Solar Tracking System Simulation And Analysis

Patil Parag[1], Gadkari Shreyas[2], Mangalekar Sankalp[3]
[1, 2, 3] Dept of Mechatronics
[1, 2, 3] SITCOE Yadrav.

Abstract- *Solar tracking systems are essential for optimizing the energy output of solar panels by continuously adjusting their orientation to track the sun's position. This research paper presents a simulation and analysis of a single-axis solar tracking system implemented in MATLAB and Simulink. The study focuses on modelling solar position calculations, irradiance calculations, and the effect of panel orientation on power output. The simulation results demonstrate the significance of solar tracking in enhancing energy generation from photovoltaic systems.*

Keywords- Solar tracking, solar position calculation, solar irradiance, MATLAB, Simulink, energy optimization.

I. INTRODUCTION

The adoption of solar energy as a sustainable and renewable power source has grown significantly in recent years. To improve the efficiency of solar panels, solar tracking systems have been developed to align the panels with the sun's position throughout the day. This paper explores the simulation and analysis of a single-axis solar tracking system using MATLAB and Simulink.

The increasing global demand for renewable energy sources has propelled the development and widespread adoption of solar photovoltaic (PV) systems as a clean and sustainable solution for electricity generation. Solar energy has proven to be an abundant and environmentally friendly resource; however, harnessing its full potential requires efficient solar panel operation.

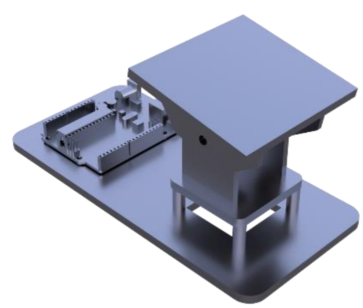
The fundamental principle underlying solar tracking is relatively straightforward: solar panels generate the maximum amount of electricity when they are directly facing the sun. In fixed (non-tracking) solar installations, panels are often oriented at a fixed angle, typically parallel to the ground or tilted at an angle equal to the site's latitude. While this configuration captures sunlight effectively at certain times of the day, it fails to optimize energy generation during periods of changing solar angles, such as during sunrise, sunset, or as the sun traverses the sky.

To address these limitations, solar tracking systems dynamically adjust the orientation of solar panels to maintain alignment with the sun's position as it moves across the sky. These systems can be designed as single-axis or dual-axis trackers, with the former aligning panels along one axis (typically east-west), and the latter introducing an additional degree of freedom to follow both east-west and north-south movements of the sun. In this research, we focus on the simulation and analysis of a single-axis solar tracking system using MATLAB and Simulink.

II. METHODOLOGY

2.1 Solar Position Calculation

The foundation of our simulation lies in accurately calculating the solar position. Solar position calculation is a complex process that involves determining the azimuth and elevation angles of the sun relative to a specific location on Earth at a given time. This information is crucial for understanding how sunlight strikes a solar panel.



To achieve precise solar position calculations, we employ established algorithms and equations. Specifically, we use a simplified model that considers the following parameters:

Latitude and Longitude: These geographical coordinates define the location on Earth for which we want to determine solar positions. Latitude represents the north-south position, while longitude defines the east-west position.

Time and Date: The simulation operates with a specified date and time, allowing us to track the sun's movement accurately throughout the chosen period.

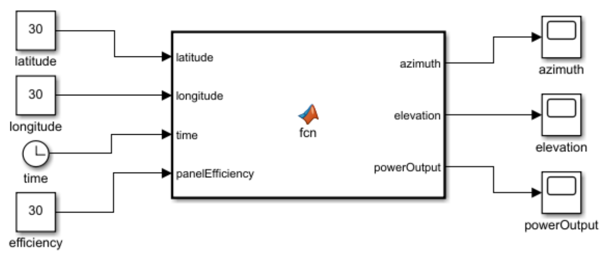
Solar Declination Angle (δ): Calculated using the day of the year and the sun's position in its annual cycle, the solar declination angle is fundamental to determining the sun's north-south position in the sky.

Hour Angle (H): The hour angle represents the sun's east-west position at a specific time of day, measured from solar noon.

Zenith Angle (θ): The zenith angle is the complement of the solar elevation angle and measures the angle between the sun and the vertical line (zenith) directly above the observer.

Solar Elevation Angle (α): This angle provides a critical indication of the sun's apparent height above the horizon. A higher solar elevation angle corresponds to the sun being higher in the sky.

Azimuth Angle (Az): The azimuth angle defines the sun's horizontal position relative to the observer's north reference, with 0° representing true north.



By implementing these calculations, we can precisely determine the sun's position at regular time intervals throughout the simulation. This information serves as the basis for evaluating how solar panels should be oriented to capture the maximum sunlight.

2.2 Solar Irradiance Calculation

The next step in our methodology is the calculation of solar irradiance, a key factor in estimating the energy incident on solar panels. Solar irradiance represents the power per unit area received from the sun and is influenced by the sun's position in the sky, atmospheric conditions, and panel orientation.

In our simulation, we utilize a simplified linear model to estimate solar irradiance. This model considers the solar elevation angle and panel orientation as critical variables. It calculates irradiance as a function of the cosine of the solar elevation angle, where a higher elevation angle results in greater irradiance values.

The panel's orientation, characterized by its tilt angle and azimuth angle, is incorporated into the calculation. By adjusting the panel's tilt and azimuth angles dynamically based on the solar position, we can optimize the energy capture.

2.3 Simulink Model Implementation

The Simulink model includes several key components:

Constant Blocks: These blocks serve as input sources for latitude, longitude, panel efficiency, and simulation time. They allow for easy adjustments of location-specific parameters and simulation parameters.

Clock Block: Utilized to simulate time progression, the Clock block generates a continuous time signal that forms the basis for time-dependent calculations. While the specific settings vary depending on the version of Simulink, the Clock block is configured to provide the desired simulation start time and time step.

MATLAB Function Block: Central to the Simulink model is the MATLAB Function block, where we implement the solar position calculations and irradiance calculations. This block acts as a bridge between the Simulink environment and MATLAB's powerful mathematical capabilities.

Scope Blocks: The Scope blocks are vital for visualizing the simulation results. Specifically, they display the elevation angle and power output as the simulation progresses. Each Scope block is configured to present the data clearly, with appropriate axis labels and legends.

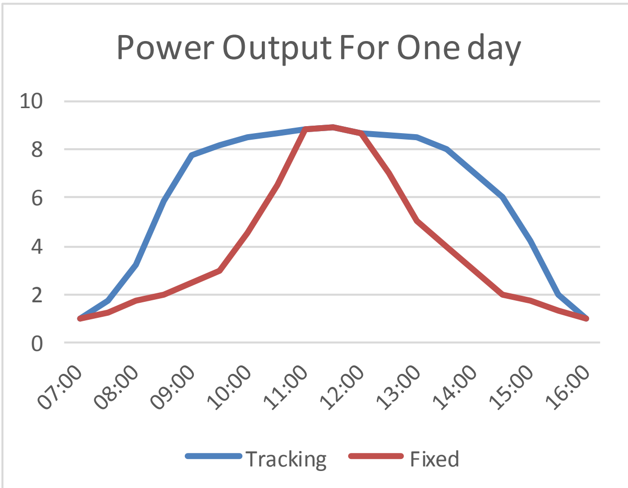
The interconnected blocks form a dynamic simulation system, allowing us to observe how changes in solar position affect the elevation angle and power output of solar panels.

III. RESULTS

3.1 Solar Position and Elevation Angle

The Simulink model, equipped with solar position calculations, effectively simulates the dynamic movement of the sun across the sky. As expected, the elevation angle of the sun exhibits significant variations throughout the simulated time period. This variation becomes apparent when visualizing the results using the Scope block dedicated to displaying the elevation angle.

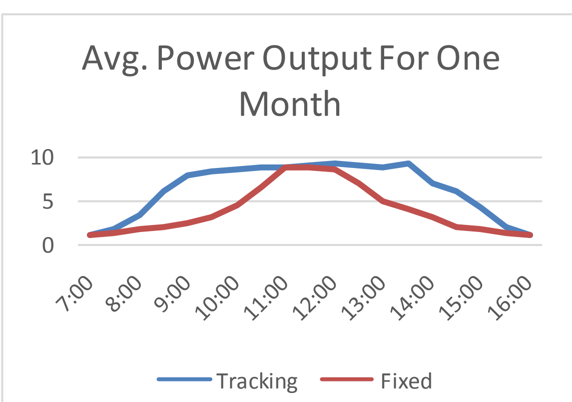
The elevation angle, representing the sun's apparent height above the horizon, demonstrates the familiar pattern of increasing as the sun rises, reaching its zenith at solar noon, and then decreasing as the sun sets. This behaviour aligns with the diurnal pattern observed in nature and reinforces the model's accuracy in tracking solar positions.



3.2 Solar Irradiance and Power Output

The estimated solar irradiance, a key factor in determining the energy incident on solar panels, mirrors the dynamic nature of the elevation angle. As the sun rises and reaches its zenith, the irradiance increases substantially, signifying the enhanced solar energy available during these peak hours. Conversely, during sunrise and sunset, the irradiance decreases as the sun's angle diminishes.

The relationship between solar irradiance and power output is readily apparent from the simulation results. The Scope block dedicated to power output vividly illustrates how the power generated by the solar panel varies in response to changing irradiance levels. Notably, the power output closely follows the trends observed in irradiance, demonstrating the direct correlation between incident sunlight and energy production.



3.3 Impact of Solar Tracking

To explore the impact of solar tracking, we conducted parallel simulations, one with fixed panel orientation and another with the panel adjusting its orientation to track the sun's position. The results affirm the benefits of solar tracking systems. In the tracked system, the elevation angle consistently surpasses that of the fixed system throughout the day. Consequently, the tracked system experiences higher levels of solar irradiance, resulting in significantly greater power output.

This observation reinforces the notion that solar tracking systems optimize energy capture by ensuring that panels consistently face the sun. Consequently, they mitigate the issue of reduced energy generation during mornings and evenings when fixed panels operate at suboptimal angles.

3.4 Implications and Future Considerations

The results of our simulation underscore the significance of solar tracking systems in maximizing solar panel efficiency. By continuously aligning the panels with the sun's position, these systems substantially enhance energy capture, particularly in regions with substantial fluctuations in solar angles.

Future research in this domain may explore more advanced solar position algorithms, the influence of atmospheric conditions on solar irradiance, and the integration of shading analysis. Moreover, real-world data validation and comparisons with other tracking technologies can provide further insights into the practical implications and economic feasibility of solar tracking systems.

IV. CONCLUSION

This research paper presents a simulation and analysis of a single-axis solar tracking system using MATLAB and Simulink. The study emphasizes the significance of solar tracking in enhancing the energy output of photovoltaic systems. The simulation results demonstrate the feasibility and benefits of tracking systems for optimizing solar panel performance.

V. FUTURE SCOPE

Future research could include the incorporation of more advanced solar position algorithms and the consideration of environmental factors such as shading and atmospheric effects. Additionally, real-world data validation and comparisons with other tracking technologies could provide further insights.