21th ECORFAN® International Conference - Science, Technology and Innovation

Booklets

RENIECYT 1702902 CONAHCYT

RENIECYT - LATINDEX - Research Gate - DULCINEA - CLASE - Sudoc - HISPANA - SHERPA UNIVERSIA - Google Scholar DOI - REDIB - Mendeley - DIALNET - ROAD - ORCID - V|LEX

Title: Prototype of a structure with variations in the angle of inclination for photovoltaic panels

Authors: Herrera-Romero, JV., Escobedo-Trujillo, BA., Alaffita-Hernández, FA. and Morales-Salas, L.

Universidad Veracruzana, Facultad de Ingeniería 57198233150 0000-0001-9462-0160 163163
Universidad Veracruzana, Facultad de Ingeniería 54417142300 0000-0002-8937-3019 173174
Universidad Veracruzana 57103583500 0000-0002-7971-6356 216715
Universidad Veracruzana, Facultad de Ingeniería 57619713500 0000-0002-8192-5405 174023

Editorial label ECORFAN: 607-8695
BECORFAN Control Number: 2024-01
BECORFAN Classification (2024): 121224-0001

RNA: 03-2010-032610115700-14
Pages: 13

CONAHCYT classification:
Area: Engineering
Field: Engineering
Discipline: Mechanical Engineering
Subdiscipline: Energy

Introduction

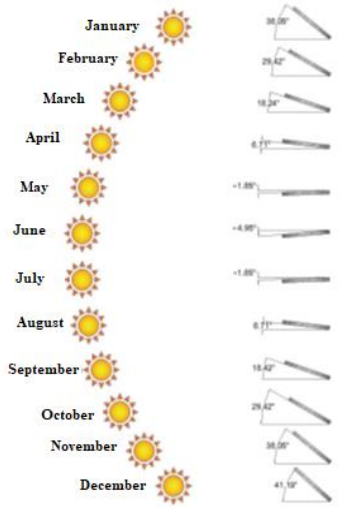
Methodology

Results

Conclusions

References

Objective: Maximize solar incidence in PV

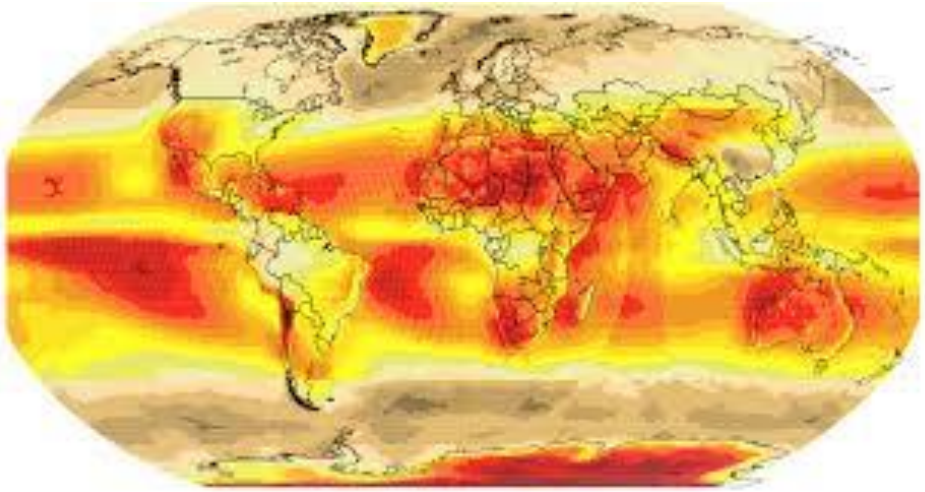


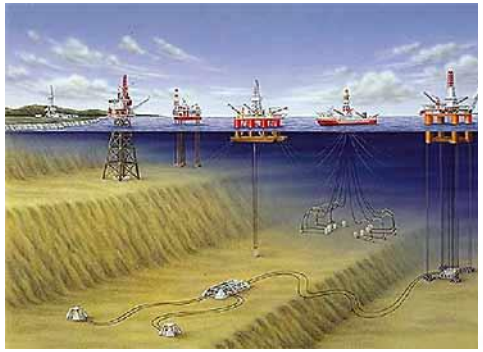
Methodology

Contribution

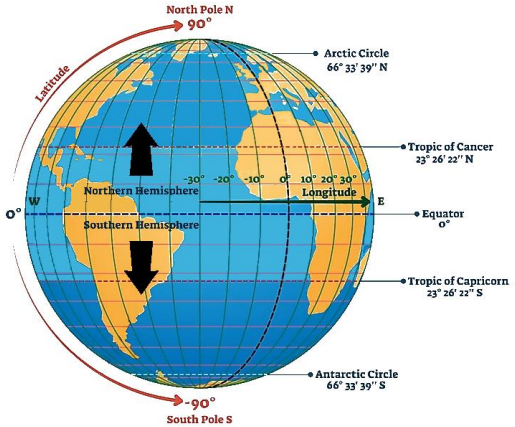
Introduction

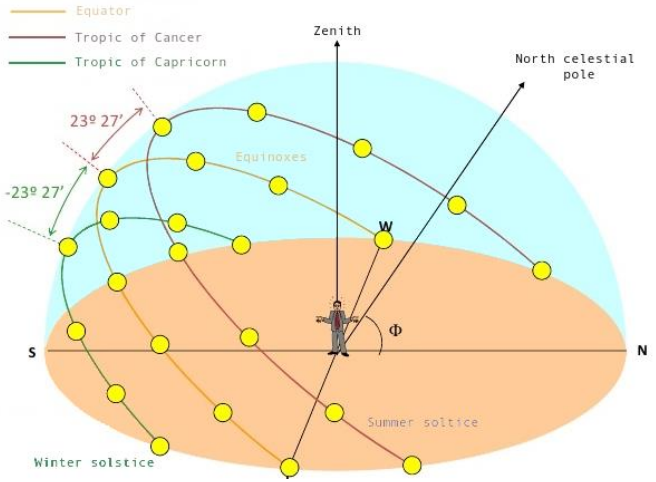
- Photovoltaic (PV) solar energy is a renewable energy that has seen its prices drop in recent years and has become comparable to conventional energies such as coal and natural gas (Muñoz, 2023).
- Solar energy is a resource that naturally benefits countries located within the sun belt or tropical areas.
- It can be converted into thermal energy via a solar collector or electrical power through a PV cell.
- It plays a vital role in the future due to the scarcity of non-renewable resources

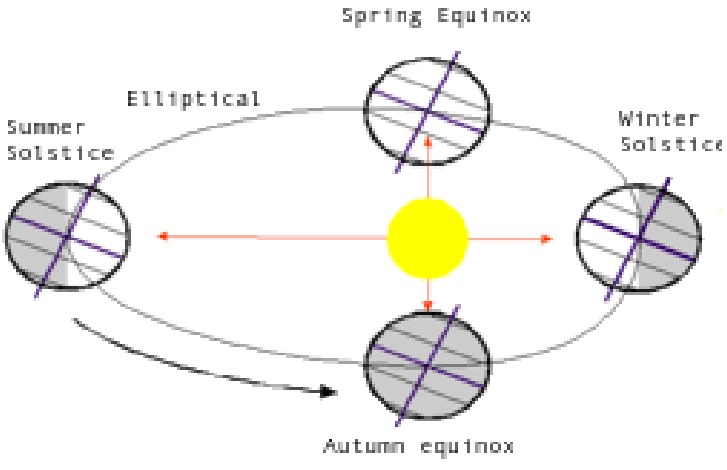


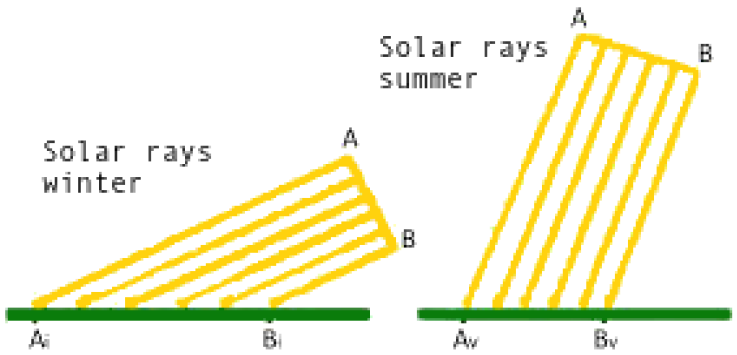


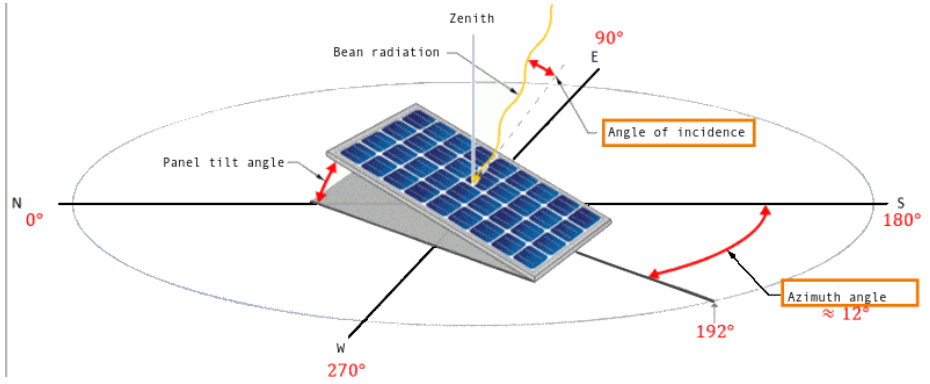
- Variations throughout the day and year characterize solar radiation;
- To design photovoltaic systems, the angle of inclination of the panels must be optimized to obtain maximum incident irradiation (Yadav, 2013).
- The amount of solar energy received on a collector depends on the following variables [(Yadav, 2018), (Duffie, 2013), (Makenzi, 2020)]:
  - latitude (Φ),
  - day of the year (n),
  - tilt angle (β),
  - surface azimuth angle (ɣ),
  - hour angle (ω), and
  - incidence angle (θ), Etc.





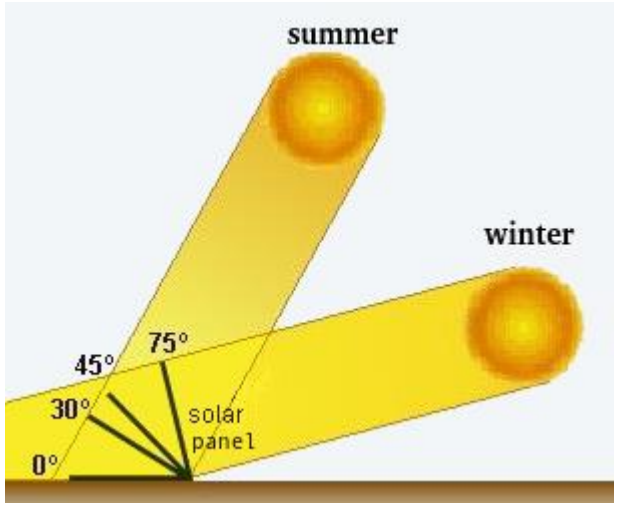






Angle of incidence (θ)

- The angle between the Sun's rays incident on the solar panel and the normal of the panel's surface.
- It is related to the amount of solar radiation that reaches a solar panel.
- It leads to maximizing the solar radiation incident on the solar panel.



General objective

- The work consists of the design and manufacture of a prototype for mounting photovoltaic solar panels, having as its main function the adjustment of the inclination angles for said panels,
- Thus, seven configurations for the inclination angles will be presented throughout the year.
- The main function of this prototype is to maximize solar incidence, which in turn generates more electrical energy (it is activated manually every month).

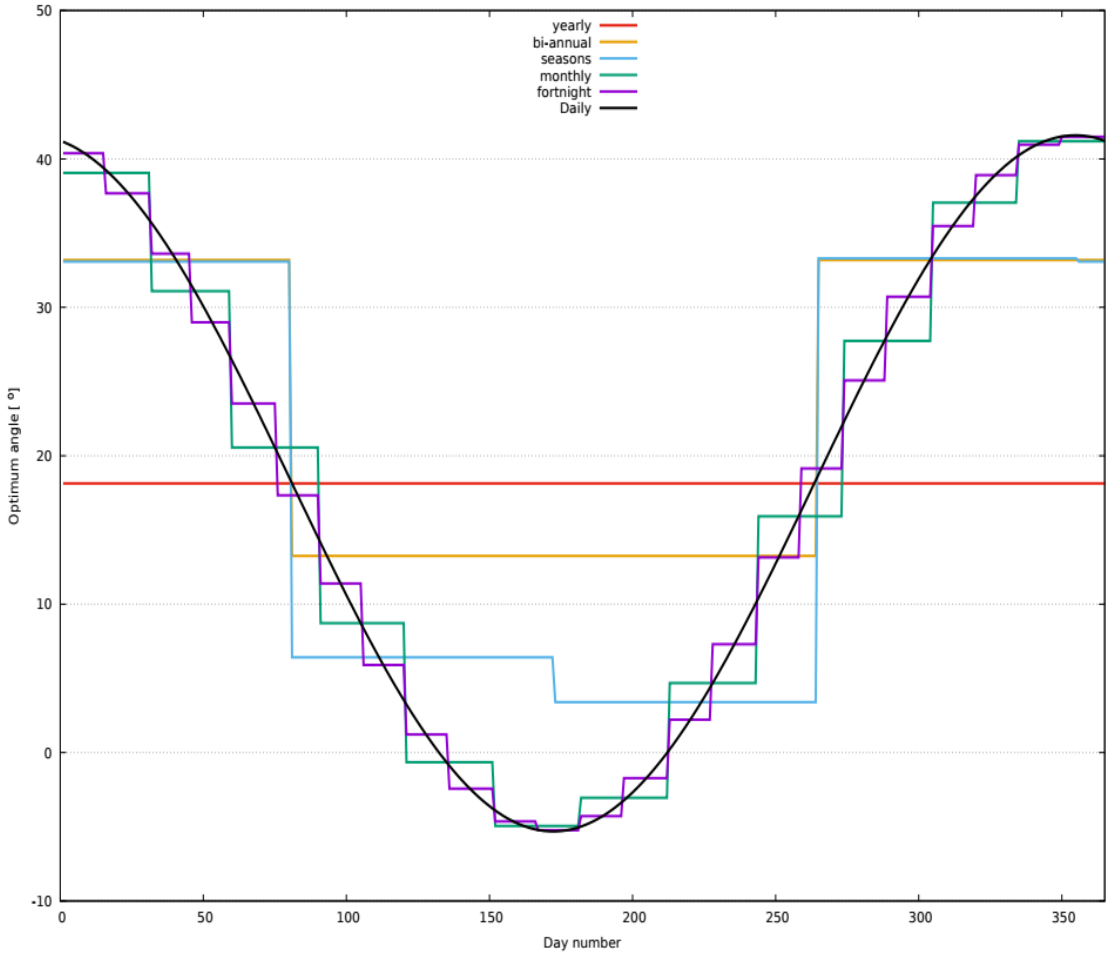
Methodology

- When installing a fixed collector, the factors that can be controlled to maximize the solar radiation flux received on a collector are γ and β.
  - A fixed collector is typically oriented toward the Equator (γ = 0 or γ = 180).
- Duffie and Beckman [2013] give a “rule of thumb” to provide maximum annual energy availability:
  - The optimum should be β = Φ.
- This means that:
  - A collector in the northern hemisphere should face south (γ = 0°) or,
  - In the southern hemisphere, it should face north (γ = 180°).
- There are techniques around the world to deduce the optimal tilt angle based on different parameters [(Alyami, 2020), (Makenzi, 2020), (Yadav., 2018)].
  - Cruz-Hidalgo (2021) determines the monthly tilt angles of photovoltaic panels facing the Equator in Coatzacoalcos, Veracruz, Mexico, with a latitude of 18°8'16''.

Optimal daily, fortnightly, monthly, seasonal and bi-annual angle

- The optimal daily angle for Coatzacoalcos, Veracruz (Φ = 18.14° N) is calculated for the 365 days of the year.

- The biweekly optimal inclination angle has been divided into twenty-four fortnights annually.
- As for the monthly optimal angle, Kleint [1977] takes the characteristic monthly days on inclined surfaces.
- The division by seasons is carried out in four quarters, where each period is represented by a solar season.
- In the case of bi-annual periods,
  - the first part of the year includes the spring and summer periods,
  - the second period covers the autumn and winter seasons.



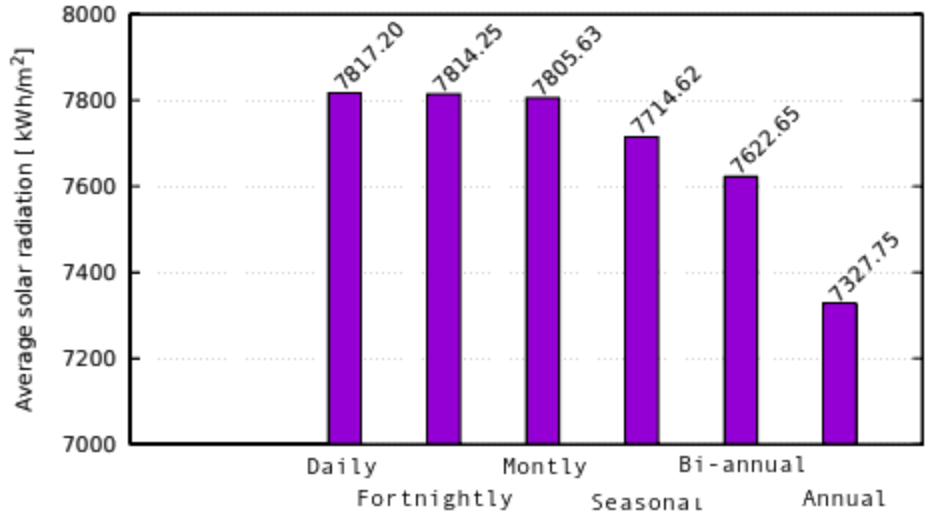
Comparison of energy received for different scenarios

The values of annual energy incident on the surface are calculated based on the optimal angles calculated for each scenario.

	Sum [MW h/m²]	Average error[%]
Daily	2 853 276	0
Fortnightly	2 852 202	-0.04
Montly	2 849 056	-0.15
Seasonal	2 815 838	-1.31
Bi-annual	2 782 266	-2.49
Annual	2 674 630	-6.26

Period selection:

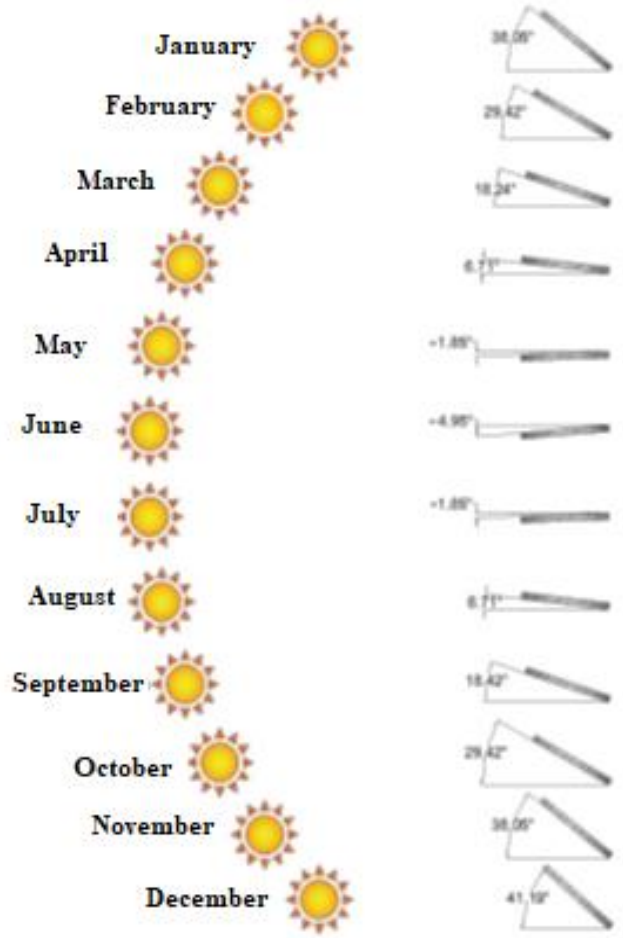
- **Monthly adjustments are recommended.**

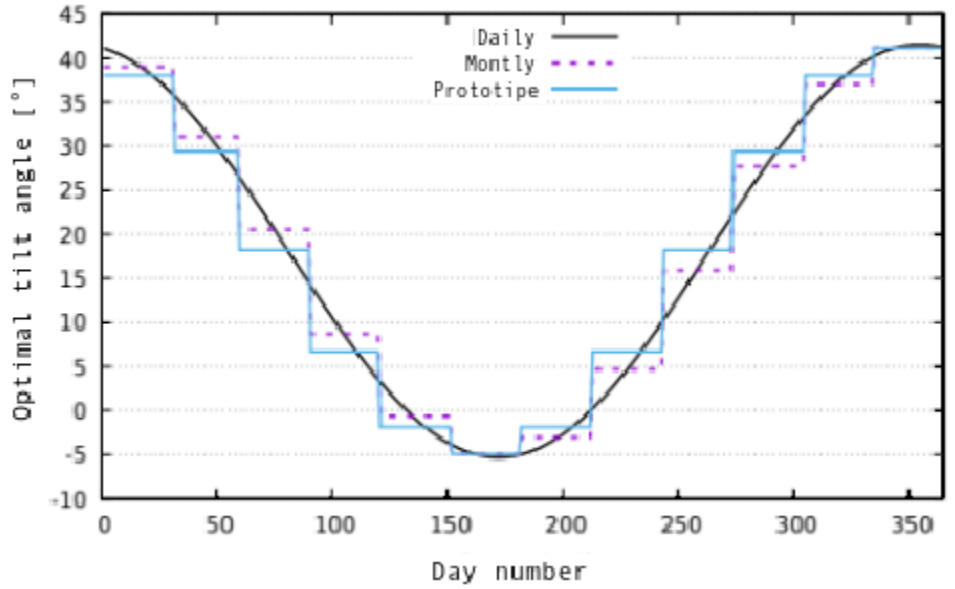


Results

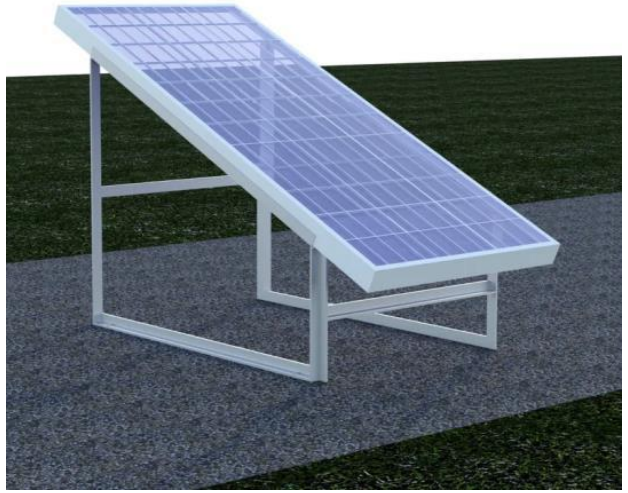
For the prototype, months with similar values are identified, forming five groups of two months and averaging them to obtain the angle corresponding to that pair of months.

	Monthly angle of the prototype [°]
January	38.05
February	29.42
March	18.24
April	6.71
May	-1.85
June	-4.95
Julie	-1.85
August	6.71
September	18.24
October	29.42
November	38.05
December	41.19





- The prototype design was created from a fixed structure with an inclination angle 18°.
- The aim was to create an economical and easy-to-build structure, resulting in the final design shown in the Figure on the right.



Fixed structure for PV solar panel

Variable structure for PV solar panel

The final result of the complete structure.

Installation: For panel-frame mounting, stainless steel screws are required; four holes are made in the solar panel frame.

- And thus, be able to satisfactorily fix the structure with the panel on the surface (floor).

- Experimental measurements are then carried out.

Conclusions

- The mathematical formulation for calculating the optimal angle of inclination is presented.
- The optimal angles for Coatzacoalcos, Veracruz, Mexico, are obtained
- In periods ranging from daily (values from (-4.95 to 41.19), biweekly, monthly, seasonal, bi-annual, and annual.
- The latter with an average value equal to the latitude;
- The inclination angles for a structure, which will be placed in Coatzacoalcos, Veracruz, Mexico, are obtained.
- The monthly angle of the prototype can have positive and negative values (tropical region),
- The methodology can be applied to build a similar structure that will work in any city as long as the information from the city in question is used.

References

- Alyami, F. H. (2020). Semi-seasonally optimized tilt angles for design of utility-scale photovoltaic generation station. In 2020 IEEE Texas Power and Energy Conference (TPEC) (pp. 1-5). IEEE., doi: https://doi.org/10.1109/TPEC48276.2020.9042500.
- Muñoz, A. (09 de octubre de 2023). ¿Qué son los costes operativos de una instalación fotovoltaica sobre cubierta? Obtenido de solarfam: https://solarfam.com/que-son-los-costes-operativos-de-una-instalacion-fotovoltaica/#:~:text=Los%20costes%20operativos%20de%20las,rendimiento%20energ%C3%A9tico%20de%20la%20instalaci%C3%B3n.
- Yadav, A. K. (2013). Tilt angle optimization to maximize incident solar radiation: A review. Renewable and Sustainable Energy Reviews, 23, 503-513. doi: https://doi.org/10.1016/j.rser.2013.02.027
- Yadav, A. K. (2018). Formulation of new correlations in terms of extraterrestrial radiation by optimization of tilt angle for installation of solar photovoltaic systems for maximum power generation: case study of 26 cities in India. Sādh. Sādhanā, doi: https://doi.org/10.1007/s12046-018-0858-2.
- Despotic, M., & Nedic, V. (2015). Comparison of optimum tilt angles of solar collectors determined at yearly, seasonal and monthly levels. Energy Conversion and Management, 97, 121-131. Doi: https://doi.org/10.1016/j.enconman.2015.03.054
- Duffie, J. A. (2013). Solar engineering of thermal processes. New Jersey: John Wiley & Sons.
- Makenzi, M. M. (2020). Maximization of site-specific solar photovoltaic energy generation through tilt angle and sun-hours optimization. Journal of Renewable Energy, doi: https://www.hindawi.com/journals/jre/2020/8893891/.
- Cruz-Hidalgo, D. H.-R.-G. (2021). Determination of optimum tilt angle of photovoltaic panels with monthly variations for Coatzacoalcos, Veracruz. 2021 IEEE International Conference on Engineering Veracruz (ICEV), 1-7. doi: https://doi.org/10.1109/ICEV52951.2021.9632637

MARVID®