COMPARATIVE ANALYSIS OF THE DUST LOSSES IN PHOTOVOLTAIC MODULES WITH DIFFERENT COVER GLASSES

M. Piliougine[1], J. Carretero[1], M. Sidrach-de-Cardona[1], D. Montiel[2] & P. Sánchez-Friera[2]
[1]Department of Applied Physics II. University of Málaga, Málaga 29071, Spain
Tel: +34952132772/23/22, Fax: +34952131355, E-mail: {michel,carretero,msidrach}@ctima.uma.es
[2]Isofotón S.A., Parque Tecnológico de Andalucía, Severo Ochoa 50, Málaga 29590, Spain.
Tel: +34 951233500, Fax: +34 951233212, E-mail: {d.chicharro,paula.sanchez}@isofoton.com

ABSTRACT: One cause of power losses in photovoltaic systems is the accumulated dirt on modules surface, mainly dust but also bird droppings. It is usual to include a loss factor for this cause about 3-4%. The large grid-connect photovoltaic plants include periodic modules cleaning to avoid these losses. In this paper we have quantified the losses caused by accumulated dirt on module surface. The use of textured glasses increases the performance of the modules due to the decrease of reflection losses. We have checked if these losses depend on the structure of the module surface and also if the rain cleans well enough the modules and in which conditions this cleaning happens. The obtained results show that losses due to accumulated dirt in modules can reach values about the 15% for period without rain. We have measure yearly average dirt values of losses about 6% that is greater than the values used in the sizing and design of grid-connected photovoltaic systems. We can conclude that textured glasses do not accumulate more dirt than the non-textured glasses and therefore the maintenance of photovoltaic system with textured glasses does not mean additional expenses.

Keywords: PV System, Energy performance, Environmental Effect.

1 INTRODUCTION

The peak power of photovoltaic grid connected systems installed in Spain has strongly grown in recent years: from the peak power of 5,2 MWp installed for 2002 it will be reached the 1700 MWp at the end of September of 2008. 1000MWp of them have been installed this year. Nowadays, it is easy to find photovoltaic plants with peak power that ranges from 5 to 10 MW. Many of these systems are installed in the South of Spain, in areas with high levels of irradiation that are arid and desert land; these areas usually have a strong presence of dust particles in the air and important absence of rain for long time periods.

The losses associated with dirt accumulated on the surface of the modules are one of the loss factors that have influence in the system performance ratio. This dirt can be due to the dust accumulated on the modules surface, usually uniformly distributed. This fact implies that the photovoltaic cells receive less irradiance. In other cases there may be non-uniformly distributed dirt that frequently is due to bird droppings; this dirt produces important partial shading on the cells.

Obviously, if maintenance tasks include periodic cleaning of modules these losses can be avoided. However, these tasks are costly in time and depending on the type of system (fixed, sun-tracking) moreover they are expensive in many cases, especially because of water scarcity in these areas.

These losses are quantified by a yearly constant factor in the programs used for the design of grid-connected photovoltaic systems. It is accepted that the value of these factor is about 3 or 4 percent.

In this paper we have dealt with checking the losses due to dirt in an experimental way. We want to answer the following questions:

- How much time is reached 4% of losses?
- Does the rainwater clean the modules by itself? And, if it is so, how it depends on the amount of rainfall received?
- Is it possible to define how many times it is necessary cleaning modules to ensure that these losses remain in the limits used in the design of the plant?

Last but not least, we have also checked if the use of textured glasses has any influence in the dirt accumulation. It is well known that the use of textured glasses increases the performance of the modules compared to the use of non-textured glasses [1], mainly due to the decrease of reflection losses [2]. This advantage as regards flat glasses may be reduced if textured glasses accumulate more dirt that flat ones and as result the losses increase.

2 EXPERIMENTAL PROCEDURE

We have selected four monocrystalline silicon modules with three different types of glasses. We have used flat and textures glasses. The characteristics of the used modules are summarized in table 1.

Table 1: Main characteristics of the used modules.

	I-75A	I-75B	I-150B	I-150C
Technology	Si- m	Si-m	Si-m	Si-m
Cells num.	36	36	72	72
Nom.Power	75 Wp	75 Wp	150 Wp	150 Wp
Glass surfa.	Textu. 1	Textu. 2	Text. 2	Non-text

The textured glasses are composed of little pyramids on the surface. In one case the pyramids follow an angle pattern (textured 2), in the other one the pyramids show an orthogonal pattern (textured 1), in line with the sides of the module.

The modules have been installed at the same plane, in our laboratory flat roof, facing south and tilted 30º as regards a horizontal plane. The modules were perfectly clean.

We have measured the short circuit current for each module by using a shunt. Simultaneously we have recorded the values of irradiance received by using a Kipp-Zonnen CM11 pyranometer. Figure 1 shows the experimental system installed at the laboratory.

The recorded values have been corrected to standard conditions of irradiance following the expression:

$$Isc(STC) = Isc\frac{G_\beta^{STC}}{G_\beta}$$

The influence of temperature in the short circuit current has not been considered.

Figure 1. Experimental PV facilities at the University of Málaga.

As far as possible, to avoid the influence of the solar spectral changes in the measures we have selected only those that have been done in clear days and in the hours next to the midday, with values of irradiance greater that 800 W/m^2.

The measures have been obtained from August 2006 to July 2007. For this time the modules had been only cleaned by rain. We have used the rain values recorded in the meteorological station of the Malaga airport that is 5 km away from our laboratory. In figure 2 it is shown the total monthly values for the rain in l/m^2 recorded in this meteorological station.

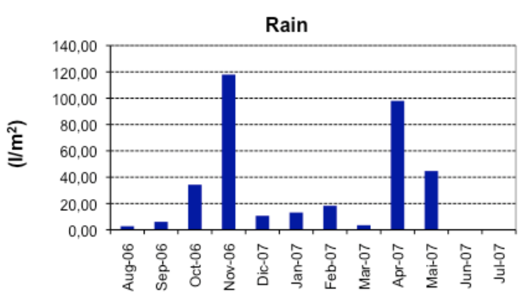

Figure 2: Total monthly values for the rain in l/m^2 recorded in Málaga airport.

3 EXPERIMENTAL RESULTS

In figure 3 it is shown recorded values of short circuit current (Isc) in standard conditions standardized to its value in clean modules conditions for two textured cover glasses modules with different technology. It is also shown the rain daily values for this period.

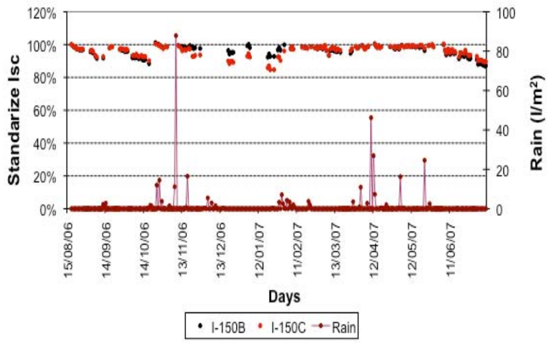

Figure 3: Recorded values of Isc in standard conditions standardised to its value in clean module conditions for two modules. Rain daily values for this period.

There are no significant differences between the losses values obtained for flat glass modules (I-150) and the losses obtained for textured cover glass modules (I-150B). In both cases, after 15 days without rain the losses are greater than the 4%.

The modules recover their initial conditions with little rain, even rain values less that 2 l/m^2 are enough. However, these losses can be greater than 15% when there are long time periods without rain, periods greater than two months. In figure 4 it is shown the modules details on July 2007 with losses about the 15%.

For the period from November 2006 to February 2007 it is observable significant losses due to dirt on the flat glass module greater than the observed in the other modules. These losses are due to extreme conditions of dirt in this module due to bird droppings; these losses increase the usual losses due to dust accumulation.

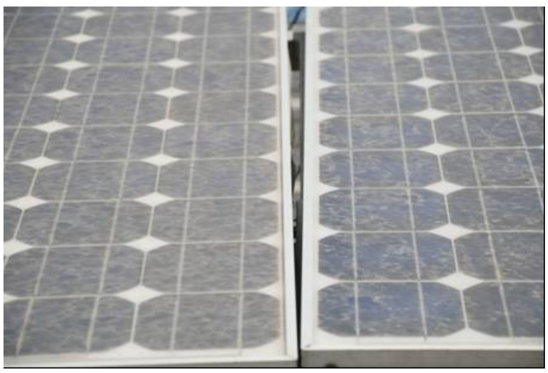

Figure 4: Modules detail on July 2007 with dirt losses about the 15%.

In figure 5 it is shown the recorded values of Isc in standard conditions standardized to its value in clean module conditions for two different textured cover glass modules. It is also shown the daily values rain for this period.

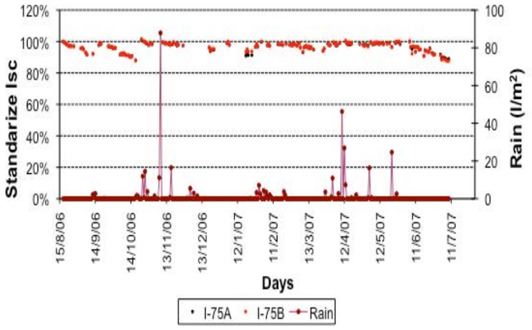

Figure 5. Recorded values of Isc in standard conditions standardised to its value in clean module conditions. Daily rain values for this period.

It can be observed that there is no significant difference in the losses due to dirt for the modules with textured cover glasses with different technology.

We have estimated only one monthly mean value of the dirt losses, because there are no significant differences in the values obtained for each one of the measured modules (fig. 3 and 5). The estimated values are shown in figure 6.

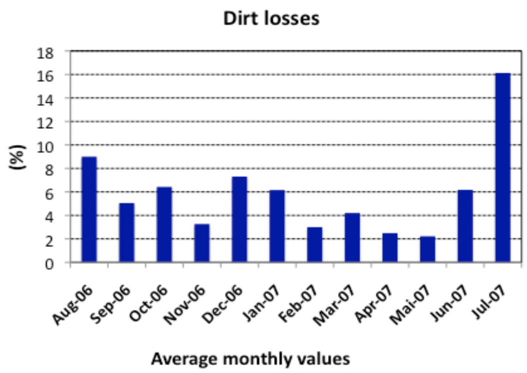

Figure 6. Average monthly values of the dirt losses.

These values are greater than 2% for all months. The maximum value is 16%. The yearly average value of the dirt losses is about 6% for the analyzed period.

4 CONCLUSIONS

The dirt losses have a negative influence in the performance ratio of the photovoltaic systems. Theses losses are mainly due to dust particles in the module surface. These losses can reach significant values, greater than 15% for dry climate, so it is necessary to clean frequently modules to minimize these losses.
When there are not cleaning tasks, we have measured average losses about 6%. This value of the losses is greater than the values used in the sizing and design of grid-connected photovoltaic systems.
We have checked that light rain is enough for cleaning the modules when they are tilted 30º. However, it has not been possible to determine the optimum cleaning frequency because the dirt strongly depends on the local climatic conditions. In our study and without rain it will be desirable to clean modules one a month.

In large installations it is necessary to quantify these losses and to decide on the modules cleaning due to the high variability of these losses for the year and their influence in the performance ratio of the system. Taking into account the obtained results it is difficult to schedule maintenance tasks on the basis of the external modules aspect.

Our recommendation is to measure these losses as another parameter with the monitoring system. For this, it is necessary to install two calibrated cells in the modules plane and to systematically clean one of them (clean cell). One easy and fast comparison between the data recorded for the two cells is enough to obtain precise information about losses due to dirt on the modules plane. Obviously, the other cell only will be cleaned when all the modules all cleaned. In this way we can evaluate every day these losses and we can also economically quantify them.

The plant maintenance manager can decide about the adequacy of cleaning modules according to the cost of this task and the economic value of the dirt losses.

5 REFERENCES

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