BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg
BG PULSE JOURNAL

Assessing the Effects of Temperature and Dust Accumulation on Solar Panel Efficiency

Fiorella Bellandi
Technical reserarcher
doi:https://doi.org/10.5281/zenodo.24140071

Abstract: The performance of photovoltaic systems depends on environmental conditions as well as the technical characteristics of solar modules. Elevated operating temperature and dust accumulation can reduce electrical output through different mechanisms. This article examines these mechanisms and proposes an approach for assessing their individual and combined effects. A narrative review of selected technical publications and institutional guidance was conducted, focusing on photovoltaic conversion efficiency, module temperature, surface soiling, and maintenance practices. The analysis indicates that meaningful performance comparisons require simultaneous consideration of solar irradiance, module temperature, and surface condition. A comparative monitoring framework using clean and naturally soiled reference modules is proposed. The discussion addresses ventilation, cleaning strategies, measurement uncertainty, and the distinction between instantaneous efficiency and energy yield. The article concludes that temperature management and site-specific soiling control should be evaluated together, with decisions supported by measured performance rather than assumed universal loss percentages. No original experimental results are reported.

Keywords: photovoltaic systems, solar panels, module temperature, dust accumulation, soiling losses, conversion efficiency, energy yield.

Introduction

Photovoltaic systems convert solar radiation into electrical energy, but their performance under outdoor conditions differs from performance measured under controlled laboratory conditions. Solar irradiance, operating temperature, surface contamination, and installation characteristics influence the electricity delivered by a system. Understanding these influences is necessary for assessing whether an observed reduction in output reflects normal environmental variation, an avoidable operating loss, or a technical fault.

Conversion efficiency describes the proportion of incident solar energy converted into electrical energy. Energy yield describes the electrical energy produced over a specified period. These concepts are related, but they answer different questions. A module can operate at lower efficiency during a hot, sunny period while still producing more electricity than during a cooler period with weak sunlight. The United States Department of Energy emphasizes the role of environmental factors, including heat, dirt, and shade, in determining photovoltaic energy yield. Department of Energy

Temperature and dust accumulation deserve joint attention because they can affect the same installation at the same time. Temperature influences the electrical behavior of photovoltaic cells, while deposited particles alter the amount and distribution of sunlight reaching them. A performance assessment that considers only one factor may incorrectly attribute losses caused by the other. The objective of this article is to explain these mechanisms and propose a practical framework for separating their effects under outdoor operating conditions.

Materials and Methods

This article presents a narrative technical review of selected public materials from the United States Department of Energy, Sandia National Laboratories, the European Commission's Joint Research Centre, the International Energy Agency Photovoltaic Power Systems Programme, and the National Renewable Energy Laboratory. The selected sources address photovoltaic performance, module temperature, soiling mechanisms, and operation and maintenance practices. The review is qualitative and does not claim exhaustive coverage of published research.

The analysis was organized around three questions: how temperature affects photovoltaic output, how surface deposits influence light transmission and electrical performance, and how these effects can be assessed without confusing them with changes in irradiance. A comparative monitoring framework was developed from this synthesis. No modules were experimentally tested, and no original measurements were collected. The numerical example below illustrates a calculation using explicitly assumed conditions.

Results

Temperature affects photovoltaic performance through changes in the electrical characteristics of solar cells. The Department of Energy explains that solar cells generally operate more efficiently at lower temperatures. As temperature increases, voltage typically declines, while the increase in current is comparatively small; the resulting effect is generally a reduction in electrical power for common photovoltaic technologies. The magnitude of this response depends on the module technology and its temperature characteristics. Consequently, the temperature coefficient provided for the selected module should be used in performance calculations. Department of Energy

Module temperature must be distinguished from ambient air temperature. The European Commission's photovoltaic modeling guidance identifies both air temperature and solar irradiance as influences on module temperature. Installation and heat-transfer conditions also matter when interpreting outdoor performance. An assessment based only on weather-station air temperature therefore cannot fully describe the thermal conditions experienced by the photovoltaic cells. Measuring module temperature provides a more direct basis for investigating temperature-related changes in output. Joint Research Centre

A hypothetical calculation demonstrates how a temperature coefficient can be interpreted. Assume that a module has a maximum-power temperature coefficient of −0.35% per degree Celsius and that its cell temperature increases from 25°C to 55°C. Under a simplified linear approximation, with irradiance and other relevant conditions held constant, the estimated power reduction would be 10.5% relative to the reference-temperature output. This value is calculated from the assumed

coefficient and a temperature increase of 30°C. It is an illustrative estimate rather than a measured result or a coefficient applicable to every solar panel.

Dust accumulation affects performance primarily by changing the sunlight transmitted through the module's front surface. Sandia National Laboratories describes soiling as the accumulation of dust, soot, organic matter, and other particles that absorb or scatter part of the incoming radiation before it reaches the photovoltaic module. The resulting loss depends on the properties and quantity of the deposited material. Thus, the visible presence of dust alone does not provide a reliable quantitative estimate of lost power. PV Performance Modeling Collaborative (PVPMC)

The distribution of contamination also deserves attention. Uniform deposits and concentrated patches should not automatically be treated as equivalent conditions. Experimental research on nonuniform photovoltaic soiling has demonstrated that electrical losses can exceed those expected from an equivalent uniform reduction in light transmission. This finding supports documenting the location and pattern of deposits in addition to estimating their overall quantity. However, the magnitude observed in a particular experiment should not be transferred directly to another module design or installation. doi.org

Temperature and soiling effects should therefore be evaluated through synchronized measurements. In the framework proposed here, two comparable modules are installed with the same orientation and tilt, with one maintained as a clean reference and the other allowed to accumulate natural deposits. Their electrical output, module temperatures, and incident irradiance are recorded over the same periods. An initial clean-condition comparison is used to identify differences between the modules before attributing later performance differences to soiling.

The proposed framework also records cleaning events, rainfall, shading, and interruptions in system operation. Measurements taken under unsuitable or inconsistent conditions should be identified before analysis. Comparing observations within similar irradiance and temperature ranges can help distinguish soiling-related changes from weather-driven variation. Where a correction model is used, its assumptions and uncertainty should be reported.

Performance should be assessed over both short and extended periods. Instantaneous measurements can help identify changes in operating behavior, while cumulative energy measurements show their practical effect on electricity production. The Department of Energy's performance guidance describes comparison between measured production and modeled production using corresponding solar-resource and temperature information. This supports evaluating output against the conditions actually experienced by the installation.

Literatures:

1. Скворцова, Л. А., Махмудов, Д. Э., Усманов, Д. Р., Адылходжаев, А. А., & Хегай, Л. Н. (2019). АСПЕКТЫ СПОРТИВНОЙ АДАПТОЛОГИИ ПРИ ИЗУЧЕНИИ ВИТАМИНА D 25 (OH) D У ФУТБОЛИСТОВ. In От фундаментальных знаний к тонкому владению скальпелем (pp. 51-54).
2. Хегай, Л. Н., Скворцова, Л. А., Махмудов, Д. Э., Усманов, Д. Р., Муслимов, О. Я., & Адылходжаев, А. А. (2019). СОДЕРЖАНИЕ 25-ОН-ВИТАМИНА D У ФУТБОЛИСТОВ

В УСЛОВИЯХ СОЛНЕЧНОЙ РАДИАЦИИ УЗБЕКИСТАНА. In Actual Questions and Innovations in Science 2 (pp. 160-161).

3. Mavlyanov, I., Parpiev, S., Sadikov, A., Kurganov, S., & Makhmudov, D. (2020). Relative features of the PPARA (Rs4253778), PPARGC1A (Rs8192678) and PPARG2 (Rs1801282) polymorphisms genes in athletes engaged in cyclic types of sports. European Journal of Molecular and Clinical Medicine, 7(2), 1860-1869.
4. Кантович, Л. И., Клементьева, И. Н., & Кузиев, Д. А. (2020). Обзор конструкций и технологических возможностей современных очистных комбайнов. Техника и технология горного дела, (2 (9)), 26-41.
5. Пирназаров, М. М., Садиков, А. А., Махмудов, Д. Э., & Хегай, Л. Н. (2021). Магнитно-резонансная томографическая визуализация повреждений коленных суставов. Re-health journal, (1 (9)), 152-159.
6. Махмудов, Д. Э., & Саитов, Т. А. (2023). Анализ персонализированного питания высококвалифицированных спортсменов управленческих видов спорта. Klinik va profilaktik tibbiyot jurnali, (3), 79.
7. Даминова, Г. (2020). ROLE OF TEACHERS'MOTIVATION IN TEACHING. Архив исследований.
8. Кузиев, О. Ж., Муродов, Н. Х., Мавлонов, У. О., & Отакулов, С. И. (2016). Особенности повреждений таза и нижних конечностей у водителей при несмертельной травме. Молодой ученый, (10), 512-514.
9. Махмудов, Д. Э., & Саитов, Т. А. (2023). Анализ персонализированного питания высококвалифицированных спортсменов управленческих видов спорта. Klinik va profilaktik tibbiyot jurnali, (3), 79.
10. Usmanovna, N. G., & Oybekovna, D. G. (2018). The importance of motivation in education. Достижения науки и образования, (16 (38)), 33-35.
11. Sharipovna, J. J., & Oybekovna, D. G. (2019). Role of teachers' motivation in teaching. Вопросы науки и образования, (3 (47)), 84-88.
12. Решетняк, С. Н., Кузиев, Д. А., & Уроков, Ф. Э. (2019). АКТУАЛЬНЫЕ АСПЕКТЫ ПОВЫШЕНИЯ ЭНЕРГЕТИЧЕСКОЙ ЭФФЕКТИВНОСТИ ТЕХНОЛОГИЧЕСКОГО ТРАНСПОРТА КОМПАНИИ АК «АЛРОСА». Научные разработки: евразийский регион, 231.
13. Таралева, Т. А., Махмудов, Д. Э., Атабаева, С. М., & Сагитов, Д. М. (2026). ВАРИАБЕЛЬНОСТЬ СЕРДЕЧНОГО РИТМА В ЦИКЛИЧЕСКИХ ВИДАХ СПОРТА: СОВРЕМЕННЫЕ ПОДХОДЫ К ОЦЕНКЕ ФУНКЦИОНАЛЬНОГО СОСТОЯНИЯ СПОРТСМЕНОВ. South Aral Region Medical Journal, 2(Maxsus son-2), 587-593.
14. Нагаева, Г. А. (2021). Исторические факторы формирования населенных пунктов (на примере Черноморского побережья Краснодарского края). Известия высших учебных заведений. Поволжский регион. Гуманитарные науки, (3 (59)), 24-37.

15. Горбань, В. В., & Черноглазов, К. С. (2015). Особенности вариабельности ритма сердца у молодых людей, ассоциированные с массой тела. Кубанский научный медицинский вестник, (4), 63-68.
16. Кузиев, О. Ж., Рузиев, Ш. И., & Искандаров, А. И. (2014). Усовершенствование бескрасочного метода снятия отпечатков пальцев и ладоней. Морфология, 145(3), 107-108.
17. Дьяченко, В. В., Шеманин, В. Г., Черняева, Р. В., Алексеева, О. В., Вишневецкая, В. В., Лохова, Т. В., ... & Чартий, П. В. (2021). Управление городской средой: социальноэкономические и экологические аспекты/г. Краснодар: Изд-во КубГТУ.
18. Носов, А. Е., Байдина, А. С., Власова, Е. М., & Алексеев, В. Б. (2016). Анализ вариабельности ритма сердца при нарушении сердечной деятельности у работников нефтедобывающего предприятия. Гигиена и санитария, 95(1), 41-45.
19. Нагаева, Г. А. (2008). Женщины в социокультурном пространстве Черноморской губернии: конец XIX-начало XX вв.[Электронный ресурс]: автореф. дисс.... к. и. н. 2007. URL: http://cheloveknauka. com/zhenschiny-v-sotsiokulturnom-prostranstve-chernomorskoy-gubernii-konets-xix-nachalo-xx-vv-1# ixzz48FQ3sLjm (дата обращения: 10.06. 2016).
20. Chekalina, S. I., Umurzakova, R. Z., Saliev, K. K., & Abdurakhmanov, T. R. (1994). Effect of berberine bisulfate on platelet hemostasis in thrombocytopenia patients. Gematologiia i transfuziologiia, 39(5), 33-35.
21. Zyablitskii, V. M., Romanovskaya, V. N., Umurzakova, R. Z., Starosel'skaya, A. N., & Mikhal'skaya, T. Y. (1996). Modification of the functional state of hemostasis system using berberin sulfate. Экспериментальная и клиническая фармакология, 59(1), 37-39.
22. Chekalina, S. I., Umurzakova, R. Z., Saliev, K. K., & Abdurakhmanov, T. R. (1994). Trombositopeni hastalarında berberin bisülfatın trombosit hemostazına etkisi. Gematologiia i Transfuziologiia, 39(5), 33-35.
23. Chekalina, S. I., Umurzakova, R. Z., Saliev, K. K., & Abdurakhmanov, T. R. (1994). Effet du bisulfate de berbérine sur l'hémostase plaquettaire chez les patients thrombocytopéniques. Gematologiia i Transfuziologiia, 39(5), 33-35.
24. Махмудов, Д., Абдуллаева, Х., Таралева, Т., Аблялимов, Р., & Парпиев, С. (2025). АНАЛИЗ ФУНКЦИОНАЛЬНЫХ ПОКАЗАТЕЛЕЙ ФУТБОЛИСТОВ НА ЭТАПЕ ОТБОРА К СОРЕВНОВАНИЯМ. Медицина и спорт, (3), 162-162.