ABSTRACT: In building integrated photovoltaic (PV) systems, the reflection of the solar radiation by the walls of the buildings may cause a non-uniform distribution of the incident radiation on the different PV modules. However, by using micro-inverters at strings levels, electricity production may increase instead of provoking losses by mismatching. For this purpose, the maximum possible solar gain due to reflections is required. The annual profit of the solar radiation depends on factors such as climate, latitude and the relative position of the cell to the reflective surface. In the location of Seville (Spain), the gain on a PV cell generation due to radiation reflected by a TiO$_2$ treated perpendicular surface reaches a 13% for an entire year. Therefore, it is well demonstrated that using micro-inverters not only involves a loss reduction of a solar installation but also to obtain a profit from the solar radiation that cannot be achieved with centralized inverters.

Keywords: TiO$_2$, Solar radiation, Photovoltaic.

1 INTRODUCTION

In building integrated PV systems, the solar radiation distribution on the different PV modules can be inhomogeneous. This is due to the presence of partial shadows, dirt and/or PV modules with very different orientations and inclinations.

The inhomogeneous distribution of the solar radiation on a PV module usually produces significant reductions on the electrical production of the installation due to mismatching. A way to reduce these energy losses due to partial shadows and dirt is using micro-inverters at cell, string or module levels [1-7]. The benefits of micro-inverters against of centralized inverters have been extensively analyzed in the scientific literature [8-20]. Nevertheless the use of micro-inverters can encourage another phenomenon that occurs in the building sector. Sometimes due to structural elements of the building and its surrounding the reflection of the solar radiation occurs on the PV modules. These reflections of radiation produce a gain of the global total radiation on cells, strings or modules. If mismatching losses between cells, string or modules are avoided by using micro-inverters, the electric production of the PV system can be increased due to its increased solar radiation gains.

To achieve the maximum reflections is necessary to dispose of superficially treated surfaces with highly reflective materials. Among the most common reflective materials used on the exterior of the buildings include aluminum, galvanized steel, white cement or coatings finished with white paint highlight.

One of the pigments that have better reflective qualities is the TiO$_2$. This is the whitest pigment available in the market. With a low price, it has very good reflective properties in the visible range, reflecting around 90% of the incident radiation. It has a high refractive index, making it a material with a high opacifying power. TiO$_2$ also has a wide range of application in nano-technology field, as it shows photocatalytic and super-hidrophilic properties that make it a self-cleaning material, used in plenty of solar applications like PV or building integration [21-35].

The goal of this study is to evaluate the use of TiO$_2$ as a reflective pigment to increase the gain of reflective incident irradiance on PV modules that have micro-inverters at string or module level. To this the solar radiation gain of a cell that receives reflection respect of other that not receives has been experimentally measured. Besides this gain, the spectral distribution of reflection radiation by the TiO$_2$ treated surface is analyzed.

As Figure 1 shows, it has been dealt a vertical surface facing with TiO$_2$ towards south over a horizontal monocrystalline silicon calibrated solar cell (cell 2) located outside. Simultaneously another identical calibrated cell (cell 1) was placed on a horizontal surface without reflection. We assessed the gain of solar radiation that receives the reflected cell (cell 2) versus the non-reflected cell (cell 1) in different types of days.

Figure 1. Experimental installation.

2 RESULTS

The solar radiation gain received by the cell depends on geometrical considerations defined by the relative position between the sun, the reflecting surface and the solar cell. Climatic considerations as the level of irradiance at each time, the value of the direct solar radiation and the composition of the atmosphere also affect to the value of the solar radiation gain. The existing combinations are limitless.

By way of example, Figure 2 and Figure 3 show the incident solar irradiance between cell 1 and cell 2 along a
cloudy day and another clear day. The vertical plane of the reflecting surface is facing south.

Figure 2. Solar radiation on the reflected and non-reflected cell for a cloudy day.

On the basis of the results obtained of solar radiation gain for each relative position, the results have been extrapolated for a typical meteorological year of Seville (Spain). It is regarded that the analyzed cell is in a horizontal position and the reflecting surface of TiO$_2$ is facing south.

Furthermore, it has been experimentally established that in the Northern Hemisphere for solar altitudes between 10° and 35°, in the morning and with vertical reflective surfaces south-east facing, the gains reach maximum values of 150%.

Solar radiation gain not only has been measured in absolute value, since reflected radiation presents a specific spectral distribution in function of the reflective material. Figure 4 ans Figure 5 show, in function of wavelength, the behaviour of the reflecting surface treated with TiO$_2$.

Figure 4. Spectral reflectivity of the surface treated with TiO$_2$.

Figure 5. Accumulated values of solar irradiance and reflected irradiance of a surface treated with TiO$_2$.

It is noted as above a wavelength of 700nm the reflectivity of the surface is between 75% and 80%. For wavelengths of 400nm the reflectivity decreases in order of 35%, that is, the reflectivity of the reflecting surface improves as the wavelength increases.

On the other hand, each PV technology has its own spectral response and thus their behaviour varies depending on the spectral distribution of the incident solar radiation, both radiation reflected and radiation directly reflected.

Figure 6 shows a comparative analysis of the intensity that would be generated for the same reflected solar radiation for five different PV technologies, monocrystalline, polycrystalline, amorphous, CdTe and CIGS due to the spectral response of each technology in function on the spectral distribution of the incident solar radiation.

Figure 6. Comparative analysis of the intensity produced by each technology to the same spectral radiation emitted by a surface treated with TiO$_2$.

3 CONCLUSIONS

The results show that the use of these painted surfaces can significantly increase the PV production in buildings. The use of TiO$_2$ pigment as reflector achieves an homogeneous distribution of the additional solar radiation reflected with appreciable results and without incurring in huge costs.

The annual profit in solar radiation depends on the relative sun-surface-cell position and the amount of direct solar radiation and weather conditions.

The electrical production gain at the output of the module depends on the solar radiation gain and the spectral response of the PV technology.
Monocrystalline silicon technology obtains higher electrical production gains compared to other PV technologies.

Therefore, it is well demonstrated that using micro-inverters not only involves a loss reduction of a PV solar installation, but also allows to obtain a profit from the solar radiation that cannot be achieved with centralized inverters.

4 REFERENCES


