INFLUENCE OF DUST IN SOLAR CELLS USED FOR MEASURING SOLAR RADIATION

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ABSTRACT: The photovoltaic cells (PV) are commonly used as global radiation measurement device, even though when it has been proved that there are significant differences with respect to using pyranometers. The dirt deposited on the surface of the PV is one of the most influential factors in the measurement of the solar radiation. In this work we have made experimental measurements with four identical cells, two cleans and two dirties with different soil density (0.2 g/m^2, 0.4 g/m^2, 0.8 g/m^2, 1.2 g/m^2 and 1.5 g/m^2) and different size particles (< 125 μm) comparing the results and obtaining a correlation between the density of the dust and the difference between the measured irradiance for clean and dirty cells for each particle size.

Keywords: Solar radiation, solar cell, pyranometer.

1 INTRODUCTION

Pyranometers are nowadays the most accurate sensor to measure the solar global radiation due to they cover all solar radiation spectrum. However, PV cells, that only cover a fraction of the solar radiation spectrum depending on the technology, are also used as a measurement device of solar global radiation. There are differences between both kind of devices, pyranometers and PV cells, and the values given by PV cells are usually lower than those given by pyranometers [1].

On the other hand, PV cells are cheaper than pyranometers and when it is needed to evaluate the performance of a PV plant, the actual available global radiation is more precisely given by a cell (made of the same technology than the plant) than by a pyranometer, because the incidence angle and spectrum losses of the plant are accounted on the cell measurements but they are not on the pyranometer measurements.

The difference between the measurements from PV cells and pyranometers is determined by multiple variables as the cell technology, the cell temperature, the spectral response of the cell (characterized by the humidity and the cloudiness index) and, obviously, the dirt level of the cell and of the pyranometer. After nine months of measurements it has been proven that the higher the humidity and the cloudiness the lower the differences between the PV cell and the pyranometer are, while the higher the incidence angle the higher these differences are.

A relevant factor that affects to the measurements from PV cells is the dust level. In general terms, the dirt deposited on a surface affects, among others, to the transmittance. In a solar cell, as the protective surface transmittance is affected (usually glass), the cell response is influenced. This effect on the trasmittance has been extensively studied for several material and different weather conditions [2,3].

The effect of the dust on a PV device has been also analyzed and it has being determined the influence of the dust on the performance of a PV module. The studies have been based on the weather conditions of the site (desert areas, humidity, and wind speed), the orientation and the tilt of the module or solar cell and the characterization of the dust, especially from the size, the density and the geometry of the particles. [4,5].

There are even studies that have taking into account the influence of the dirt on PV modules as a function of the cell technology [6].

As a summary, in every case the following effects have been observed:

- On one hand the higher the dirt on the cell the lower the short-circuit intensity and the out power are, relation that can be approximated by a least squares fit. On the other hand, the open circuit voltage does not depend on the dirt [7].
- In addition the solar cell degradation is more significant for fine particles than for coarse particles [4].
- The PV cell efficiency decreases with a much higher slope for dust density lower than 1.5g/m^2. From this value, the particles begin to be deposited one above the other, and then they do not cover more effective area of the [7].
- The solar cell tilt directly affects to the dust accumulation. So, devices with little inclination show a higher trend to the accumulation of dust. Moreover, the transmittance decreases as the tilt angle is decreasing [3].
- The influence of the cosine factor is decisive on the reliability of a solar cell response. In this sense, for incidence angles higher than 20º, the cell reflectance increases rapidly and this response is out of reliable values [8].
- With respect to the air mass, the studies show that this factor is significant for solar elevations up to 30º [8].
- The Bonner and Sapsford study [1] proposes two calibrations constant to correct the radiation data recorded by a silicon cell: one for clear sky and the other for overcast sky.
- Correlations have been developed to compensate the deviation on the response that a solar cell experiment due to temperature changes and the solar spectrum [9]. The response improves significantly when it is corrected by solar spectrum. Anyway, diffuse radiation results show a higher deviation than direct ones.
- The variables that influence on the dust quantity that it is deposited on a surface is quite studied topic.

Dust induced degradation of pyranometer sensitivity. All these considerations show the multitude of variables, besides dust, that influence on the performance of a PV cell as a solar radiation measurement device.

2 OBJECTIVE

The purpose of the work is to analyze and prove experimentally the influence of dust in the measure of the solar radiation with photovoltaic cells depending on the density and size of the dust and in the level of irradiance. It has been carried out by the experimental comparison between clean and dirty identical cells.

3 HYPOTHESES AND METHODOLOGY

This paper answers this question under the following assumptions:

Two identical calibrated pyranometers have been used (PL and PS) and four identical calibrated monocristaline silicon PV cells. The cells are encapsulated by pairs, two to two. One of this pairs (CL1 and CL2) has been kept always clean (cleaned diary), while the other pair (CS1 and CS2) has been dirtied using different soil densities (0.4; 0.8; 1.2 and 1.5 g/m^2) and different particle size of clay and silt (between 0 µm and 65 µm for clay and between 0.65 µm and 150 µm for silt).

In the same way one of the pyranometers has been kept always clean (PL) and the other has been dirtied in different levels (PS).

Every device has been placed on a horizontal surface. The data have been recorded every five seconds and the mean value for both the clean and the dirty cells have been determined. As a previous step it was proved that the maximum error in the radiation measures was less than 0.1% for the four cells and less than 0.05% for the two pyranometers.

4 THEORETICAL BACKGROUND

In Figure 1 the absolute difference between the measurements from the clean cells and the dirty ones is shown as a function of the mean value measures by the clean cells. This first figure is for clay particles (between 0 µm and 65 µm) and for different dirty density values (0.2, 0.4, 0.8, 1.2 and 1.5 g/m^2). It can be observed that the higher the density and the irradiance, the higher the absolute difference between the clean and the dirty cells is. The maximum value for the difference is around 20 W/m^2 for a density of 1.5 g/m^2.

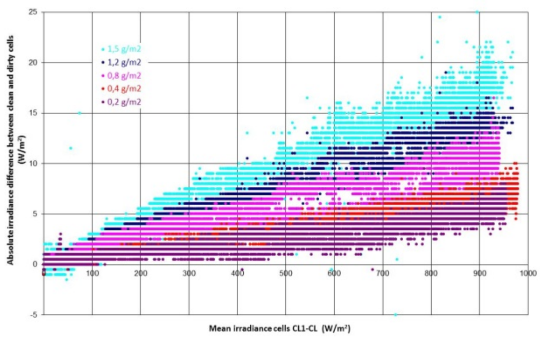

Figure 1. Absolute irradiance difference between clean and dirty cells for five different dirt densities as a function of irradiance. Clay

Similarly, in Figure 2 the absolute difference between the measurements from the clean cells and the dirty ones is shown as a function of the mean value measures by the clean cells, but for silt particles in this case (between 65 µm and 125 µm) and for different dirty density values (0.2, 0.4, 0.8, 1.2 and 1.5 g/m^2). Again, the difference increases with the dirt density and also with the irradiance. For low densities, lower than 0.4 gr/m^2, Figure 1 and Figure 2 are very similar but they are not so similar for higher densities than 0.4 gr/m^2 (for silt the maximum difference between clean and dirty cells is around 40 W/m^2). In any case the absolute difference depends mainly on the irradiance more than on the cell temperature, the incidence angle or the solar spectrum.

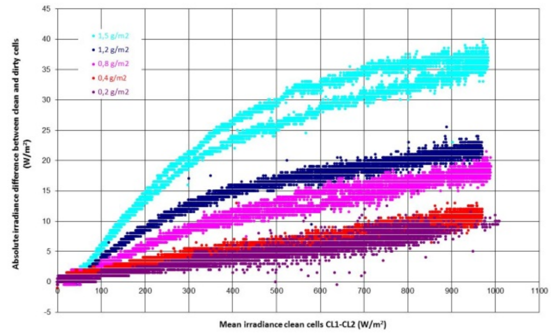

Figure 2. Absolute irradiance difference between clean and dirty cells for five different dirt densities as a function of irradiance.

Figures 3 and 4 show the same information but in percentage terms.

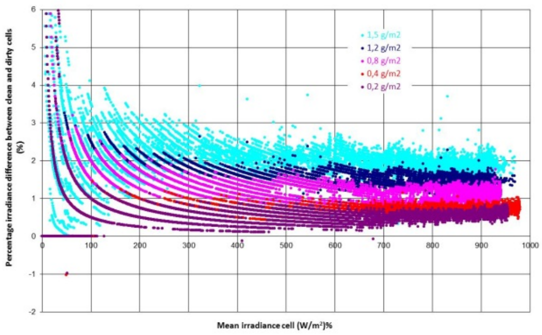

Figure 3. Percentage irradiance difference between clean and dirty cells for five different dirt densities as a function of irradiance. Clay

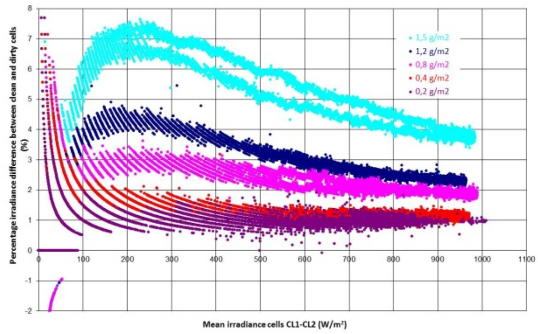

Figure 4. Percentage irradiance difference between clean and dirty cells for five different dirt densities as a function of irradiance.

It is noted that the error in the measurement increases as the level of irradiance increases in absolute terms but remains almost constant in percentage terms for irradiance levels above 300 W/m^2 and medium-low dirt levels (<0.4g/m^2), especially for clay, while for high levels of contamination, the difference decreases as the level of irradiance increases, reaching a maximum at 200 W/m^2.

The results show the influence of the dust level in the measurement of the solar radiation with a PV stating that the errors, when expressed in percentage, are practically constant for each density level depending on the dust particle size. This conclusion can be extrapolated to the production of a photovoltaic plant.

6 CONCLUSIONS

The absolute error between the measurements from a clean and a dirty cell depends mainly on the irradiance level and the particle size more than on the cell temperature, the incidence angle or the solar spectrum.

A dirty monocristaline PV cell makes a bigger absolute error when the irradiance and the particle size are higher. The maximum value of the error is around 40 W/m^2 for 1000 W/m^2, for a particle size of 125 µm and for a dirt density of 1.5 g/m^2. In the same conditions but for particles up to 65 µm, the maximum error is around 20 W/m^2.

A dirty monocristaline PV cell makes a percentage error that practically only depends on the dirt density for particle sizes up to 65 µm.

The same effect can be observed for particles up to 125 µm and densities up to 0.4 g/m^2. For higher densities than 0.4 g/m^2, the percentage error in the solar radiation measurement depends also on the irradiance level.

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