
Anna Manowska 1, Artur Dylong 1,*, Bogdan Tkaczyk 1 and Jaroslaw Manowski 2

1 Faculty of Mining, Safety Engineering and Industrial Automation, Silesian University of Technology, 44-100 Gliwice, Poland; anna.manowska@polsl.pl (A.M.); bogdtka040@student.polsl.pl (B.T.)
2 Rockwell Automation, 44 Francuska, 40-028 Katowice, Poland; jaroslaw.manowski@rockwellautomation.com
* Correspondence: artur.dylong@polsl.pl

Abstract: This article explores the efficiency of photovoltaic (PV) panels, which is crucial in the search for sustainable energy solutions. The study presents a comprehensive analysis of the maximum solar potential achievable through photovoltaic technologies amidst the increasing global energy demands. The research examines solar radiation measurement techniques, the incidence angle of solar rays, and the intricacies of PV panel efficiency. It highlights the potential for improving the performance of solar-based energy systems. Four main sections are covered, beginning with an introduction to the importance of energy storage in sustainable energy production, especially in the context of the European Union’s energy goals and the Green Deal. The following sections discuss the precision needed in the geographical positioning of measurement systems, the impact of light physics, and variable weather conditions on energy capture. The last section presents a novel clock algorithm regulation system designed to enhance the efficiency of the measurement system.

Keywords: maximum solar potential; energy production; photovoltaic panels; renewable energy sources; solar radiation measurement; photovoltaic panel efficiency; optimization of photovoltaic systems

1. Introduction

In the face of growing global energy needs and inevitable challenges related to climate change, the need to transform energy production methods to be more ecological is becoming increasingly important. In light of applicable legal regulations, such as the Paris Agreement, which obliges European Union [EU] member states to significantly reduce greenhouse gas emissions, and ambitious climate goals aimed at achieving climate neutrality by 2050, the development of sustainable energy sources is becoming not only a matter of technological innovation, but also a legal and environmental imperative [1–6].

The development and optimization of photovoltaic (PV) technologies are becoming key elements in the pursuit of a sustainable future. This article is a study that explores the maximum solar potential achievable using photovoltaic technologies, highlighting the importance of precise monitoring methods such as measuring solar radiation, solar angle, and PV panel efficiency.

The study carefully analyzes the impact of geographic location, atmospheric conditions, and light physics on the ability to obtain energy. An innovative regulation system based on a clock algorithm, which aims to increase the efficiency of solar systems, is presented. This approach is distinguished by the integration of advanced algorithms using geolocation data and accurate astronomical calculations that allow for optimal positioning of panels to maximize solar energy absorption. The article consists of four main sections. It begins with an introduction that highlights the importance of energy storage in the context of sustainable energy production, with a particular focus on the European Union’s energy goals and the Green Deal. It then moves on to a discussion of the precision required in the
geographic positioning of measurement systems, the impact of light physics, and changing weather conditions on the ability to harvest energy. The last section presents a novel clock algorithm adjustment system designed to increase the performance of the measurement system. Additionally, the article presents an example Python script that illustrates the use of the clock algorithm in practical applications to optimize the performance of photovoltaic systems. This script uses basic astronomical equations to calculate the sun’s azimuth and altitude, which is necessary for the precise positioning of solar panels. Thanks to this tool, it is possible to dynamically adjust the angle of inclination of the panels in real-time, which allows for maximum use of available solar energy. The script is designed to easily integrate with existing PV systems and can be adapted to different geographic locations and system scales.

2. Literature Review

Photovoltaics play a crucial role in the “Green Deal” as one of the most significant elements of the energy transition toward a sustainable and low-emission energy system [7–20]. The transformation encompasses several key aspects:

- Photovoltaics is a renewable energy source, which means that the production of electricity using photovoltaic panels is not associated with the emission of greenhouse gases or the consumption of non-renewable resources.
- The popularization of photovoltaics contributes to a significant reduction in carbon dioxide emissions, especially if it replaces traditional energy sources based on fossil fuels. This aligns with the “Green Deal” goals regarding climate neutrality.
- The development of photovoltaics supports the overall increase in the share of electricity from renewable sources, which is a priority of the “Green Deal”. This promotes the transformation of the energy sector.
- Photovoltaics enables energy production at the local level, especially thanks to installations on building roofs or smaller solar farms. This increases the energy independence of regions and supports local communities.
- Photovoltaics can be used to charge electric vehicles, an integral part of the “Green Deal” strategy concerning the electrification of transport and reducing emissions in this sector.
- Photovoltaics enriches smart energy grids, enabling efficient management of energy production, distribution, and consumption, which supports goals related to energy efficiency.
- Investments in photovoltaics support the development of modern technologies and innovations in the field of energy storage, improving the flexibility and reliability of renewable sources.
- Photovoltaics is an integral part of the pursuit of green production, especially in the industrial sector, where sustainable energy sources are key to minimizing the ecological footprint.

Photovoltaics is an integral part of the “Green Deal” strategy, contributing to the reduction of greenhouse gas emissions, increasing the share of renewable sources in the energy mix, and supporting a sustainable and smart energy system [21]. The “Green Deal” is one of the most important European projects aimed at combating climate change and creating a more sustainable and ecological future for the European Union.

In the current demand for sustainable energy sources, it is necessary to overcome challenges related to transitioning from traditional, unsustainable energy sources to more ecological and sustainable alternatives.

The key elements are:

- Limited resources—The challenge lies in the need to use energy sources that are not only durable but also sufficient to meet the growing global demand.
- Environmental pollution—Conventional energy sources, such as fossil fuels, generate pollution and contribute to climate change. The challenge is to find alternatives that minimize the negative impact on the environment.
Need for modern technologies—Implementing sustainable energy sources requires developing and adapting modern technologies, which can be challenging due to investment costs and the need for continuous research and development.

Variable characteristics of renewable sources—Renewable energy sources, such as solar and wind energy, are variable in availability. The challenge is to develop effective energy storage systems to cope with fluctuating access.

Need for social acceptance—Effective energy transformation requires societal acceptance. The challenge is to persuade people to change habits and attitudes towards energy and to understand the benefits of sustainable sources.

Economic issues—The cost of investing in sustainable energy sources can be challenging, especially in the early stages of implementation. It is necessary to develop economically efficient models to enable the widespread adoption of sustainable solutions.

Variable regulations and energy policy—this results primarily from a lack of consistency in guidelines at the national and international levels. Coordination and cooperation between countries pose further challenges.

In conclusion, the challenges in today’s context of sustainable energy include technical, economic, social, and political aspects, and effectively overcoming them requires cooperation, innovation, and engagement on various levels of the global community.

Photovoltaic efficiency has been addressed in many scientific publications [22–29]. Table 1 presents an overview of this research.

Table 1. Characteristics of methods/models for improving the efficiency and sustainability of solar energy systems.

<table>
<thead>
<tr>
<th>Methods/Models</th>
<th>Source</th>
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<tbody>
<tr>
<td>In the article by Albert Polman et al., the authors review the current state of photovoltaic (PV) materials and their efficiencies, providing a comprehensive overview of the landscape as of 2016. They discuss the various types of PV technologies available, including crystalline silicon, thin films, and emerging materials like perovskites. The authors identify key challenges that need to be addressed to further improve efficiencies and reduce costs, such as enhancing light absorption, minimizing energy losses, and improving the stability of PV materials.</td>
<td>[24]</td>
</tr>
<tr>
<td>In the study by Fuad Alhaj Omar, a novel methodology is introduced to enhance the efficiency of indirectly coupled photovoltaic-electrolyzer systems, which are pivotal for hydrogen production. The research focuses on optimizing the interface between the PV array and the electrolyzer to maximize the overall system efficiency. By employing a new maximum power point tracking (MPPT) technique, the system can adapt to changing solar conditions and ensure that the PV array operates at its most efficient point. The proposed approach also includes a novel energy management strategy that dynamically adjusts the operation of the electrolyzer in response to the variable power output from the PV array.</td>
<td>[26]</td>
</tr>
<tr>
<td>In the study conducted by Bernardo et al., the performance of low concentrating photovoltaic/thermal (PV/T) systems, which simultaneously generate electrical and thermal energy, was evaluated. A case study was carried out in Sweden, where climate poses unique challenges for PV/T technology due to variable sunlight exposure and low temperatures. The findings indicate that PV/T systems can be effective in moderate latitudes, providing a stable source of electrical and thermal energy. This research highlights the potential of integrating photovoltaic systems with thermal technologies as a means to enhance overall efficiency and utilization of renewable energy sources in diverse climatic conditions.</td>
<td>[27]</td>
</tr>
<tr>
<td>Kim et al. made strides in enhancing the efficiency of solar power systems by employing a hybrid control method that leverages differential power processing. This approach is designed to maximize system efficiency by swiftly targeting the zone of maximum power, taking into account various power conversion losses observed during their experimental research.</td>
<td>[28]</td>
</tr>
<tr>
<td>The research outlines two methods for real-time monitoring of solar power systems to capture the peak sunlight intensity. The first method involves a dual-axis solar tracking system that’s user-friendly and relies on Light-Dependent-Resistor sensors, coupled with specially designed printed circuit boards. The second method eschews these sensors in favor of artificial intelligence, specifically neuro-fuzzy systems with a self-adjusting reasoning framework. This AI-driven setup precisely follows the sun’s position throughout the year using solar tracking data on azimuth and elevation angles, leading to a significant boost in efficiency and performance thanks to the neuro-fuzzy adaptive reasoning. By implementing this advanced dual-axis solar tracking system, the study demonstrates a potential increase in energy efficiency for the solar installation under examination, with gains in solar energy capture of up to 24.44% over a stationary setup.</td>
<td>[29]</td>
</tr>
<tr>
<td>Khan and Pushparaj introduced a hybrid controller aimed at optimizing the maximum power point tracking for solar installations, even under changing environmental conditions. They utilized artificial intelligence, specifically fuzzy logic, to achieve a more stable and optimal performance of the solar power system.</td>
<td>[30]</td>
</tr>
<tr>
<td>Rezk and Harrag developed a robust system for tracking the maximum power point, using a more advanced type 2 fuzzy logic to accurately determine the best operating points as conditions fluctuate.</td>
<td>[31]</td>
</tr>
</tbody>
</table>
The research described in Table 1 focuses on specific aspects of PV technology, such as developing new materials, improving light absorption, or minimizing energy losses. Although the described tracking systems represent an important step toward improving the efficiency of solar systems, they indicate opportunities for further development and integration with advanced technologies. Currently, developed tracking systems do not use the full potential of algorithms based on geolocation data and precise astronomical calculations and do not consider variable environmental conditions, such as panel temperature and sunlight intensity, which directly impact the performance of photovoltaic panels.

It is universally acknowledged that the amount of electricity generated by a photovoltaic system depends on many factors, but key factors can be distinguished, including:

- **Solar light intensity**: The amount of solar energy reaching the photovoltaic panels depends on the intensity of sunlight. The geographical location, weather, and time of year affect the amount of energy supplied [32–35].
- **Angle of solar ray incidence**: The optimal tilt angle of photovoltaic panels relative to solar rays can significantly affect their efficiency. Adjusting the angle of the panels to the direction of the sun’s rays increases energy absorption [36,37].
- **Temperature**: High temperature can affect the reduced efficiency of photovoltaic panels. Most panels are more efficient in cooler conditions, so the ambient temperature is an important factor [38,39].
- **Shadow effects**: Shadows on the panels can significantly reduce their efficiency. Therefore, it is important to avoid shadows on the panels, especially during hours when the intensity of sunlight is crucial [40,41].
- **Panel technology**: Different photovoltaic panel technologies have different performance characteristics. For example, monocrystalline panels may be more efficient than polycrystalline ones under certain conditions [42,43].
- **System configuration**: The configuration of the photovoltaic system, including the number, connection, and arrangement of panels, as well as the type of inverter, can affect the overall efficiency of the installation [44,45].
- **Energy export and storage**: The effectiveness of the energy storage system and the potential export of excess energy to the grid affect the overall efficiency of the photovoltaic system [46,47].
- **Panel aging**: Over time, photovoltaic panels may undergo gradual aging, which can affect their efficiency. However, modern technologies strive to minimize this effect [48,49].
- **Technological innovations**: Technological progress in the production of photovoltaic panels, such as new materials or technologies, can affect their overall efficiency [50,51].

Understanding these factors is important for designing, installing, and maintaining photovoltaic systems to achieve optimal performance and efficiency [52,53].

This article focuses on issues aimed at fully understanding the impact of geographical location, the angle of solar ray incidence, and atmospheric conditions on the efficiency of photovoltaic panels. These actions are key to optimizing the efficiency of photovoltaic systems under various environmental conditions.

### 3. Materials and Methods

The topic presented in this chapter is focused on issues related to the precise geographical location of the measurement and actuation system, as well as considering factors related to the physics of light and variable weather conditions. In the context of analyzing the efficiency of photovoltaic panels, understanding the impact of various aspects, both technical and natural, on the overall efficiency of photovoltaic systems is undoubtedly a key element. The efficiency of photovoltaic panels is a multi-dimensional issue. It is not limited to the construction and technology of photovoltaic cells but also includes the complexity of their interaction with the environment and depends on the availability of solar radiation. The greater the amount of solar radiation that falls at an angle of ~90°, the better the energy gain. Therefore, achieving the highest energy production is possible by
ensuring the maximum amount of solar energy falling on the photovoltaic panels. The greater the intensity of sunlight, the greater the current intensity generated by the PV cell. Although the best energy gain is achieved when solar radiation falls perpendicularly to the surface of the panels, the thermal effect should be considered. The thermal effect in the context of photovoltaic panels refers to the effect of temperature on the efficiency of solar panels. When solar panels are exposed to sunlight, their temperature increases, which can lead to reduced performance of the panel’s semiconductor components. High temperatures can reduce the panel’s ability to generate electricity because the internal resistance of the semiconductor material increases, leading to lower voltage and power output. During the irradiation of panels by the Sun, especially when it is at its zenith, they can heat up to high temperatures of the order of 50+ °C, which reduces the efficiency of semiconductor elements and, therefore, the energy gain of photovoltaic cells, as shown in Figure 1.

![Figure 1](image_url)

**Figure 1.** Influence of PV cell temperature on shaping characteristics $I = f(U)$, based on [54].

The above graphs present the current–voltage characteristics of PV panels under theoretical standard test conditions (STC), providing values such as voltage under no-load conditions at 25 °C and a radiation intensity of 1000 $W/m^2$ (Figure 2). Based on these characteristics, it can be confirmed that the higher the solar radiation power, the greater the current intensity generated by the photovoltaic panel. However, the higher the panel heating temperature, the smaller the voltage drop across the cells, which can risk burning them out. Unfortunately, real climatic conditions are significantly different from STC tests. In Poland, photovoltaic modules can heat up to 70 °C at a solar radiation intensity of 1000 $W/m^2$. This is conditioned by the geographical location of the country, the inclination of the PV panels relative to the ground, and weather conditions (cloud cover, sky clarity, wind, dust, etc.). To minimize the negative effects of heating photovoltaic panels and maximize the production of electrical energy, the optimal tilt angle of the panels is determined, considering the solar map of the given country. In Poland, PV panel modules are set in a southerly direction for stationary systems. For the southern region of the country, the optimal tilt angle of the panels is between 20–30°, while for northern Poland, it ranges between 25 and 40°, as shown in Figure 3.

Monitoring the maximum solar potential for energy production using photovoltaic panels cannot be limited to static, modular systems. An increasing number of photovoltaic companies also offer the design and installation of PV panel modules that track the position of the sun in the sky, at least in the vertical direction, i.e., single-axis. However, considering the potential of solar radiation during the entire daily cycle of the sun’s journey across the sky, there is a consensus on the need to construct a tracking system, i.e., one that follows the sun from its rise to its set in the vertical and horizontal planes. The greatest potential for solar radiation is achieved when a constant, optimal angle of incidence of sunlight on the PV panel modules is maintained. A tracking system, known as a solar tracker controlled in both axes, can increase the conversion of light energy into electrical energy by up to 40% [55].
In the field of solar energy tracking systems, there are good practice examples in Europe and worldwide:

- In Poland, installations with single-axis trackers that track the movement of the sun in one plane are used in many photovoltaic projects. They allow you to increase the efficiency of the panels, especially in the spring and summer periods. However, advanced two-axis tracking systems are currently being tested, which can further increase the panels’ efficiency by optimizing the angle of sunlight throughout the day [56,57].
- In Germany, where photovoltaics is highly developed, single-axis and dual-axis trackers are used to maximize the use of weaker sunlight, especially in the winter months [58,59].
- In Spain, which is one of the European leaders in solar energy production, trackers are a key element of many modern photovoltaic installations, increasing their efficiency by up to 30–40% compared to installations without a tracking system [60,61]
- In the United States, especially in states such as California and Nevada, where sunlight is very high, solar trackers are widely used in large photovoltaic farms, making it possible to significantly increase energy production compared to stationary systems [62].

Good practices regarding solar trackers include not only their use but also ongoing monitoring of their operation, regular maintenance, and integration with intelligent energy management systems that allow for the optimization of energy production depending on current needs and weather conditions.

A solar tracker requires an appropriate structure for the anticipated weight of the photovoltaic panels and correspondingly selected servo mechanism power capable of...
controlling a specific mass. These mechanical and structural issues will not be further addressed in this article. However, the most important aspect of designing a tracking system is preparing an optimal control algorithm and a measurement system. To fulfill the assumptions of this article, it is also necessary to consider a method for monitoring the maximum solar potential and, thus, the maximum production of electrical energy. Therefore, it is necessary to consider which sensors to use in this system, which controller, sensor peaking data, and calculations will control the solar tracker, and what method of transmission and data storage read by the controller to apply. This work proposes the development of a system based on Raspberry Pi. Figure 4 presents a proposed solution.

![Figure 4. Block diagram of the photovoltaic measuring system; own study.](image)

In the author’s system for monitoring physical quantities and parameters of the photovoltaic installation, a Raspberry Pi microcontroller was chosen as the tracking system controller. Information read from measurement sensors and data read by the GPS module (responsible for reading the geographical position of the receiver, coordinated universal time, and day of the year) will help optimize calculations of the sun’s position in the sky according to the solar time algorithm, and thus the calculation of the PV panels’ orientation and angle of inclination relative to the earth.

Next, parameters were selected to be transmitted to the SQL database and displayed in the mobile application. The geographical location of the measurement system and the executive system are basic information in the control algorithm to determine the solar azimuth (sunrise point) and, thus, the receiver’s orientation. The application also shows the current angle of the panels relative to the ground with updates, for example, every hour.

Subsequently, the consumer has the opportunity to see the current temperature of the panels, the sunlight power, and the current power generated by the panels.

The capabilities of the tracking control system can be utilized by applying various algorithms (Figure 5). One is the clock algorithm that takes into account the geographical location of the receiver, the date, and time and is based on mathematical calculations that determine the parameters of the sun’s position. This makes it possible to optimally control the receiver in both axes.
The position of the sun can be sufficiently determined by knowing two parameters (see Figure 3):

- the height of the sun above the plane of the earth (horizon) $\alpha$
- solar azimuth $y_s$

In [63], universal formulas were indicated, which were used in the clock algorithm:

$$S = 2\pi \cdot \frac{\varphi}{180}$$  \hspace{1cm} (1)

$$t = 2\pi \cdot \frac{(day - 1)}{365}$$  \hspace{1cm} (2)

$$D = (0.322003 - 22.971 \cdot \cos(t) - 0.357898 \cdot \cos(2t) - 0.14398 \cdot \cos(3t)
+ 3.94683 \cdot \sin(t) + 0.0019334 \cdot \sin(2t) + 0.05928 \cdot \sin(3t)) \cdot \frac{\pi}{180}$$  \hspace{1cm} (3)

$$W = \arcsin(\sin(D) \sin(S) + \cos(D) \cos(S) \cos(15(time - 12))) \cdot \frac{\pi}{180}$$  \hspace{1cm} (4)

$$A = \arccos\left((\cos(S) \sin(D) - \cos(D) \sin(S) \cos(15(time - 12))) \cdot \frac{\pi}{180}\right) / \cos(W)$$  \hspace{1cm} (5)

where:

- $S$—latitude in radians
- $D$—declination of the sun
- $W$—height
- $A$—azimuth
- $Day$—the day of the year (1–365),
- $Time$—time in hour (0–23)
- $\varphi$—latitude of geographical changes

The period of change of the steering angle and the geographical latitude of the city where the executive device is located are constant parameters of the above algorithm. However, time and day read from the GPS module are variable parameters.

The principle operation of the control system according to the clock algorithm is shown in Figure 6.

The algorithm includes several key steps:

- **Geolocation measurement**: The system starts by measuring the geolocation, which allows you to determine the location of the photovoltaic installation.
- **Measuring the angle of incidence of sunlight**: The algorithm then uses measurements of the angle of incidence of sunlight at a given place and time, which allows for determining the optimal angle of inclination of the panels to maximize solar energy absorption.
- **Taking into account the change in the position of the sun**: The algorithm takes into account the change in the position of the sun during the day and depending on the
season, which allows you to constantly adjust the angle of the panels to maintain optimal exposure to solar rays.

- **Tracking system use:** The system uses these data to control a real-time tracking system that adjusts the panels’ tilt angle to optimize performance in changing lighting conditions.

- **Panel temperature monitoring:** The algorithm monitors the panel temperature to prevent overheating, which can negatively impact their performance.

- **Application of the control algorithm:** The control algorithm uses these data to continuously optimize the angle of the panels to maximize electricity production.

![Figure 6. Block diagram of the clock algorithm; own study.](image)

The control algorithm (Listing 1) described in the article is a comprehensive system that considers many factors affecting the efficiency of photovoltaic panels and enables continuous panel angle adjustment to maximize electricity production.

In this work, a simple script example is proposed for visualization, which illustrates the general idea of the clock algorithm, using approximate calculations to determine the position of the sun and the appropriate tilt angle of the photovoltaic panels. The following Python script uses basic astronomical equations to calculate the sun’s azimuth and height above the horizon, which can be used to control a sun-tracking system. It should be added that this is a simplified example and does not consider all aspects of the real environment, such as variability of atmospheric conditions or measurement accuracy. This code defines a function `solar_position` that calculates the solar azimuth and elevation angles. The example usage at the bottom of the script demonstrates how to use this function for a specific location (Gliwice, Poland), date, and time of day (noon). The calculated azimuth and elevation angles are then printed out.
Listing 1. An example of the clock algorithm for the location Gliwice, Poland.

```python
import datetime
import math

def solar_position(latitude, day_of_year, local_time):
    """
    Calculate the solar azimuth and elevation based on the latitude, day of the year, and local time.
    
    :param latitude: Latitude in degrees.
    :param day_of_year: Day of the year (1 through 365 or 366).
    :param local_time: Local time as a float (e.g., 14.5 represents 14:30).
    :return: Solar azimuth and elevation in degrees.
    """
    # Constants
    axis_tilt = 23.45  # Earth's axial tilt in degrees
    day_length = 24.0  # Length of day in hours

    # Convert latitude to radians
    latitude_rad = math.radians(latitude)

    # Calculate the declination of the sun
    declination = math.radians(axis_tilt * math.sin(2 * math.pi * (day_of_year - 81) / 365))

    # Calculate the time correction for solar noon
    time_correction = (2 * math.pi / 365) * (day_of_year - 81)
    time_correction = (9.87 * math.sin(2 * time_correction)) - (7.53 * math.cos(time_correction)) - (1.5 * math.sin(time_correction))

    # Calculate solar hour angle
    solar_noon = 12.0 + (time_correction / 60.0)
    hour_angle = math.radians((local_time - solar_noon) * (360 / day_length))

    # Calculate solar elevation
```
Listing 1. Cont.

```python
solar_elevation = math.asin(math.sin(declination) * 
    math.sin(latitude_rad) + 
    math.cos(declination) * 
    math.cos(latitude_rad) * math.cos(hour_angle))

# Calculate solar azimuth
solar_azimuth = math.acos((math.sin(declination) - 
    math.sin(solar_elevation) * math.sin(latitude_rad)) / 
    (math.cos(solar_elevation) * 
    math.cos(latitude_rad))))

# Convert solar azimuth to degrees
solar_azimuth_deg = math.degrees(solar_azimuth)
solar_elevation_deg = math.degrees(solar_elevation)

# Adjust azimuth from South to West
if local_time > solar_noon:
    solar_azimuth_deg = 360 - solar_azimuth_deg

return solar_azimuth_deg, solar_elevation_deg

# Example usage:
if __name__ == "__main__":
    # Replace with your actual latitude, day of the year, and local time
    latitude = 52.0  # Example for Gliwice, Poland
    day_of_year = datetime.datetime.now().timetuple().tm_yday
    local_time = 14.5  # Example for 2:30 PM

    azimuth, elevation = solar_position(latitude, day_of_year, 
    local_time)
    print(f"Solar azimuth: {azimuth:.2f} degrees")
    print(f"Solar elevation: {elevation:.2f} degrees")
```

Figure 7 visualizes the principle operation of the script. Two graphs were generated: one for the sun’s azimuth and the other for its height above the horizon during the day. These graphs show changes in these parameters depending on the hour of the day for a given latitude and day of the year.
The advantage of a tracking system operating based on such an algorithm is tracking the sun despite unfavorable weather conditions such as cloud cover. The device does not have to “see” the sun to set the panel modules parallel to our star.

The last step of the task of monitoring the maximum solar potential in photovoltaic panel systems is the preparation of a mobile application synchronized with the SQL database.

In conclusion, monitoring the maximum solar potential is crucial for the effective use of solar energy in producing electrical energy. This facilitates:

- optimization of the placement of photovoltaic panels to maximize exposure.
- conducting system performance analysis under different weather conditions.
- planning investments in solar energy based on real data on solar potential in a given region.

The use of various measurement methods and data analysis allows for optimal use of solar energy, contributing to the development of balanced energy sources. Further research in the area of solar potential monitoring can lead to improved photovoltaic technologies and even greater efficiency in the use of solar energy in producing electrical energy.

The tracking algorithm described in the article can be developed by taking into account additional factors affecting the efficiency of photovoltaic panels:

- Use of artificial intelligence: Implementing artificial intelligence technology to analyze data from the tracking system could enable more precise prediction of the optimal position of panels depending on forecast weather conditions.
- Energy consumption optimization: The tracking algorithm could be developed to take into account not only energy production but also energy demand at a given time. This allows the system to optimize energy production depending on current needs.

4. Conclusions

The research presented in this article culminates in several significant conclusions, which are further enriched by the development of a Python script designed to optimize the performance of photovoltaic systems:

- **Optimal geographical positioning**: The study underscores the importance of precise geographical positioning for photovoltaic panels. Optimal orientation and tilt, informed by regional solar mapping, are crucial for maximizing energy capture from solar radiation.

![Figure 7. The principle operation of the script calculating the position of the sun; source: this study.](image-url)
• **Innovative tracking systems**: Implementing solar trackers, particularly those that adjust in two axes, can substantially increase the efficiency of photovoltaic panels. The study demonstrates potential efficiency improvements, emphasizing the value of dynamic tracking systems over static installations.

• **Impact of environmental factors**: Environmental conditions, including temperature, solar light intensity, and atmospheric phenomena, significantly influence photovoltaic efficiency. The research highlights the need for systems that can adapt to these variable factors to maintain optimal performance.

• **Technological advancements**: Advancements in photovoltaic technology, including the development of new materials and system designs, are pivotal for enhancing energy conversion efficiency. The study points to ongoing innovation as a key driver in the evolution of photovoltaic systems.

• **Monitoring and control systems**: A Raspberry Pi-based monitoring and control system is proposed, utilizing a clock algorithm to optimize the orientation and angle of inclination of PV panels. This system is designed to adjust the panels’ position in real-time, accounting for the sun’s trajectory and environmental conditions.

• **Python script for solar positioning**:
  - The Python script developed as part of this research represents a practical tool for calculating the sun’s position in the sky, which is essential for the optimal alignment of photovoltaic panels.
  - By utilizing basic astronomical equations, the script provides a method for determining the azimuth and elevation of the sun, enabling the solar tracker to adjust the panels accordingly.
  - The script’s design allows easy integration with existing photovoltaic systems and can be adapted for various geographical locations and system scales.
  - As a simplified model, the script serves as a foundation for more complex algorithms that could incorporate additional environmental variables and predictive analytics.

In summary, the article contributes to the field of renewable energy by providing a comprehensive analysis of factors affecting photovoltaic panel efficiency and proposing an innovative system for monitoring and optimizing solar energy utilization. The findings underscore the potential for significant improvements in the performance of photovoltaic systems, which is essential for the global transition towards sustainable and low-emission energy sources. The inclusion of the Python script exemplifies the practical application of research findings and offers a pathway for future enhancements in photovoltaic technology.


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