Soiling in Photovoltaic Systems and the Negative Effects of Unpreventive Maintenance

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Soiling in photovoltaic system equipment is one of the main parameters that negatively impacts its performance and useful life. This work presents a case study of dirtiness most frequently found in distributed generation photovoltaic systems and the negative effects of no preventive maintenance. The study was based on 96 maintenance reports from a company in the solar energy segment from May 2021 to May 2022. Among the maintenance performed, 84.37% were preventive, 15.63% were corrective, being found 100% were dust on modules and inverters. This study highlighted the problems caused by the soiling in photovoltaic systems and expects to encourage more preventive maintenance due to the real productivity improvement after cleaning.
Keywords: Solar Photovoltaic Energy. Preventive Maintenance. Efficiency. Soiling in Photovoltaic Modules. Distributed Generation.

Introduction

Installing a photovoltaic (PV) system for solar power generation benefits those investing in this technology. The main advantage is the economy promoted in the energy bill, covering the entire cost of the consumer unit. Another advantage is the possibility of sending energy credits to reduce the consumption of other units within the same state and in the same ownership. In addition, the return on investment is becoming increasingly short, which makes it more interesting [4,11]. Since ANEEL Normative Resolution No. 687/2015 [3], revising resolution 482/2012 [1,2] entered into force in Brazil, the adhesions by PV systems have been gradually increasing in the country, leading to the current number of 1,017,642 consumer units with solar photovoltaic energy installed and connected to the national grid. Of this total, 77.8% are residential, 12.3% commercial, 7.7% rural, 1.9% industrial, and 0.3% public sector [7]. However, to generate energy, reduce self-consumption, and contribute to the planet's sustainability, it is necessary to understand the PV function and continuously follow up this system throughout its operation since preventive maintenance is fundamental to guarantee productivity. This maintenance is also essential to ensure the safety and useful life of the equipment. As the performance level of the equipment in a PV system decreases over time, frequent inspections can help minimize the drops in energy efficiency [10]. The soiling in PV systems is considered one of the main parameters that negatively impacts equipment performance. One definition for soiling is the reduction of effective solar irradiation due to absorption, scattering, and reflection by contaminants present on the surface of the photovoltaic module [6]. The presence of particulates in the Earth's atmosphere occurs in many ways. These particulates, transferred by the wind, come from the soil, pollution produced by industries, automobiles, burning, construction, the presence of animals, and other sources. Thus, the dust and the deposition profile characteristics have a highly regional and seasonal character, specificities that result in the most various percentages of efficiency loss [12].

Regarding the loss of efficiency of photovoltaic modules, soiling is the third most important environmental factor which impacts the power value produced by a solar energy generation system, being inferior only to irradiation and temperature [6]. Although photovoltaic modules are installed with a tilt equal to or close to their local latitude for

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maximum use of solar irradiation throughout a year [5], this tilt cannot be large enough for the modules to be cleaned by rain. Sometimes, the place does not get constant rainfall or has very long dry periods, such as in the semi-arid region. Other times, leftover dirt will accumulate on the module frame and sediment over time, requiring external action. After the dirt has been sedimented, it becomes embedded in the module, making self-cleaning difficult. The soiling can cause irreversible damage to the modules, not just temporary loss of efficiency. There are other impacts on PV energy production, e.g., the mismatch due to dirt inhomogeneity, which is an electrical incompatibility of voltage and current between clean and dirty cells in the same series of modules, generating thermal stress that can contribute to the development of micro-cracks in the cells [6].

Solar inverters are also affected by dirt accumulation. The equipment has an air inlet and an air outlet, making it even more likely that the presence of soiling them. In addition to dust, this kind of equipment is attractive to animals because it offers an environment higher than the ambient temperature. This accumulation forms a barrier and prevents heat exchange between the equipment and the environment, causing an increase in internal temperature and consequently generating a drop in power. It occurs through a defense mechanism of the solar inverter to control the temperature, reducing the production of electrical energy [8]. In this context, this work aims to present, from a case study, the most frequent soiling and the problems caused by the lack of preventive maintenance in photovoltaic systems for solar energy generation belonging to the distributed generation system in the residential and commercial sectors.

Materials and Methods

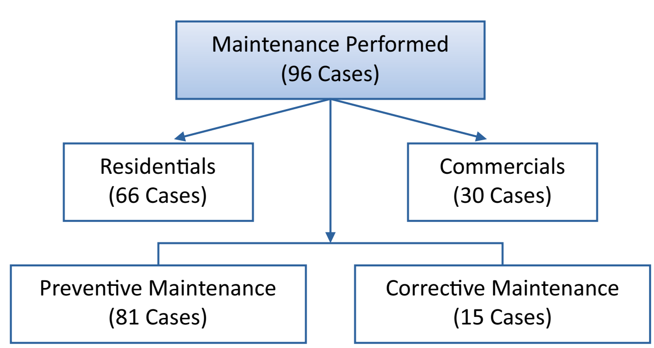
The procedure adopted in this work was the quantitative and qualitative analysis of data provided by a company that has operated in the renewable energy sector since 2016, with more than 1,300 micro and mini generation plants installed in the states of Bahia, Pernambuco, and Piauí. Throughout its operation, this company encountered several situations during maintenance, generating an extensive database that favored elaborating a case study. In total, 96 technical reports of preventive and corrective maintenance performed between May/2021 and May/2022 were available for data collection, classified by the type of consumer, types of soiling, and types of maintenance performed (Figure 1). We obtained the percentage values from this classification for quantitative analysis. In contrast, we did a visual comparison of the photovoltaic systems before and after maintenance for qualitative analysis.

Results and Discussion

Regarding the type of consumer, during the analysis of the 96 reports, 66 (68.75%) were from residential systems, and 30 (31.25%) were from commercial systems. The types of dirt found in each maintenance were tabulated and presented in percentage terms to quantify their frequency in solar energy systems. Table 1 summarizes the data collected concerning the types of soiling on the modules and inverters and how many reports they were mentioned. Dust, for example, was cited in all reports.

Among the maintenance carried out in the period in analysis, 81 (84.37%) were preventive-type, and 15 (15.63%) were corrective-type. Preventive maintenance, in general, is an initiative of the service provider company, which suggests a

Figure 1. Flowchart of the maintenance performed by a solar energy company in this study.



periodicity of twelve months for their customers. In photovoltaic systems, preventive maintenance includes the solar plates and inverter cleaning and a complete inspection of all the electrical components (modules, inverter, string box, and connectors) and mechanical components (supports and fixing structure). As for corrective maintenance, most customers call the service provider to diagnose and repair the problem in their photovoltaic system. Usually, the owner notices that the solar inverter has shut down or notices a substantial drop in energy production. Therefore, it was possible to observe that the accumulation of dirt in systems that receive periodic preventive maintenance is very subtle.

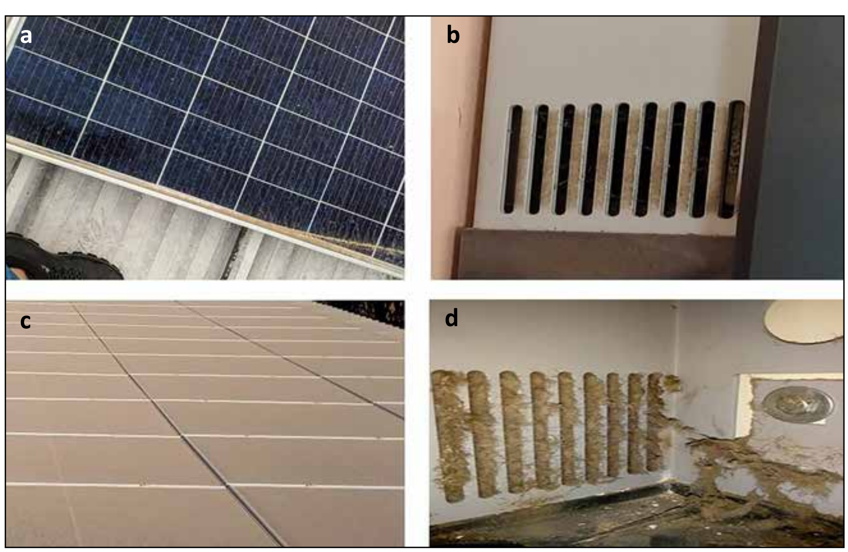
In contrast, soiling is much more severe in systems that do not adopt this conduct. Figures 2(a) and 2(b) show plants that performed maintenance every 12 months. Figures 2(c) and 2(d) present plants that have not performed maintenance for three years.

The inverter monitoring system allows viewing of the electrical voltage, current and power curves over time. Figure 3(a) refers to the curves before maintenance, where it is possible to observe very sharp drops in the system power due to overheating the dirty inverter. Figure 3(b) refers to the curves after maintenance. In this case, the power curve significantly changes, showing the characteristic

Table 1. Frequency of the types of soiling found in the reports.

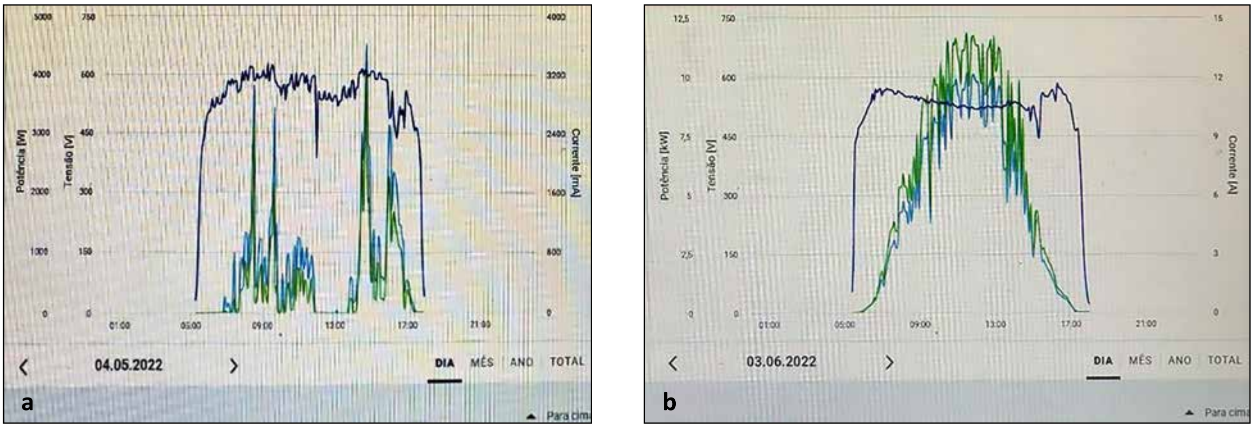
Soiling	Modules	Inverters
Dust	100%	100%
Sand	27.08%	9.37%
Animals	7.50%	5.20%
Limo	33.33%	-
Sheets	4.16%	2.08%
Construction Material	9.37%	3.75%

Figure 2. Comparison between photovoltaic plants.



(a) and (b) with periodic preventive maintenance; (c) and (d) without periodic preventive maintenance.

Figure 3. Power curve plots.



(a) before maintenance; (b) after maintenance. Green: power; Dark blue: voltage; Light blue: current.

bell-shaped format exceeding 10.000W for the peak insulation hours. Therefore, this graph clearly shows an improvement in power production from maintenance.

In the reported cases of corrective maintenance, the most affected item was the photovoltaic inverter, a fundamental part of the use of the energy produced by the modules because if its operation is interrupted, the system stops. The causes for the interruption of the operation of the inverters were the high dust accumulation and the presence of animals on the site. Figure 4 shows inverters damaged in different ways: image (a) is a bird's nest that completely closed off the inverter air circulation, while image (b) shows a frog that managed to enter the inverter, causing an internal short circuit. Image (c) suffered from renovating the owner's house; a lot of construction dirt entered the ventilation to interrupt the inverter operation; finally, image (d) is obstructions caused by excessive leaf litter.

With the popularization and the increasing eagerness to generate their energy, several problems have arisen due to lack of maintenance, as exemplified in this case study. On the one hand, the owners of these plants, technically unaware people with little understanding of the operation and care required to have a power plant, can make an adequate follow-up difficult. On the other hand, some service companies focus only on the installation, leaving the after-sales in second place. In addition, as photovoltaic solar energy generation systems are relatively simple to monitor (e.g., using a mobile application) and require a restricted set of requirements, this may undermine the fundamental importance of preventive maintenance. Nevertheless, this single annual maintenance significantly affects these plants' operation.

Conclusion

From the proposed methodology, it was possible to achieve the objectives of this case study and find the central answers to the research. It was possible to know the most common soiling cases found in a photovoltaic system, how often it appears, and the impacts the soiling causes on equipment (physically) and its operation (efficiency). It was also possible to conclude that systems that receive preventive maintenance within the indicated period have a low accumulation of dirt, lower wear by time and dirt, and good productivity.

The graphics with the inverter performance illustrated another point observed. There was a significant improvement in the rated power of the system, which was very deficient, after carrying out the general maintenance of the solar plant equipment.

Based on the quantitative and qualitative analysis presented in this case study, the value of preventive maintenance to the owner of a solar plant was validated. Besides generating savings by keeping the

Figure 4. Images of drives that required corrective maintenance.

(a) interruption by a bird's nest; (b) interruption by a frog; (c) interruption by building material; (d) interruption by dry leaves.

PV system working correctly, it also guarantees the life of the equipment and safety in the installations.

Further research should deepen the study to include more statistical analysis for future work. It also enables the development of a basic management protocol for residential and commercial PV plants directed to the owners in simple language. It enables and prepares them to take care of their plants, focusing on after-sales: operation and maintenance.

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References

1. ABNT. Associação Brasileira de Normas Técnicas. ABNT NBR 10899:2006 Energia Solar Fotovoltaica, 2006.
2. ANEEL– Agência Nacional de Energia Elétrica – Resolução normativa nº 482, 2012.
3. ANEEL – Agência Nacional de Energia Elétrica – Resolução normativa nº 687, 2015.
4. CallejoLH, Saavedra SG, Gomes VA. A review of photovoltaic systems: Design, operations at maintenance. Solar Energy 2019;188:426-440.
5. Costa SCS et al. Avaliação da sujidade em módulos fotovoltáicos em Minas Gerais, Brasil, In: Congresso Brasileiro de Energia Solar. Gramado, 2018.
6. Hickel BM. O impacto no desempenho de sistemas fotovoltaicos causado pelo acúmulo de sujeira sobre os módulos fv - metodologia e avaliação através de curvas em campo. Florianópolis, 2017. Dissertação (Mestrado em Engenharia Civil) - Programa de Pós-Graduação em Engenharia Civil, Universidade Federal de Santa Catarina, Florianópolis, 2017.
7. Infográfico: Panorama da solar fotovoltaica no Brasil e no mundo. ABSOLAR, 2022. Disponível em: <https://www.absolar.org.br/mercado/infografico/>. Acesso em: 27, abril/2022.
8. International Fronius. Installations Instructions Manual. Australia, 2022.
9. Moscardini Jr.,EF, Ruther R, Vergara LGL. Avaliação do conhecimento em O&M de sistemas fotovoltáicos por profissionais no mercado de energia solar brasileiro. Revista Brasileira de Energia Solar 2017;8(2):131-139.
10. PinhoJT, Galdino MA. Manual de Engenharia para Sistemas Fotovoltaicos. Rio de Janeiro, 2014. Grupo de Trabalho de Energia Solar (GTES), CEPEL - CRESESB, edição revisada e atualizada.
11. Reza M et al. Power Loss due to soiling on solar panel: A review. Renewable and Sustainable Energy Reviews 2016;59:1307-1316.
12. Rezende VGS, Ziller R. Análise das perdas de produtividade em geradores fotovoltaicos por efeito de sujidade. In: Congresso Brasileiro de Energia Solar. Gramado, 2018.