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A Bibliometric Review of characterization of outdoor solar PV panel for shading and validation by PV emulator

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A Bibliometric Review of Characterization of outdoor solar PV panel for shading and validation by PV emulator

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Many researchers and experts have begun to work in Renewable Energy (RE) Research and Development (R&D) as an interdisciplinary area ineluctable solution to lower the use of conventional power generation or non-renewable resources. Solar photovoltaic energy has gained a lot of recognition as one of the best green alternatives. However, its firm reliance on environmental and climatic conditions makes it difficult for researchers to conduct experiments at the operational temperature (T) and Solar insolation level (G). These solar PV panels with a controllable light source are inefficient, unreliable, and unsuitable for testing PV algorithms such as Maximum Power Point Tracking (MPPT), microgrids, and energy storage mechanisms. PV array emulators have been developed to address these issues and effectively replace actual solar PV modules in laboratory tests by generating identical PV characteristics and simulating the electrical behavior of PV sources such as maximum power point monitoring (MPPT). Simulating PV arrays under partial shading conditions and PV modules under various climatic conditions has become a significant study area, primarily to validate PV emulators.

Keywords: PV panels, PV emulator, IV characteristics, PV characteristics, Shading effect.

1. Introduction

Because of the growing need for green power to solve problems such as fossil fuel exhaustion, carbon emission, climate change, and other challenges, Research & Development (R&D) of alternative and sustainable energy sources has risen rapidly in recent years (Aktar, Alam, & Al-Amin, 2020; Essa, 2021; Kabir, Kumar, Kumar, Adelodun, & Kim, 2018; Olivier, Schure, & Peters, 2017; Peters et al., 2020; Piłatowska & Geise, 2021). Solar energy is one of the most promising, globally available and popular source to fulfil the energy need on the mankind. A solar cell is the basic unit of the solar Photovoltaic (PV) system. It works upon the PV effect; hence it has also called a PV cell. It generates electricity when sunlight hits its surface. The potential difference formed across the PV cell's terminals is fixed at 0.5 volts, and it is independent of incident light intensity (Patel & Agarwal, 2008; Ramaprabha & Mathur, 2009). However, its current capacity is proportional to incident light intensity and the area exposed to the sun. A single solar cell is not able to provide sufficient power output. More PV solar cells must be connected to increase the output power level of a PV device. Connecting more and more solar cells in series and parallel photovoltaic modules is formed (Ramabadran & Mathur, 2009). To get desired output current, PV modules are connected in parallel, and for obtaining desired voltage, they are connected in series.

An interconnection of several photovoltaic modules in serial and/ or parallel is known as PV array. A PV system is comprising of one or more solar panels combined with an inverter and other electrical components and mechanical hardware. The relationship between the output voltage and current produced by a solar cell is swiped as I-V characteristics curve which shows key electrical properties of a PV module and also helpful to extract many other electrical specification for fault findings (Nasikkar & Sayyad, 2020; J. Sayyad & P. Nasikkar, 2020; J.

Sayyad & Nasikkar, 2021; J. Sayyad, Nasikkar, Singh, & Ozana, 2021; J. K. Sayyad & P. S. Nasikkar, 2020a). For outdoor characterization of solar PV many methods have been discussed by researches in the literature(Duran, Piliougine, Sidrach-de-Cardona, Galan, & Andujar, 2008; J. K. Sayyad & Nasikkar, 2019). For indoor characterization, the solar PV cell can also be modelled using single or double diode modelling (J. K. Sayyad & P. S. Nasikkar, 2020b). The current (I) is regulated by the intensity of solar radiation, also known as insolation, that strikes the cell, whereas the voltage is reduced by increases in the solar cell's temperature (V). Characteristics I-V Curves are a graphical representation of a solar cell or module's activity that summarizes the relationship between current and voltage under any irradiance and temperature conditions. We may arrange a solar system such that it operates/works as close to its Maximum Power Point (MPP) as possible using knowledge obtained from IV curves.

Shading is a significant issue in PV modules caused by shadows falling on a PV panel due to nearby objects, trees, or structures (Abdulazeez & Iskender, 2011; García, Hernández, & Jurado, 2011; Rao, Ilango, & Nagamani, 2014). Shading reduces the intensity of the light, which reduces the current flowing through the PV panel's terminal. The majority of the time, shading can be unevenly distributed on solar PV panels, reducing the power output of one of the solar PV cells to zero. Depending on the specific issues, even if only 1% of a solar PV panel is in the shade, total power generation will lose up to 50% – 80% from the entire solar array.

2. Study Design

Implementation of the Bibliometric approach was done from 2004 to 2021.

2.1 Framing the keywords

The part carries the Scopus data set into thought with the guide of significant keywords found for

continuous solar PV panel for shading and validation by PV emulator investigation. The Scopus data set in query was gathered into three squares as essential, auxiliary, and discretionary catchphrases. The proposed Keywords procedures applied for this investigation as shown in Table 1.

Table 1: Planned keywords search tactics for Scopus database

Primary Keywords (AND)	(PV panels OR PV cell OR PV module OR PV array)
Secondary Keywords (AND)	(Characterization AND IV Characteristics OR PV Characteristics AND emulator)
Optional Keywords (AND)	Shading

Document type-wise trend analysis

The document type wise analysis shows that the researchers have published nearly 45% of articles, 32.42% of conference papers of the total publications on characterization of outdoor solar PV panels for shading and validation by PV emulator shown in Figure 1. It also shows that only 12.28% review, a 1.70% book chapter, and a 7.84% book have been published. This
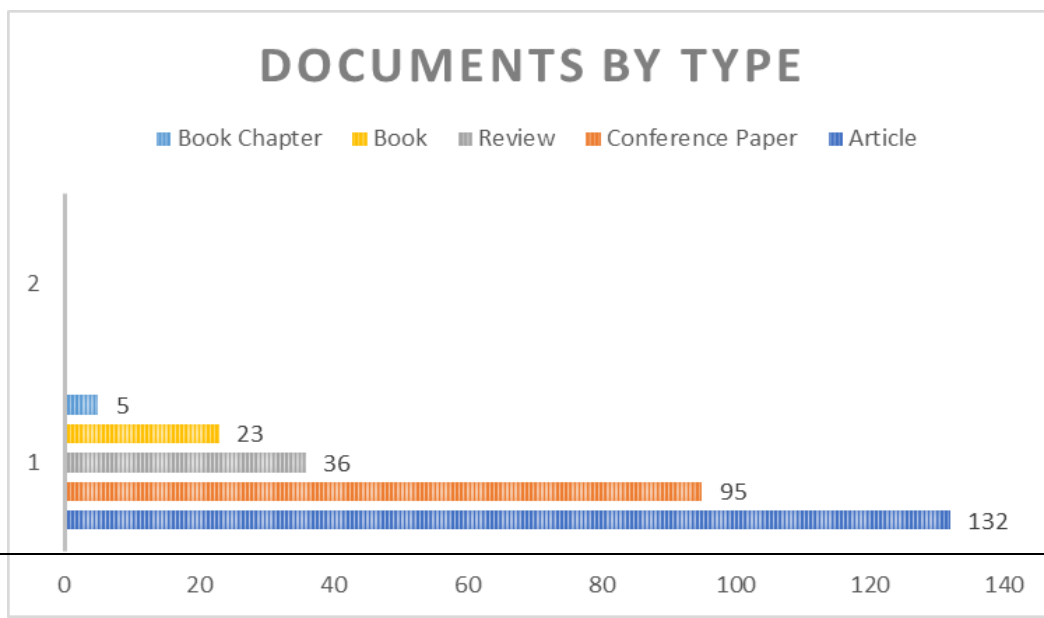
research will help student and professors to do further research on this topic, and also research paper can help budding engineers to learn the pre-requisite thing before researching this topic.

Figure 1: The Documentation type-wise trend of publications on outdoor solar PV panel for shading and validation by PV emulator accessed on 20th May 2021 (Source: http://www.scopus.com)

Year-wise trend

In this study, the trend analysis shows that the researchers publish journal papers, conference papers, articles, book chapters, etc. From 2011 to 2021. It shows a consistent increase in the number of

Year	No. of Publications	Year	No. of Publications
2004	1	2013	27
2005	0	2014	17
2006	0	2015	17
2007	0	2016	31
2008	3	2017	35
2009	3	2018	28
2010	6	2019	30

publications during this period. In this domain, many authors have published most of the documents year 2016 onwards. Table 2 and Figure 2 shows that the maximum number of papers, articles, books, etc., were published in 2020 and 2021; there is a high chance that it will touch 50 this time, as this year is not completed yet.

Table 2: Year wise trend about the publication on this research publication on outdoor solar PV panel for shading and validation by PV emulator accessed on 20th May 2021 (Source: http://www.scopus.com)

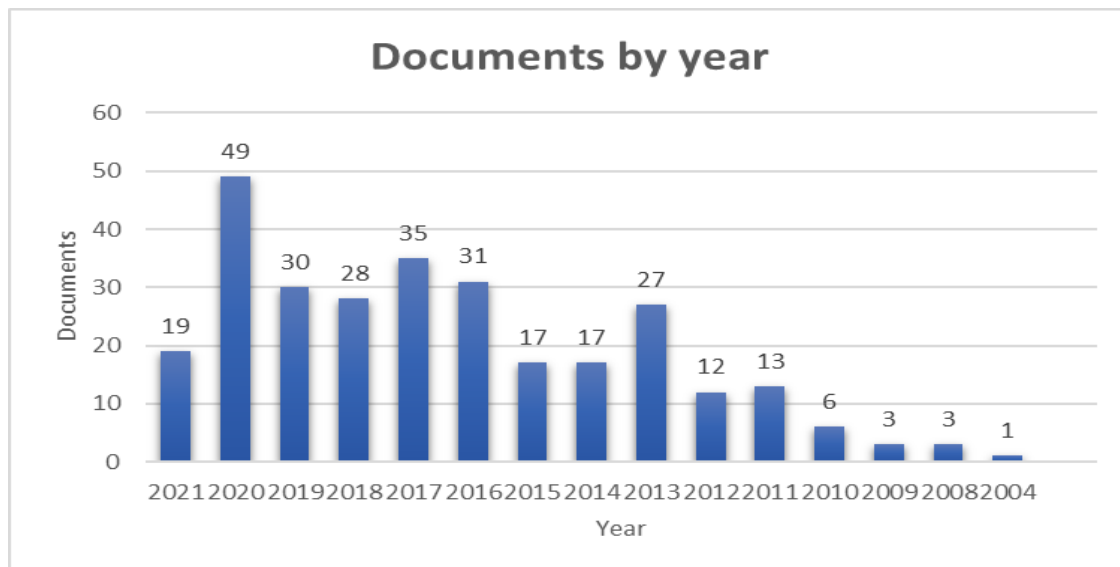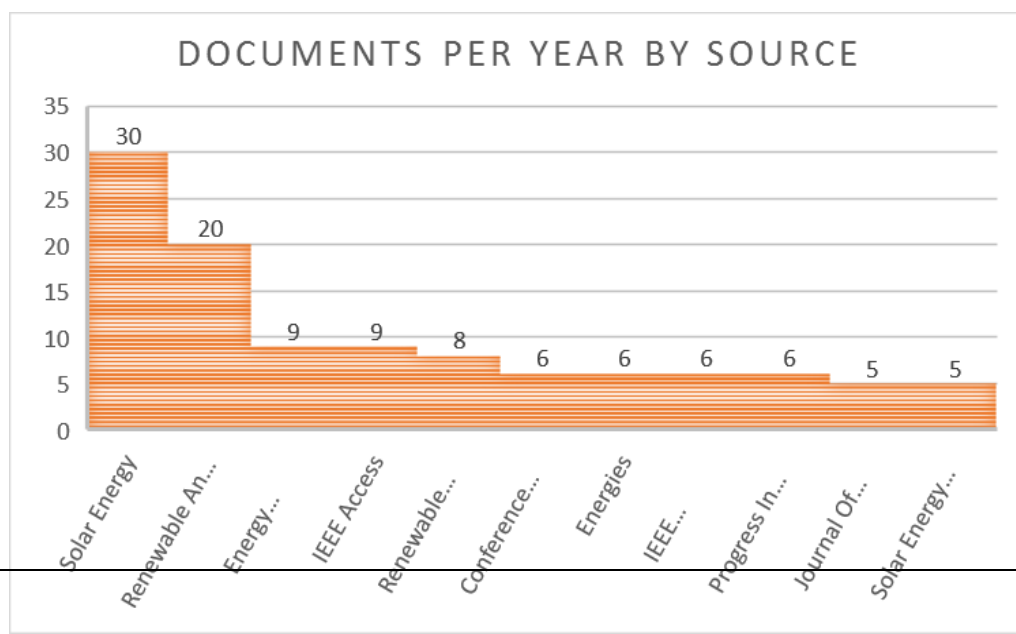| 2011	13	2020	49
2012	12	2021	19

Figure 2: Year wise trend about the publication on this research publication on outdoor solar PV panel for shading and validation by PV emulator accessed on 20th May 2021(Source: http://www.scopus.com)

Documents per year by source

The analysis from Figure 3 shows that the solar energy and renewable energy review came the

most because that were the main reasons to start the research about it shifting the world from non-renewable energy source to renewable energy source and in renewable energy source the solar is the most important one. There are around fifty documents on solar energy and renewable review, and there are around seventy-eight topics that the documents written on this topic. Energy conversation topic also has nine documents.

Figure 3: Documents distribution per year by source in outdoor solar PV panel for shading and validation by PV emulator accessed on 20th May 2021 (Source: http://www.scopus.com)

Author - wise trend

Figure 4 shows that the number of publications for the top eighteen researchers is given in the graph. In the top eighteen, many Indian professors are publishing documents in this field. If we consider only the top eighteen, four professors whose names are Rajasekar N with six

publications, Babu TS, A Chandra, and M Jalal with three publications.

Figure 4: Top eighteen authors who have published their research documents on outdoor solar PV panel for shading and validation by PV emulator accessed on 20th May 2021 (Source: http://www.scopus.com)

Affiliation statistics

The top seventeen universities / organizational mergers are shown in Figure 5. In this many Indian Universities are there DTU, IIT Guwahati, VIT University, and many more among 167 universities. But only VIT University is in the top seventeen positions with second rank and joint first ranker are Universiti Teknologi Malaysia, Fuzhou University situated in China both have eight affiliations. VIT University has six affiliations.
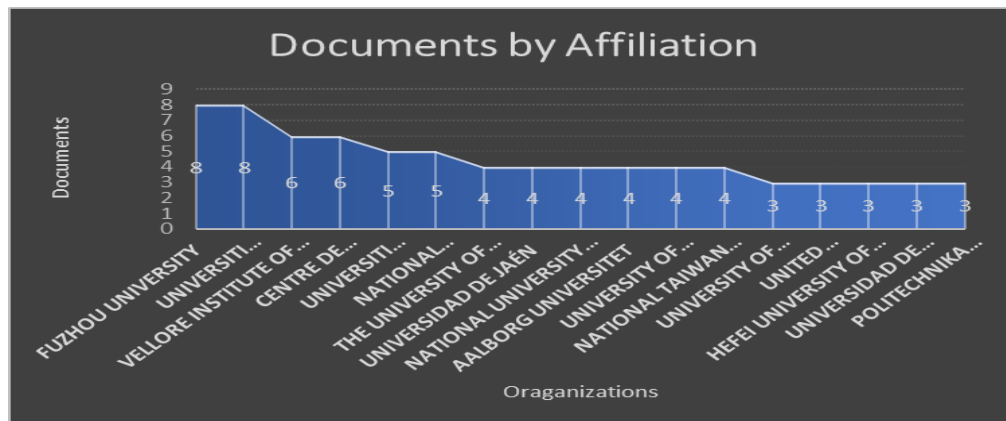

Figure 5: Top seventeen affiliation-wise institutes which have researched on outdoor solar PV panel for shading and validation by PV emulator accessed on 20th May 2021 (Source: http://www.scopus.com)

Subject area-wise

Values give an idea of a topic or study area that has had a significant impact on research. As shown in Figure 6, Energy, engineering, materials science, and computer science donated more than 80% (80.4%) of research literature and gradually evolved in-depth study of the topic. It is also noteworthy that very little research has been done in social sciences, chemical engineering, business, management & accounting, chemistry, which are the remaining subjects.
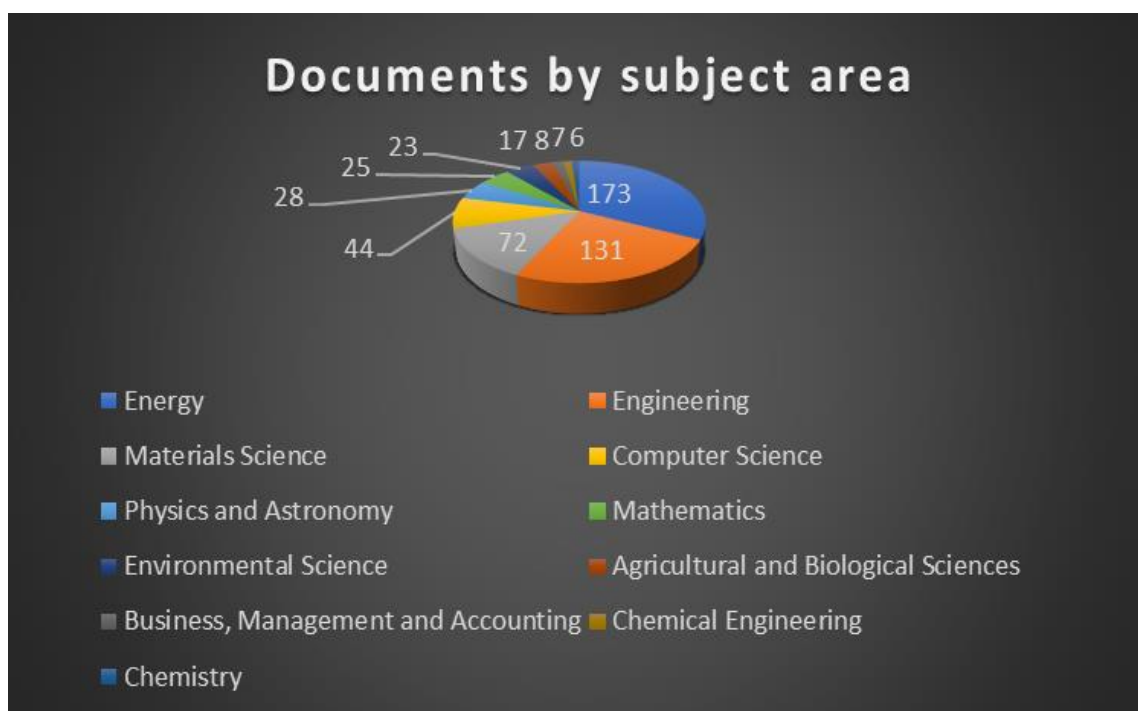
Figure 6: Subject area-wise number of documents distribution published on outdoor solar PV panel for shading and validation by PV emulator accessed on 20th May 2021(Source: http://www.scopus.com)

Country-wise trend analysis

Figure 7 shows, it is very interesting to see that most of the research literature comes from the India which is in third position and it has clear dominance on various European countries. The countries which are in top two are USA and China with total 84 documents, the India contributed 33 of them with related topics and the most visited hand among all the social media of the world. US is with 46 and China with 38 documents. It is worth noticing India can top the list after some years.
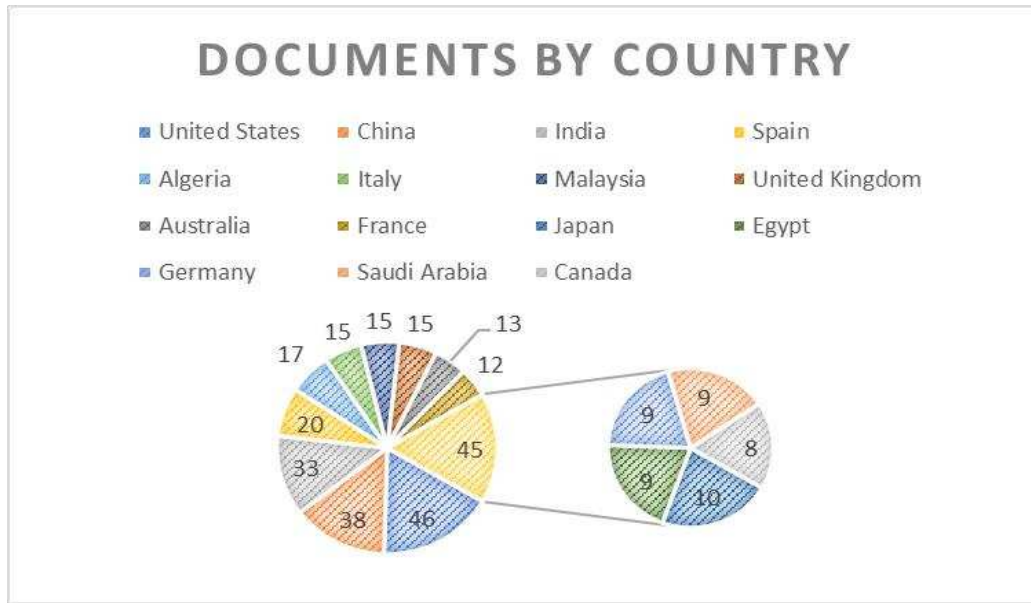
Figure 7: Top ten countries or territory where research on outdoor solar PV panel for shading and validation by PV emulator is leading accessed on 20th May 2021 (Source: http://www.scopus.com)

Funding sponsor-wise

Figure 8 shows the top sponsors of research funding in this topic. As a result, it is not surprising that most of the research funding is from China and is accepted by fourteen documents. Research and Development (R&D) funding from the European Commission (EC) of Belgium has ten documents. Third comes the National Science Foundation from US which has seven documents. Nowadays many countries are providing economic support by allocating R&D budgets to become self-sufficient in the growing capacity needed in the future which will help in the renewable energy usage and will also help the countries to become self-sufficient in sustainable development.
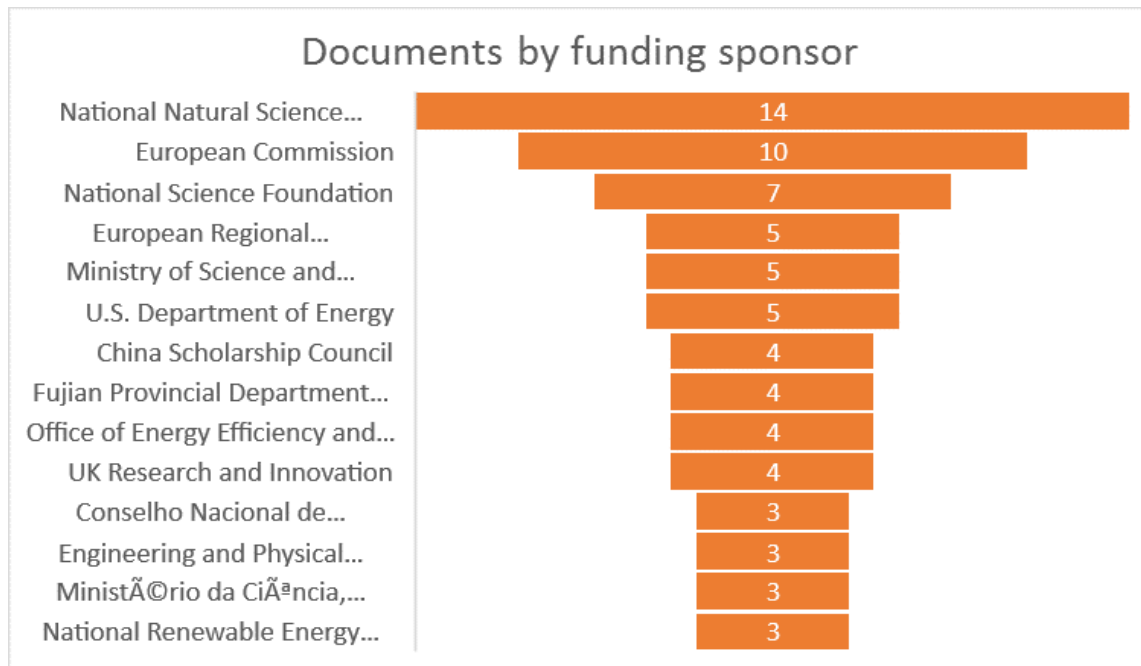
Figure 8: Top ten funding agencies in the field Solar PV emulation data accessed on 20th May 2021(Source: http://www.scopus.com)

3. Conclusion

This study discussed and analyzed all the documentation and publication in the characterization of outdoor solar PV panels for shading and validation by PV emulators. This analysis is based on trends in the type of documents, year of study, affiliated institute, funding agencies, subject area, leading authors in the field, and place of study. This study also briefs the process of how investigation and analysis are carried out while preparing this report. This study will also help researchers and authors in this area to gather the domain-specific latest information and ongoing research.

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