Quantifying PV soiling losses in the Atacama Desert

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1. Introduction

Several GWs of utility-scale PV plants are expected to be developed in the Atacama Desert of Chile over the coming years. Efforts to investigate and quantify soiling losses of proposed or operational PV parks are starting to be driven from within academia (most notably the University of Antofagasta [1,2]) as well as the industry.

GTER, a non-for-profit organisation founded and run by volunteers, aims to engage industry stakeholders and to provide a platform to advance the state of the art on technical issue specific (but not necessarily exclusive) to the Chilean and South American context. PV module soiling is one of its work streams and the soiling measurements carried out over the course of between 14 to 26 months by the developers of two proposed PV parks in the Atacama Desert in the north of Chile are presented here.

Figure 1 Soiling station site 1

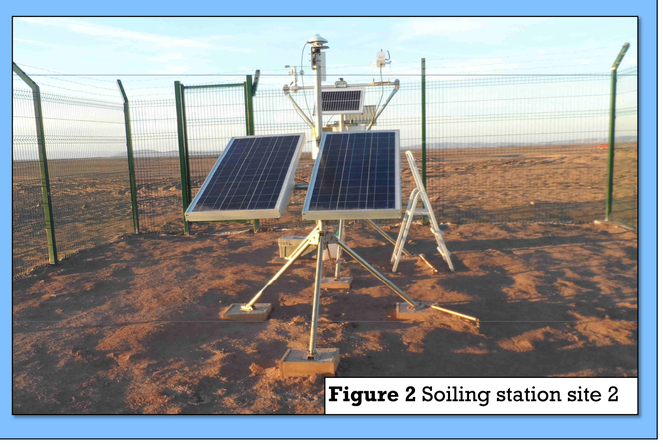


Figure 2 Soiling station site 2

2. Methodology

The temperature corrected short-circuit current (I_{sc}) of two or more co-planar PV modules, at least one of which undergoing regular cleaning, was monitored as proxy of irradiance (G). Provided the soiling is relatively uniform, the reduction of I_{sc} in the dirty module(s) can provide an estimation of the loss of generation. The soiling state of the modules was also documented regularly by means of photos taken during each maintenance visit.

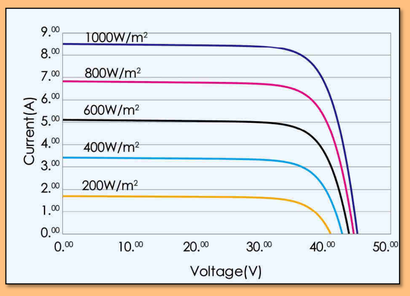


Figure 3
Relationship between G and I_{sc} at 25°C module temperature. If a relatively uniform layer of dusts blocks a proportion of the available sunlight, thus effectively reducing the available G on the module plane, the reduction of I_{sc} can indicate the soiling loss. (source: [3])

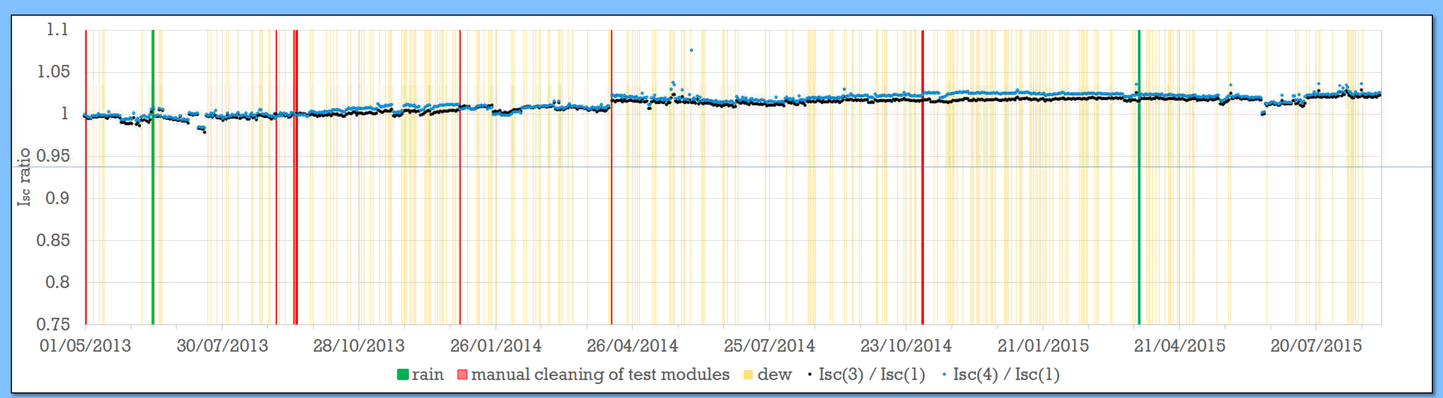
Additional meteorological parameters including wind speed, wind direction, temperature and humidity were recorded on site. Rain was only measured on site 2, however, given that the Atacama Desert is one of the driest places on earth, the rare rain events that occurred on site 1 during the measurement period were noted manually by the maintenance personnel and the available information was adequate for the analysis.

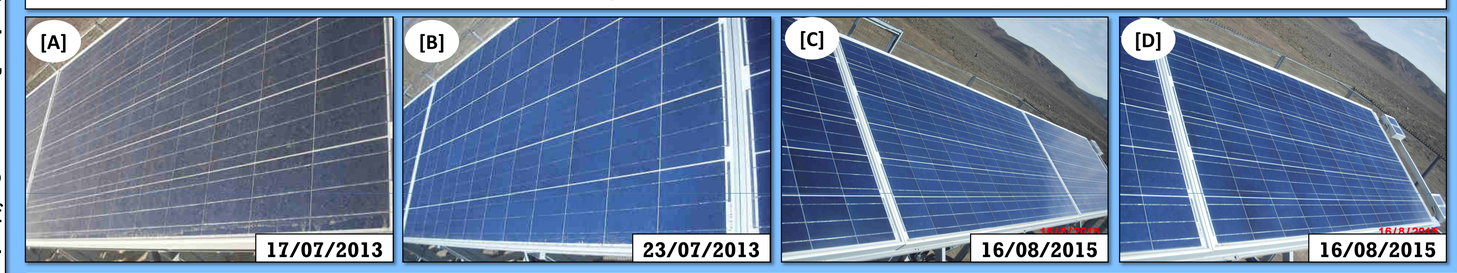
3. Case study 1 (update of [4])

Four co-planar modules with an inclination of 19 degrees were installed in landscape orientation at site 1. Modules 1 and 2 were regularly cleaned, up to three times each week. Modules 3 and 4 were cleaned less regularly, allowing them to **accumulate soiling for periods of up to 9 months** at a time.

Figure 4 summarises the I_{sc} ratios of the two test modules relative to one of the reference modules. The change in the I_{sc} ratios over time was found to be small, with **regular self-cleaning** evident due to high humidity levels and the **precipitation of dew**, arising from a coastal fog phenomenon called "Camanchaca". This coastal fog is common along the Chilean Pacific Coast, reaching in some locations several dozens of kilometres inland.

Different rates of **module degradation** are hypothesised to have **introduced a measurement error** of the same order of magnitude as the soiling effect that was to be measured, resulting in an unexpected increase of the I_{sc} ratio over time.





Additional notes:

[A] Module 3 with dust accumulated following a period with few dew events

[B] Module 3 self-cleaned a few days after [A], following dew days

[C] Module 3 after almost 9 months of no manual cleaning and 27.5 months in the field, following several dew days

[D] Module 4 on the same day as [C]

Figure 4 Site 1 I_{sc} ratios of modules 3 and 4 relative to module 1, days with manual cleaning of the test modules and self-cleaning due to rain or dew highlighted

4. Case study 2

Two co-planar modules with an inclination of 20 degrees were installed in portrait orientation at site 2. Module 2 was regularly cleaned, on average once every 7 to 14 days. Module 1 was **accumulating soiling for up to 7 months** prior to a clean.

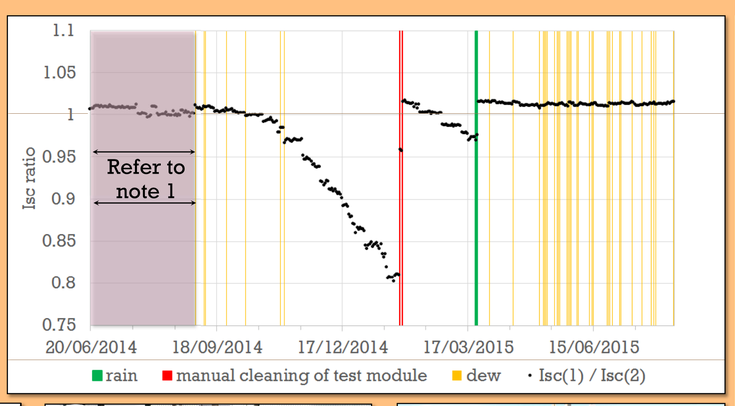
Figure 5 summarises the I_{sc} ratios of test module 1 relative to reference module 2. The I_{sc} ratios were observed to **decrease during the S-hemisphere summer to approximately 0.8 by the end of January 2015**, when the test module was cleaned manually to validate the significant soiling effect evident in the data at that point. During the **winter months** no such significant accumulation of soiling could be observed and more frequent **dew events** appear to have **self-cleaned** the modules.

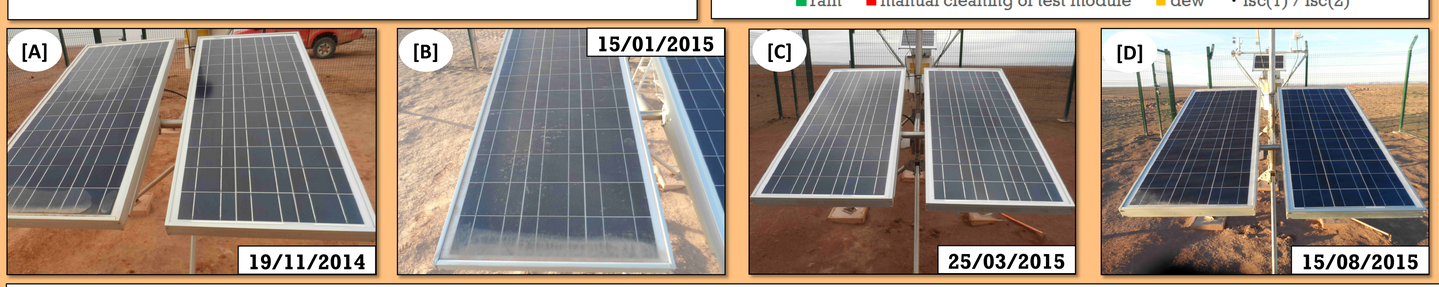
The **module soiling** was documented to be **non-homogeneous at times**, affecting the assumed relationship between I_{sc} and soiling loss (section 2) upon which the experimental setup was based, thus introducing a measurement error.

I_{sc} based daily soiling rates could be estimated for different parts of the year as per Table 1:

From	To	% / day
01/08/2014	08/11/2014	-0.03
08/11/2014	27/01/2015	-0.20
08/11/2014	28/01/2015	-0.02
01/02/2015	24/03/2015	-0.08
25/03/2015	14/08/2015	0.00

Table 1 Estimated daily soiling rates for different times of the year





Additional notes:

[1] Meteorological measurements not available for estimation of dew events

[A] Dust beginning to accumulate in mid-November

[B] Significant non-homogeneous dust accumulation in January

[C] Clean modules following a rare rain in March

[D] Soiling condition after 14 months of measurements

Figure 5 Site 2 I_{sc} ratios of module 1 relative to module 2, days with manual cleaning of the test module and self-cleaning due to rain or dew highlighted

5. Conclusions and further work

- **Soiling losses** for PV projects in the Atacama Desert can **vary** significantly between sites and with the seasons.
- Non-homogeneous soiling of the module surfaces has been documented at times, future soiling measurements could **reduce** measurement **uncertainties** by **monitoring additional parameters**, such as P_{max}, the full I-V curve and/or energy.
- **Dew** appears to contribute to **self-cleaning**.
- Non-homogeneous soiling losses of modules in **landscape vs. portrait** orientation warrant **further investigation**.
- Module degradation may need to be taken into account for soiling measurements on sites with little soiling.
- Developers **investing in soiling measurements** gain valuable information for the design process (e.g. frameless vs. framed modules, landscape vs. portrait orientation) and which assist in defining operational strategies (e.g. frequency of cleaning, tracker angles during the night) to mitigate soiling and **reduce risks for operators and investors**.

6. Acknowledgements

Mainstream Renewable Power Chile and Valhalla kindly provided the data utilised in the analysis. Pablo Ferrada of the Centro de Desarrollo Energético Antofagasta (University of Antofagasta) provided valued input for the background research.

7. References

[1] Fuentealba, E., Ferrada, P., et al, 2015. Photovoltaic performance and LCoE comparison at the coastal zone of the Atacama Desert, Chile, Energy Conversion and Management 95 (2015) 181–186

[2] Ferrada, P., Fuentealba, E., et al, 2015. Performance analysis of photovoltaic systems of two different technologies in a coastal desert climate zone of Chile, Solar Energy 114 (2015) 356–363

[3] Trinasolar, 2013, TSM-PC14 - 72 Cell Multicrystalline 290 - 310W Module Technical Specifications

[4] Darez, P., 2014, Soiling Losses in the Atacama Desert, Intersolar Europe 2014

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