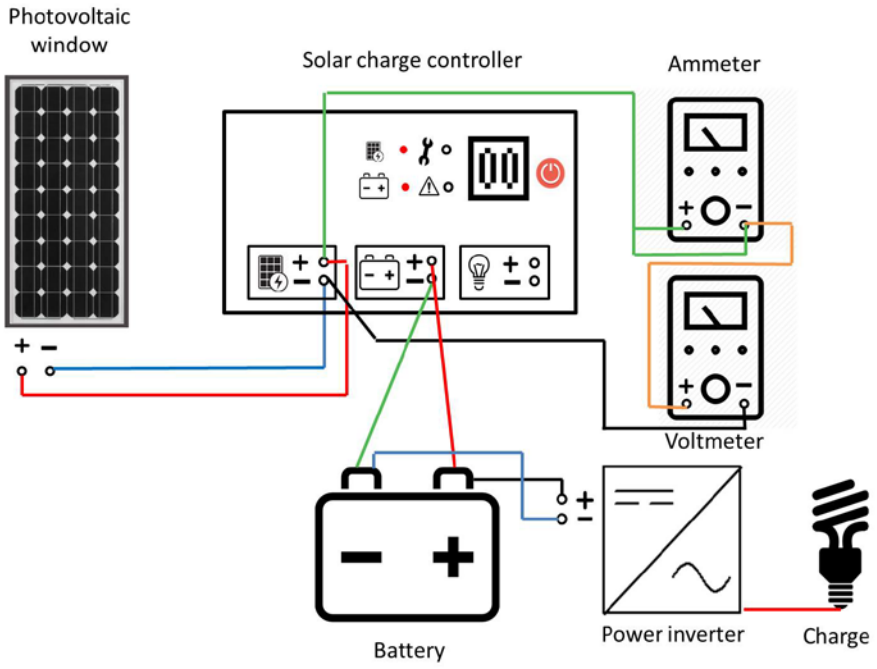

Figure 1. Experimental arrangement.

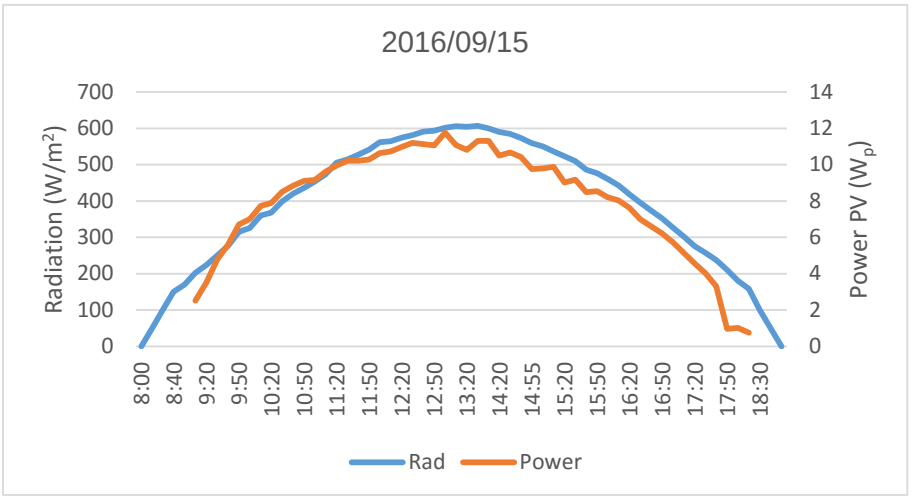

Figure 2. Solar radiation and instantaneous power of PV windows in a day.

Figure 2 shows the result obtained for solar radiation and the instantaneous power produced by the photovoltaic window on a day of measurement. The irradiance received on the plane of the photovoltaic window at daytime was 4114 Wh/m^2 and the energy produced was 71.2 Wh. These values are consistent with radiation data obtained from databases and the energy value obtained from PV window under standard test conditions.

The energy yield of a photovoltaic system depends on the power of the system under standard measurement conditions, of the normalized solar radiation received on the plane of the module and on the efficiency of the system [2]. That efficiency takes into account the total losses that occur in the photovoltaic system like the dispersion of parameters, the actual temperature of the modules, the wiring, effect of the angle of incidence of the sun on the plane of the module, the performance of the devices of power conditioning (regulator and inverter) and the battery performance. Its value for commercial systems varies between 0.75 and 0.85 usually.

With the PV window placed in vertical position, the monthly yield production for one year has been obtained. Efficiency values of 0.75; 0.80 and 0.85 and radiation data from the Energy Agency of the Junta de Andalucia for Malaga are considered [3]. Figure 3 graphically compares these results.

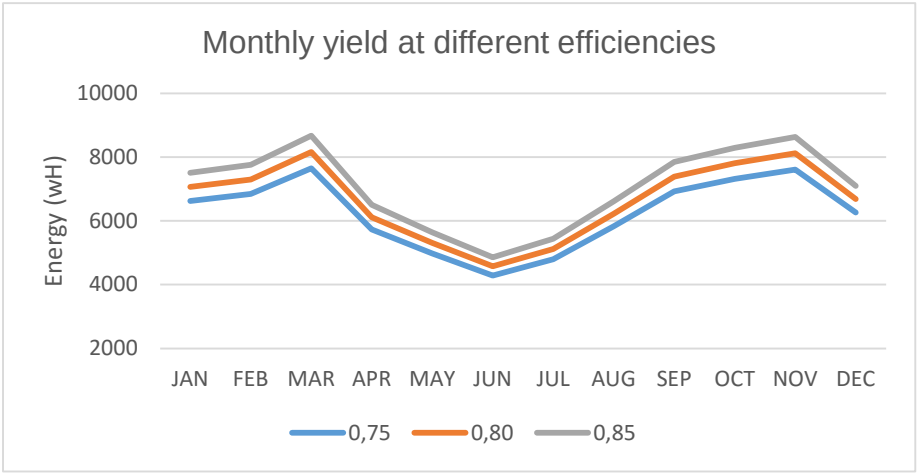

Figure 3. Monthly yield at different efficiencies.

To analyze the influence of the photovoltaic window position in a building [4, 5], the annual yield has been obtained when the PV window is placed in vertical position, and tilted 60º or 30º. Figure 4 shows the results for one square meter of PV window.

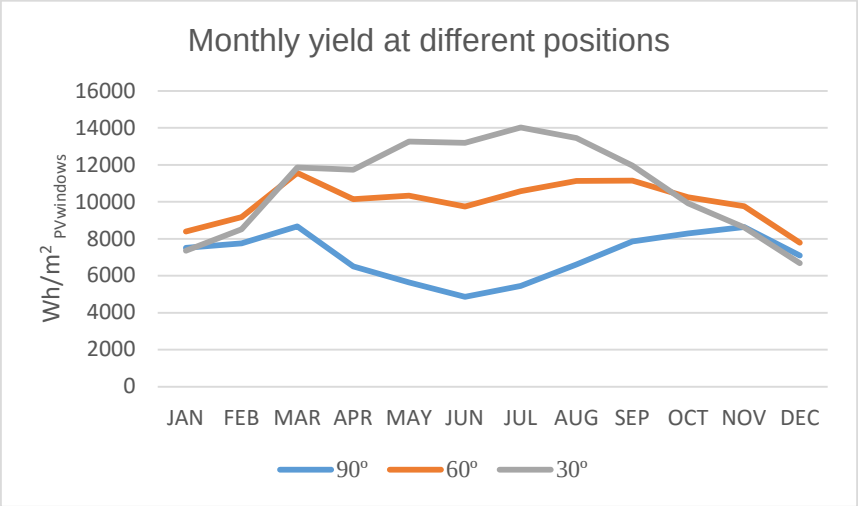

Figure 4. Monthly yield at different positions

As it can see on Figure 4, the tilt angle affect the yearly energy production of PV window. The bigger production correspond to a tilt of 30º, so the best use of this window in BIPV is as a part of an atrium [6].
When a building of a glazing surface of 4320 m^2 is considered, the integration of the window in the building could produce enough energy to meet the electricity demand of 68 apartments in a climatic zone as Malaga.

REFERENCES

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