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Solar radiation tools and analysis for grid-interconnected photovoltaic systems

Herramientas y Análisis de la radiación solar para los sistemas fotovoltaicos interconectados a la red

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Abstract

The technological tools for obtaining data allow the analysis of radiation in any part of the world, we refer us to the process with which historical data is obtained that allows determining the peak hour and the ideal geographical area for planning, design, installation, and operation. Efficient photovoltaic systems. This analysis justifies the measurement of solar radiation in the study region for the implementation and improvement of renewable energy systems, which play a fundamental role in the performance of photovoltaic systems. These technological tools are essential to guarantee that the systems make the most of the sun's energy and are a profitable investment in the generation of sustainable energy, contrasting with the costs recorded in electricity bills, the feasibility of establishing this modality of energy generation is projected electrical energy, contributes to the improvement of the environment as well as the benefit in the economy of the population.

Photovoltaics, Radiation, Solar

Resumen

Las herramientas tecnológicas para la obtención de datos permiten el análisis de la radiación en cualquier parte del mundo, referimos al proceso con el que se obtienen datos históricos que permite determinar la hora pico y la zona geográfica idónea para la planificación, diseño, instalación y operación eficiente de sistemas fotovoltaicos. Este análisis justifica la medición de la radiación solar en la región de estudio para la implementación y mejora de los sistemas de energías renovables, desempeñan un papel fundamental en el rendimiento de sistemas fotovoltaicos. Estas herramientas tecnológicas son esenciales para garantizar que los sistemas aprovechen al máximo la energía del sol y sean una inversión rentable en la generación de energía sostenible, contrastando con los costos registrados en recibos de luz, se proyecta la factibilidad de establecer esta modalidad de generación de energía eléctrica, contribuye a la mejora del medio ambiente y se refleja en beneficio de la economía de la población.

Fotovoltaicos, Radiación, Solar

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1. Introduction

The growing demand for sustainable energy has driven the exploration of renewable sources, with solar energy being a promising and environmentally friendly option. In this context, the efficiency of photovoltaic systems plays a crucial role in the transition towards a cleaner energy matrix. This study focuses on the collection and analysis of solar radiation data, which is essential for determining the peak time and optimal geographical location, thus facilitating the planning, design, installation and efficient operation of these systems.

The collection and analysis of solar radiation data is essential in the current transition to renewable energy sources. Solar radiation is the driving force behind photovoltaic systems, and a thorough understanding of it is essential to optimise the efficiency of these systems. This research is presented as a strategic tool for informed decision making in the implementation of solar technologies, highlighting their importance in sustainable energy generation.

What distinguishes this research from other existing techniques is its focus on obtaining historical global solar radiation data. The selected technological tools allow not only the collection of point-in-time information, but also the analysis of patterns over time and across geographic locations. This global approach provides a holistic view, allowing for more accurate and efficient planning in the implementation of photovoltaic systems.

Description of the solar peak hour (SPH)

The unit of measurement of solar irradiance referring to the energy per unit of a constant surface area that will be received with an assumed constant solar irradiance of 1000 W/m^2.

A peak solar hour is equivalent to 3.6 MJ/m^2 or 1 kWh/m^2.

85% of the Mexican territory has optimal solar radiation conditions, making it one of the most privileged countries in the world in terms of solar resources.

Mexico is almost six times larger than Germany, and due to its location, it has five times more solar radiation capture.

Despite this, the Teutonic country generates 42 times more energy than California (USA).

Generates 42 times more energy, and is one of the powers in terms of solar panels and renewable energies. If the comparison is made with Denmark, another leading nation in the sector, the equivalent of what Mexico generates corresponds to only 0.1% to 0.23% of the energy produced by the European country. This indicates that Mexico has a better location than many countries, and therefore a greater unexploited solar catchment.

Country	Distributed generation penetration (%)
Germany	48
California (USA)	5
Chile	10
Denmark	55
Spain	31
México	0.23

Table 1 Percentage in countries with excellent PV generation
Source: Prepared by CIEP, with data from SENER 2017

Solar energy in Mexico has grown steadily in recent years. Thanks to the trust placed in the main technology for harnessing it: solar panels.

Important physical elements for peak solar time (HSP):

- Solar Radiation
- Direct Radiation
- Diffuse Radiation
- Reflected Radiation
- Energy Flow
- Check feasibility

Solar radiation

The flow of energy we receive from the Sun in the form of electromagnetic waves that enables the transfer of energy.

Direct Radiation

Radiation received directly from the sun in a straight line, without being deflected as it passes through the atmosphere. It is the largest and most important in photovoltaic applications.

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Diffuse radiation

Radiation received from the sun after being deflected by atmospheric scattering. Diffuse radiation is the radiation that is received through clouds, as well as that which comes from the blue sky. If there were no diffuse radiation, the sky would be black even during the day, as is the case, for example, with the moon.

Reflected radiation

This is the direct and diffuse radiation that is received by reflection from the ground or other nearby surfaces. Global irradiance is the total incident radiation on a surface.

Energy flux

Radiation quantities are generally expressed in terms of radiant exposure or irradiance, the latter being a measure of the flux of energy received per unit area instantaneously as:

energy/area-time and whose unit is Watt per square metre (W/m^2).

Check feasibility

The feasibility of the solar resource must be verified in order to design and implement a photovoltaic system capable of meeting society's electricity consumption needs.

Key Characteristics for Solar Radiation Analysis for photovoltaic systems:

1. Global Accessibility: The ability of this technology platform to provide solar radiation data anywhere in the world significantly expands the scope and applicability of the research.

2. Historical Analysis: The ability to provide and analyse historical data allows for the identification of seasonal patterns and trends over time, improving accuracy in decision making.

3. Photovoltaic System Efficiency: The focus on determining the peak time and ideal geographic location directly aims to improve the efficiency of photovoltaic systems, thus maximising energy generation.

Problem statement

The central problem addressed, is the scarce dissemination of technological platforms that serve as specific tools for obtaining and analysing detailed solar radiation data on a global level. The implementation of these technological tools would support more accurate and efficient planning of photovoltaic systems by identifying the optimal peak time and geographical location.

Current State of Photovoltaic Technology

Photovoltaic technology has seen significant progress in recent years, driven by advances in solar cell efficiency, reduced production costs and increased generation capacity. Recent research has highlighted developments in semiconductor materials, solar cell structures and manufacturing methods that improve the conversion of solar radiation into electricity more efficiently. In addition, current trends in the integration of energy storage systems to overcome challenges related to the intermittency of solar generation will be explored.

The Solar Resource

The sun is an inexhaustible source of energy due to the nuclear reactions occurring at its centre. A large part of this energy reaches the Earth in the form of electromagnetic radiation, the sunlight that we can perceive by sight is in the spectral range from 400 to 750 µm in wavelength.

The sun's path

In addition to atmospheric conditions, there is another parameter that radically affects the incidence of radiation on a solar collector: the apparent movement of the sun throughout the day and throughout the year. We say "apparent" because in reality it is the Earth that is rotating and not the Sun. The Earth has two types of motion: one is around its own axis (called rotational motion) which gives rise to day and night and the other is around the sun (called translational motion) following an elliptical path, which gives rise to the seasons of the year.

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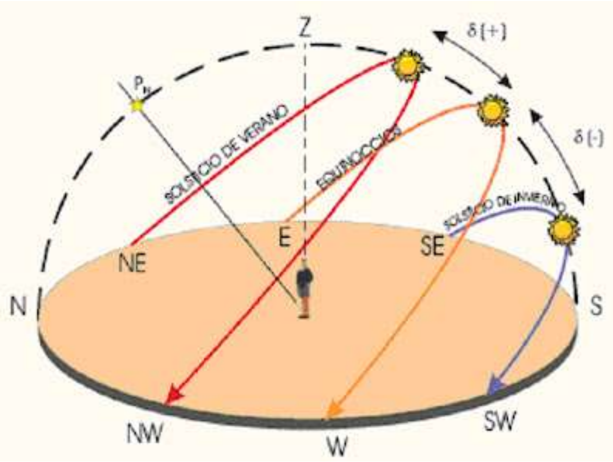

Figure 1 Angle formed by the Sun's rays with the equatorial plane
Source: https://maestrosenciencias.blogspot.com/2010/12/el-cielo-visto-desde-la-tierra-los.html?m=1

Tilt of the photovoltaic array

Maximum energy is obtained when the sun's rays are perpendicular to the collector surface. In the case of PV arrays, perpendicularity between the module surfaces and the sun's rays can only be achieved if the array mounting structures move in line with the sun. There are array support structures that automatically adjust the azimuth and/or elevation. These mounting structures are called trackers. Usually the elevation angle of the array is fixed. In some cases azimuthal trackers are used. Depending on the latitude of the site, these trackers can increase the average annual insolation by 15-25%.

Selection of Technological Tools

Exploration and evaluation of available technology tools, highlighting selection criteria.

The technology tool selection stage is crucial to ensure the effectiveness and applicability of the research. A thorough exploration of the available tools will be carried out, followed by an evaluation based on specific criteria to select the most suitable tools for the study of solar radiation and photovoltaic systems in the region of interest.

Exploration of Available Tools

A full exploration of existing technological tools for obtaining solar radiation data will be undertaken. This will include a review of commercial platforms, open source software and emerging technologies in the field.

The diversity of approaches, from weather stations to geospatial analysis platforms, will be considered to ensure an informed selection.

A table with solar radiation values per state of the Mexican Republic was made, in each state the peak solar hour per month and the annual count for each of them is denoted with information based directly from a NASA page from the year 2021, as it is the most current information found in that platform, the process was performed as follows:

Figure 2 Image Virtual Platform, NASA Projection
Source: POWER | Data Access Viewer (nasa.gov)

Figure 3 Image Approach to geolocation input
Source: POWER | Data Access Viewer (nasa.gov)

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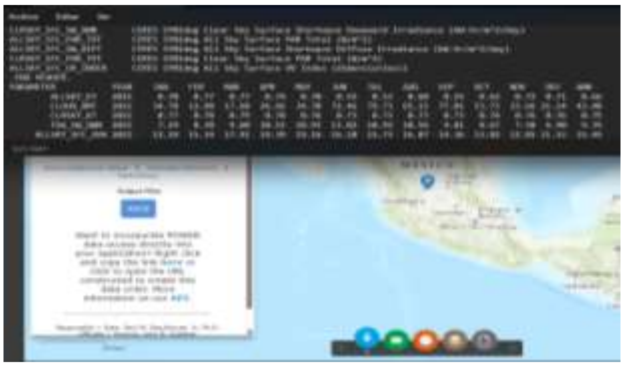

Figure 4 Image with parameterised values
Source: POWER | Data Access Viewer (nasa.gov)

NASA POWER Selection Criteria

Evaluation of these tools will be based on specific criteria designed to meet the research objectives. Some key criteria include:

a. Measurement Accuracy: Priority will be given to tools that provide accurate solar radiation measurements, ensuring reliable data for decision making.

b. Data Update Frequency: Tools with higher update frequencies will allow for more detailed analysis of temporal patterns, being beneficial for peak time identification.

c. Accessibility and Ease of Use: Data accessibility and ease of implementation will be key considerations, as a user-friendly tool will facilitate integration into the study.

d. Historical Analysis Capability: The ability to perform historical analysis at different time scales will be essential to understand long-term patterns and optimise the efficiency of PV systems.

e. Integration with Design and Planning Systems: Tools that integrate seamlessly with PV project design and planning systems will be preferred for efficient implementation.

f. Geographical Applicability: The ability of tools to adapt to the specific geographical characteristics of the study region will be a crucial criterion.

Regulatory

We verified that through the analysis of the information provided by NASA POWER POWER Data Access Viewer Official NASA Source, corresponding to the maximum irradiance in units of $KW/h/m^2$, as well as the amount of Peak Solar Hours (PSH), we corroborate that it is feasible to integrate a project of this type which will have sufficient solar resource to be optimal and also comply with the regulations (NOM-001-SEDE-2012).

Figure 5 Image created by AI

Conclusions

We corroborate that it is feasible to use NASA POWER tools to integrate a project with sufficient solar resource to be able to be optimal in its operation.

As with the integration of this solar photovoltaic system, it will be possible to generate an awareness of the use of technological tools prior to the installation of solar energy.

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