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Quantifying and Mitigating Soiling and Abrasion in Solar Power

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Countries with some of the best solar resources suffer disproportionately from soiling and abrasion, which reduces system conversion efficiencies and decreases equipment lifetime. This Special Collection covers climatological analyses, soiling metrology, best installation practices to reduce soiling and abrasion, and improvements to equipment and materials to mitigate soiling and abrasion.

INTRODUCTION

For a long time as PV systems had primarily been deployed in temperate or humid clients, losses in PV generation due to soiling were a minor aspect of the model chain that aggregates all the losses in PV generation namely, angle of incidence, wiring, inverters. For example, even in a relatively arid place like California, analyzing PV output from 57 systems, Mejia and Kleissl (2013) showed that most PV systems suffer soiling losses of no more than a few percent at any given time. However, the interest in soiling effects increased dramatically with PV development in arid places, primarily the middle east and north Africa (MENA) countries. Not only do these places experience less rainfall, but also an increased frequency and intensity of dust storms. In addition to extinction losses of irradiance incident on the soiled PV panel, the natural or forced removal of soiling material can cause abrasion damage to the surface of the PV panel. Abrasion damage is permanent and cannot be resolved by panel cleaning.

Economic interests have increased recent research interest in all aspects of soiling (Ilse et al. 2019). In particular, prominent research areas are the origin of soiling / dust in the ambient air, mechanisms and case studies of soiling deposition, mechanisms and case studies of natural soiling removal, panel cleaning technology and effects, soiling mitigation measures, and secondary effects of soiling such as abrasion. Soiling effects tend to be larger on concentrating solar power than photovoltaic solar power, but the market dominance of PV also shifted the soiling research focus towards PV.

The “State-of-the-Art Research on Quantifying and Mitigating Soiling and Abrasion for Solar Power” Special Issue in *Journal of Renewable and Sustainable Energy* brings together experts from countries with heavy soiling impacts (India and China) and international institutes with a long history of soiling research (Deutsche Luft und Raumfahrt Gesellschaft and Fraunhofer Institut) to shed light on various aspects of soiling research.

SUMMARY OF AREAS COVERED

The “State-of-the-Art Research on Quantifying and Mitigating Soiling and Abrasion for Solar Power” Special Issue in *Journal of Renewable and Sustainable Energy* starts off with an in-depth review of dust

deposition and cleaning methods for solar PV modules (Zhao et al., 2021). The paper reviews the factors that affect dust deposition and divides them into meteorological effects (humidity, wind, rainfall), particle parameters (size, quantity, and physio-chemical properties), and dust accumulation mechanisms. The paper concludes with a review and an assessment of dust cleaning methods such as mechanical, electrostatic, coatings, and acoustic wave cleaning.

The majority of the special issue is dedicated to soiling metrology. In Bhaduri et al. (2021), tapping mode atomic force microscopy phase imaging (TM AFM) was used to study the performance of four different commercial PV coating materials after outdoor exposure. Samples were exposed for 40 days during the rainy season and 63 days during the non-rainy season. Coatings significantly degraded after outdoor exposure, especially during the rainy season. TM-AFM phase imaging showed great promise in characterizing anti-soiling coatings. To improve measurements of outdoor soiling conditions Wolfertstetter et al. (2021) investigated indirect optical soiling sensors, which estimate soiling losses from particle concentration and size and are widely used in the industry. By correcting the indirect measurements for angle-of-incidence and diffuse radiation effects they substantially improved the accuracy of indirect optical soiling sensors. Finally, Ilse et al. (2020) introduced and validated a rotational force test method to determine particle adhesion and particle removal in the lab.

The special issue concludes with a study on the performance of a soiled CSP system in Inner Mongolia. The paper compares dust deposition during individual dust storm events to long-term non-storm deposition. Analysis of energy fluxes, collector efficiencies, and dust properties for the two types of events show that individual dust storms cause as much or larger impacts on collector efficiency as non-storm 40 day exposures.

CONCLUSIONS

The “State-of-the-Art Research on Quantifying and Mitigating Soiling and Abrasion for Solar Power” Special Issue in *Journal of Renewable and Sustainable Energy* showcases significant advances in laboratory and field metrology for evaluating soiling, anti-soiling coatings, and particle adhesion forces. These advances allow characterizing outdoor soiling conditions and resulting PV performance losses with greater accuracy, benefit the development and evaluation of soiling mitigation measures, and inform technologies for soiling removal. We hope that the collection will be appreciated by the community.

REFERENCES

Bhaduri S, Mallick S, Shiradkar N, Kottantharayil A. Characterization of reliability of anti-soiling coatings using tapping mode-AFM phase imaging. Journal of Renewable and Sustainable Energy. 2021 Mar 31;13(2):023702.

Fu J, Yan S, Zhao X, Zhao N, Gao H. The performance of a soiled CSP system in Inner Mongolia under various weather conditions. Journal of Renewable and Sustainable Energy. 2022 Jan 23;14(1):013705.

Ilse K, Khan MZ, Lange K, Gurumoorthy HN, Naumann V, Hagendorf C, Bagdahn J. Rotational force test method for determination of particle adhesion—from a simplified model to realistic dusts. Journal of Renewable and Sustainable Energy. 2020 Jul 19;12(4):043503.

Ilse K, L. Micheli, B. W. Figgis, K. Lange, D. Daßler, H. Hanifi, F. Wolfertstetter, V. Naumann, C. Hagendorf, R. Gottschalg et al., “Techno-economic assessment of soiling losses and mitigation strategies for solar power generation,” Joule 3, 2303–2321 (2019).

Mejia FA, Kleissl J. Soiling losses for solar photovoltaic systems in California. Solar Energy. 2013 Sep 1;95:357-63.

Wolfertstetter F, Esquelli A, Wilbert S, Hanrieder N, Blum N, Korevaar M, Bergmans T, Zarzalejo L, Polo J, Alami-Merrouni A, Ghennioui A. Incidence angle and diffuse radiation adaptation of soiling ratio measurements of indirect optical soiling sensors. Journal of Renewable and Sustainable Energy. 2021 May 10;13(3):033703.

Zhao W, Lv Y, Wei Z, Yan W, Zhou Q. Review on dust deposition and cleaning methods for solar PV modules. Journal of Renewable and Sustainable Energy. 2021 May 28;13(3):032701.