Particle Effect in a Very-High Concentration Solar Field

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1. Introduction

Soiling, defined here as particle accumulation onto surfaces, has been under study, regarding solar energy conversion technologies for quite some time [1]. Even though, studies have shown soiling on CSP is more significant than on PV, due to lower acceptance angles, soiling effect has been much widely studied for PV technology. This happened due to lower PV prices and larger installed capacity. Therefore, besides the fact that soiling needs to be carefully considered for CSP, related studies are still scarce on literature and even rarer on central receiver type plants, which makes it an important and interesting research field, mainly in the region under study. Soiling effect was assessed on heliostats of the very-high concentration solar tower (VHCST) facility located in Móstoles, near Madrid, Spain. Reflectance loss was measured with a Condor reflectometer on heliostats scattered through different locations of the solar field, while three of them were set side by side with different tilt angles. Soiling rates between 0.2%/day to 0.6%/day were found between different seasons. The aim is to evaluate soiling effect in an urban environment during different seasons, in order to characterize the soiling ratio, rates and possible stow positions to reduce soiling effect on reflectance.

2. Methodology

This location's climate is classified as Csa, with hot dry summers and a rainy season (September to May) more pronounced towards end of year. This facility has 169 heliostats, 3 m^2, which concentrate solar radiation into a solar reactor, located at the top of a solar tower [2]. Measurements were performed with a Condor reflectometer, Fig. 1a, with resolution of ±0.001, repeatability of ±0.002 reflectance units, with 95% confidence, accuracy of ±0.002 reflectance units, and (half) acceptance angle of 204 mrad.

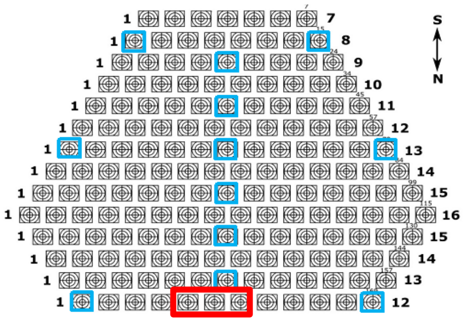

Fig. 1: a) Condor reflectometer with the VHCST on background; b) IMDEA's solar field layout with blue squares marking heliostats measured with tilt of 3º and red rectangle marking heliostats tilted 0º, 15º and 30º.

Measurement campaign was set from May 2020 to May 2021. Twelve scattered heliostats were measured through the solar filed, allowing to analyze soiling variation according to spatial disposition, Fig. 1b. Three heliostats were set side by side, but with different slopes, in order to study tilt angle effect. Soiling ratio, i.e., reflectance loss from original clean value, was calculated as follows:

$$SR = \left(1 - \frac{\lambda}{\lambda_0}\right) \times 100 = (1 - \bar{R}) \times 100 \qquad \text{Eq. (1)}$$

The parameter λ, represents reflectance measured with soiling, and λ_0 represents reflectance in clean state of each of five measured locations in each mirror. It is pointed that λ corresponds to a weighted reflectance, based on the six wavelengths (435, 525, 650, 780 and 940 nm), given as an output from Condor reflectometer. All five measurements for each heliostat, are normalized for the last clean value, which corresponds to $\frac{\lambda}{\lambda_0}$. Then, average of the five ratios is calculated, which is denominated $\bar{R} = \frac{\lambda}{\lambda_0}$. In order to calculate the soiling ratio, the average is subtracted to one, $SR = 1 - \bar{R}$, and then multiplied by 100 to have the final value in percentage.

3. Results

In Fig. 2a it is shown the soiling ratio from May 2020 to 2021. It is seen a higher soiling effect in dry periods, normally end of spring and summer, and lower one during fall and winter. It is also shown that in general all heliostats follow a similar trend.

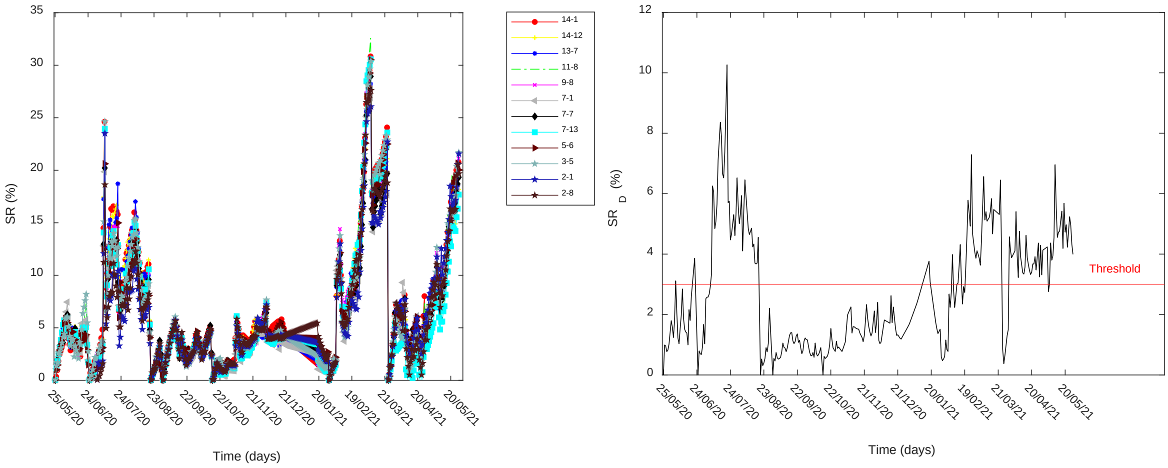

Fig. 2: a) Soiling ratio from Mat 2020 to May 2021; b) Maximum daily soiling ratio difference between all measured heliostats and with a red line showing a threshold on 3%.

For a small threshold difference of 3%, Fig. 2b, almost 59% of data is included within this margin. If massive Saharan desert dust events are excluded, this percentage increase to near 66%. This shows how soiling homogeneity levels are similar for this solar field.

4. Conclusions

Regarding soiling assessment, long-range transports of Saharan desert dust have a harsh effect in reducing reflectance, which is important, since it shows regions near Madrid can be affected by such events. Moreover, spring is also a period of interest since higher pollen concentration can increase soiling accumulation.

References

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