The Effects of Soiling on Solar Panels

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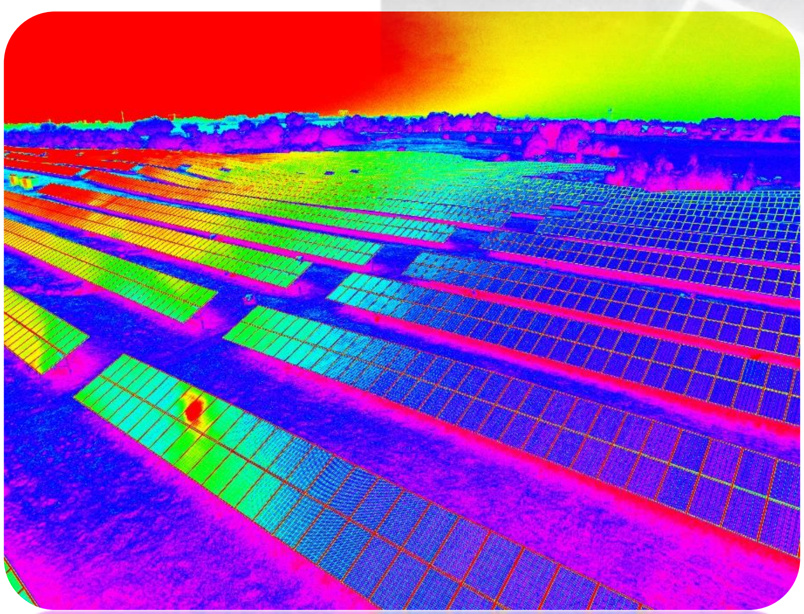

Effects of Soiling on Solar Panels

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Introduction: Solar Panels and Sustainable Energy

Solar energy has become an important source of power for many households across the world. The prices for solar energy appliances and cost for installation have decreased considerably over the last decade leading to an increase in its demand. [1]Photovoltaic (PV) cells convert sunlight to electric power. [2]The light energy or photons excite electrons in a semiconductor and the energized electrons generate electric current and voltage. Solar energy has attracted significant attention recently as more people realize the need for clean, renewable, and secure sources of energy. Solar energy is reliable, clean, sustainable, and affordable for most users. The energy has availed an alternative to fossil fuels and grid power and assisted to minimize power costs. [3]Solar panels are highly durable with the first power plant constructed in 1954 in the U.S. still being operational today. However, the energy output of these systems is highly determined by geographical locations, environmental, and climatic conditions. [4]This finding has led to significant research work attempting to model and quantify the power efficiency and output of solar systems as a function of conditions such as soiling. Dust accumulation on the surfaces of PV systems result in considerable reductions in their ability to generate power.

[1] Chanchangi, Y. N., et al. (2020)
[2] Hussain, A., et al. (2017).
[3] Hussain, A. et al. (2017).
[4] Al-Kouz, W., et al. (2019).

Soiling can reduce the power output that can be obtained from the PV technology. [5]The losses occur as a result of accumulation of dirt, snow, dust, and other particles on the surfaces of solar panels. Dust plays a huge role in the soiling of various PV modules with the area conditions determining the level of interference. Volcanic eruptions, pollution, and vehicular movements can contribute in generating dust. Adequate measures to clean solar panels are necessary to avoid reductions in the power output and avoid aggravating the soiling effect. The level of dust deposited on PV surfaces can decrease the amount of energy delivered by these systems on a daily basis. Cordero et al. (2018) noted that high dust accumulation and low rainfall in deserts located in the northern coast caused solar energy losses ranging between 18% and 39%. [6]Energy losses caused by soiling in other areas were in the range of 1-7%. Solar panels in a horizontal surface are likely to accumulate more dust when compared to ones in an inclined surface implying the need to consider the angle of inclination while installing PV systems. Additionally, wind speed determines dust deposition with reduced speed promoting high accumulation. Appropriate cleaning measures that consider these factors need to be deployed to minimize energy losses and improve the durability of solar systems.

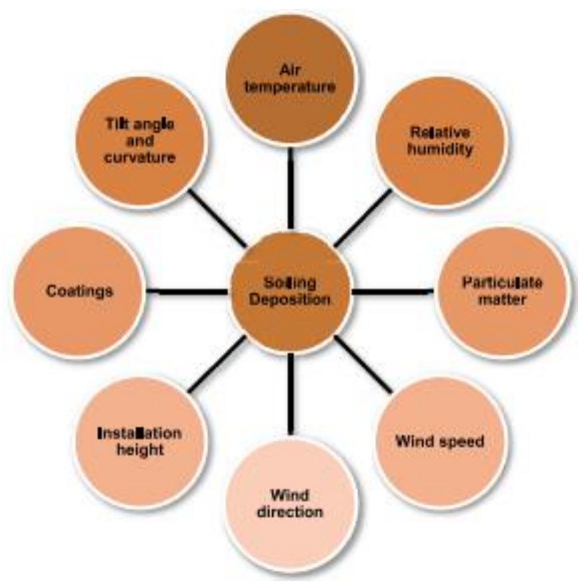

Figure1: Factors determining soiling in solar panels (Conceiçao, et al. 2022).

[5] Maghami, M. R., et al. (2016)

[6] Cordero, R. R. et al. (2018)

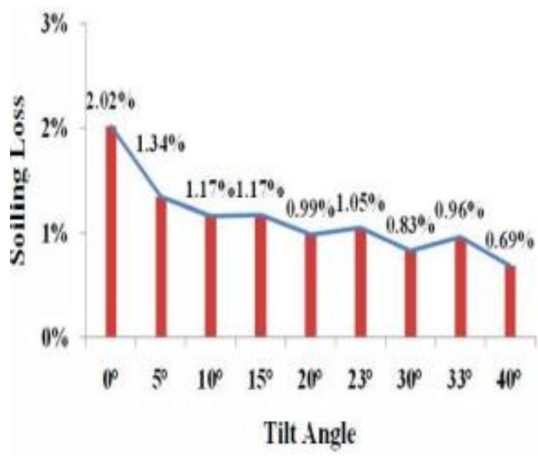

Figure 2: Graph showing a plot of tilt angle against soiling loss (Shaju & Chacko 2018).

Effects of Soiling on Solar Panels

Accumulation of dirt on the surfaces of photovoltaic panels (PPs) is a major detriment to their ability to convert energy as it reduces incident light. Transmission loss in PPs is witnessed as a result of accumulation of dust and tiny particles. Environmental factors such as humidity temperature, rainfall, and wind direction, as well as installation conditions and geographical location determine the level of soiling. [7]Soiling can lead to a decrease in electric output by about 4% in some solar panels. [8]A significant proportion of studies done to determine the impact of dust accumulation of output performance of PPs have indicated that the behavior for soiling is linear and that the degradation efficiency is dependent on dirt-particle size. The impact for finer dust particles is higher than for coarser ones, and the features of different dust types such as cement, limestone, carbon have varying contributions to the decline in the efficiency of PPs.

The efficiency of solar systems is highly affected by dust accumulation and has become an important research area for many scholars. [9]The PV systems are affected by dust deposition in two ways: one is that the solar irradiation is reduced and becomes non-uniform due to interference by dust and the second is that the particles lead

[7] Diazgranados-Garzón, J. D., et al. (2020)

[8] Diazgranados-Garzón, J. D., et al. (2020)

[9] Al Siyabi, I., et al. (2021).

to partial shading of the panels. The shading and decreased irradiation received by PV cells result in reduction in the energy output for the panels. In addition, the level of decrease in the efficiency of the PV panels is determined by the size and mass of deposited dust particles. [10]Increases in accumulated dust mass caused significant reductions in solar power output and efficiency. The smaller size of dust particles is also critical in increasing solar power loss due to their impact on solar irradiation. Air pollution can play a huge role in deteriorating the energy efficiency of PV cells and can cause a 6.5% decrease in solar output within a short period of outdoor exposure.

The quality of photovoltaic cells illumination is affected by dust accumulation. Deposited dust particles scatter and attenuate sun rays. The characteristics of the particles is important in determining their impact of PPs power output. The deposition rates, patterns, and characteristics also differ considerably in various localities. For instance, solar panels installed in desert areas are affected by soiling due to high dust accumulation. [11]Despite the high exposure to sunlight in such areas, the efficiency of the PV systems is reduced to 40%. Cleaning methods can be deployed to address this problem and improve the power output of PV systems. [12] ambient conditions, such as humidity, wind velocity, and seasonal changes determine dust deposition as well as the properties. These particles are deposited on the surfaces due to mechanical, electrostatic charge, or gravity and maintained by variations in electric potential. Changes in these factors affect the impact of soling on PV output as

[10] Hussain, A. et al. (2017).
[11]Hussain, A., et al. (2017).
[12] Paudyal, B. R., et al. (2017).

well as the efficiency of these systems in different areas.

The effect of soiling is mainly observed in the change in transmittance potential for solar systems. [13]Transmittance is determined by the amount of solar radiation that passes through a module encapsulation. The dust particles reduce transmittance leading to decrease in the power generated by the modules. Research has been done to analyze the differences in PV performance in various locations. A study by Njoku et al. (2020) noted a 26% decrease in glass optical transmission due to dust deposition. The article also pointed that fracture and corrosion of solar panels as a result of soiling lead to a decrease in their performance. Paudyal et al. (2017) noted significant variations in performance with factors such as dust types and climatic conditions playing a crucial role. For instance, [14]carbon deposition of approximately 28 g/m^2 was found to cause a 20% reduction in short-circuit current. Carbon particles can divert more solar radiation when compared to other dust particles. Measures to minimize soiling and its effects on the power output of PPs need to consider the characteristics of specific dust types and identify appropriate cleaning strategies.

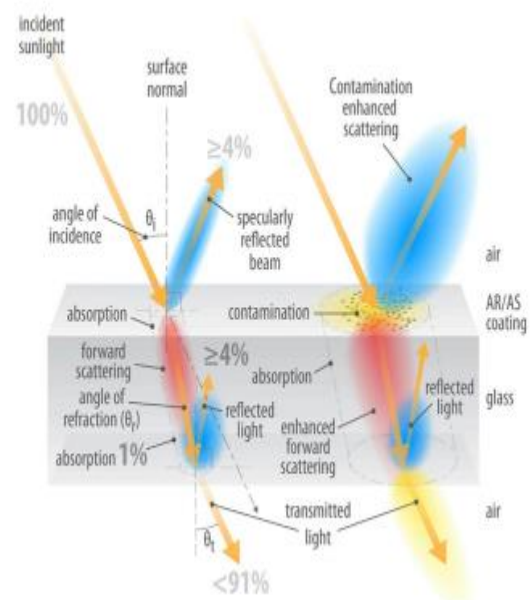

Figure 3: Soiling causes sunlight deflection, reflection, and adsorption (Bessa et al., 2021).

[13] Paudyal, B. R., et al. (2017).

[14] Paudyal, B. R., et al. (2017).

Soiling has been a major issue in the efforts to harness power from solar energy and address the increasing demand. [15]A recent study noted that soiling contributed to a loss of 3-4% in energy yield globally in 2018, which was about 5 to 3 billion euros' loss in monetary terms. The same study indicated that if the situation is not remedied, energy losses as a result of the phenomenon can rise to between 4% and 7% by 2023, amounting to a loss of approximately 7 billion euros every year worldwide. The economic loss due to the effect of soiling is likely in future due to several factors such as improvements in PV capacity. The increase in installation of PP systems in high-soiling and high-insolation areas and reduction in price of electricity are facilitate soiling loss. The low electricity prices have hindered soiling mitigation strategies as such procedures fail to make an economic sense for users and developers. However, PV cleaning is necessary to increase solar energy output and support its role in ensuring sustainability in energy consumption.

The cost of solar plants with respect to their lifespan can be considered as impressive. [16]The systems can last for about 25 years, and it takes approximately six years for energy equivalent to one used in their fabrication to be generated. [17]A decrease in efficiency of the PPs due to soiling can result in a reduction in its cost efficiency as well as lifespan. Soiling lead to shading of the panels and minimizes their ability to convert sunlight to energy. [18]The life of PV panels is determined by materials used in their construction and their stability when exposed to harsh environmental conditions. PPs are made of semiconductors that absorb incident sun rays and convert to

[15] Bessa, J. G., et al. (2021).
[16]Ahmed, M. Z., et al. (2018).
[17] Jamil, W. J., et al. (2016)
[18] Njoku, H. O., et al. (2020).

energy. However, this role can be hindered by accumulation of dust particles.

Soiling lead to deterioration and degradation of solar panels as well as shortening of their lifespan. [19]Soiling leads to heat dissipation and shading. Dust deposits absorb incident rays entering the module encapsulation and convert to heat energy. The heat obtained result in increase in cell temperatures, which may cause cracking, hotspots, or a reverse bias current. Such hotspots interfere with the normal operations of PVs and are mainly caused by corrosion, faulty cells, shading, and interfered cell connecting ribbons. Hotspots lead to reduction in power output, decrease in efficiency, and cell damage. Thus, the durability of solar panels is highly dependent on the degree of soiling.

Dust Cleaning Strategies

Cleaning can assist to solve the issue of soiling and improve the performance of solar plants across the world. Different PVs cleaning procedures have been suggested. Additionally, [20]significant research has been done to determine the impact of cleaning from a performance and economic standpoint. A study conducted in Egypt to investigate the effect of regular cleaning identified pressurized water systems as more effective when compared to non-pressurized one in cleaning solar panels. The study recommended that solar panels should be cleaned once every four days to improve their power efficiency. [21]Nano-coated self-cleaning PPs also performed well in minimizing the cost of cleaning. Paudyal et al. (2017) indicated that appropriate cleaning procedures should be utilized to improve the efficiency of solar panels in high-risk

[19] Kleissi, J. (2022).
[20] Al-Kouz et al. (2019)
[21] Al-Kouz et al. (2019)

regions such as Kathmandu, particularly during the dry season. Cleaning mechanisms are selected depending on geographical conditions.

Cleaning mechanisms can be employed to prevent shading and improve power efficiency. Solar systems are affected by both soft and hard shading. The former result in reduction in current output without change in voltage. Hard shading, on the contrary, causes significant changes in voltage obtained as it causes damage of the panel cells. A study by Maghami et al. (2016) recommended daily cleaning in case the dust accumulation is intensive and weekly cleaning during the dry season to improve power efficiency. The cause and degree of soiling need to be analyzed to determine appropriate procedures for cleaning and minimize related costs.

Conclusion

Solar plants provide reliable and sustainable source of energy. Consumers are increasingly leveraging the low installation and maintenance costs of photovoltaic panels. However, the efficiency of these panels has been limited by soiling that affect the power output and durability of such components. Appropriate cleaning strategies are required to improve the power output and reliability of solar energy across the world.

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