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INNOVATION IN ACTION: TURNING IDEAS INTO REALITY

Chapter 60
Portable Dual-Axis Solar Tracking System with 3D Printed Structure and IoT-Based Real-Time Energy Monitoring

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ABSTRACT

Solar radiation is one of the cleanest sources of renewable energy harvested throughout the world. However, the production of energy from the so-called "large-scale solar farm" is constrained by the availability of sunshine, with "peak sun hours" ranging from approximately four to six hours per day depending on the location of the solar panels. Solar panels installed on the ground or on roofs produce less power during sunrise and sunset than they do during the middle of the day. An automated solar tracking system, on the other hand, can increase energy production since it actively tracks the passage of the sun across the sky. When compared to their static counterparts, single-axis trackers can boost energy production by between 10 to 30%, while dual-axis trackers can enhance production by as much as 40%. This portable solar tracker, which was inspired by sunflowers, not only tracks the sun's movement in response to the presence or absence of light, but it also includes environmental sensors and an Internet-of-Things (IoT) energy monitoring system to provide real-time observation, data collection, and evaluate its overall performance. All these features are operated on this newly introduced simple portable energy monitoring device that comes together with customisable C programming language and python-based application to visualise all the data in real-time. This new development is adaptable for use in portable settings, such as in the military, in Search and Rescue (SAR) operations, and in leisure settings. Additionally, it has applications in the field of space exploration, particularly in satellites, planetary rovers, and the International Space Station (ISS).

Key Words: solar panels, energy, dual-axis trackers, 3D printed structure, Internet-of-Things.

1. INTRODUCTION

The world has been continuously searching for the most environmentally friendly and readily available source of electricity to continue evolving due to the current electricity issue. Renewable energy is energy derived from renewable natural resources like sunlight, wind, tides, water, biomass, and geothermal energy. Solar energy is one of the most promising renewable resources due to its abundance and sustainability. Despite significant advancements in photovoltaic (PV) technology, the efficiency of solar panels remains limited when fixed in position. A dual-axis solar tracking system can enhance energy harvesting by aligning the panel to follow the sun’s azimuth and elevation throughout the day. However, conventional trackers are often bulky, expensive, and not suitable for portable applications. This project introduces a portable dual-axis solar tracking system featuring a 3D printed structure, offering lightweight, low-cost fabrication and easy deployment. Additionally, the system is integrated with an IoT-based real-time energy monitoring platform, enabling remote performance tracking via the internet.

2. LITERATURE REVIEW

Electricity is an essential component of nature and one of the most employed forms of energy. Electricity is also known as an energy carrier because it can be converted into other forms of energy, such as mechanical energy and heat. In photovoltaic cells, the efficiency with which sunlight is converted into usable energy varies depending on the type of semiconductor material used and the technology used to make the PV cells. The efficacy of experimental PV cells and PV cells for specific applications, such as satellites in orbit, is close to 50%. Thus, solar energy research on the usage of photothermal (PT) and photovoltaic (PV) has supported the technological development and broad application of energy supply systems based on solar energy in the field of building as an important type of renewable energy (Wang et al., 2023).

Like the behaviour of a sunflower, single-axis trackers also orient themselves towards the sun, aligning their position accordingly. Due to this distinctive motion, they can maintain a perpendicular angle to the sun for prolonged durations, enabling them to absorb significantly higher amounts of energy (often 12-40% more) compared to their counterparts installed for regular usage. But for dual-axis trackers exhibit a high level of diligence and responsibility. These cutting-edge devices can precisely track the movement of the sun in both the east-west and north-south directions, so promising that they are always positioned in such a way as to provide them with direct sunlight. For ThingSpeak IoT database, a remote monitoring and analysis tool for solar trackers, ThingSpeak connects with microcontroller boards such as Arduino and Raspberry Pi. Users may construct customised dashboards with interactive charts and graphs thanks to its dynamic data visualisation capabilities, which offer real-time insights into solar tracker performance parameters.

3. METHODOLOGY

The solar tracker body part is printed using 3D printing methods. First, using Tinkercad an online 3D modelling tool that runs on a web browser, the body parts of the solar tracker were designed after the sizes of the solar panel and servos were measured. Afterwards, the design was stored in a stereolithography (STL) file format and subsequently imported into UltiMaker Cura (Fig. 3.1), the last software application before printing. The Creality Ender-3 3D printer model with PLA 3D printing filament were then used to print the designs (Fig. 3.2). The same process was repeated for constructing four similar mini solar panel grips that were attached to each side of the main solar panel. Assembly and testing came next, following the successfully completed printing of every design.

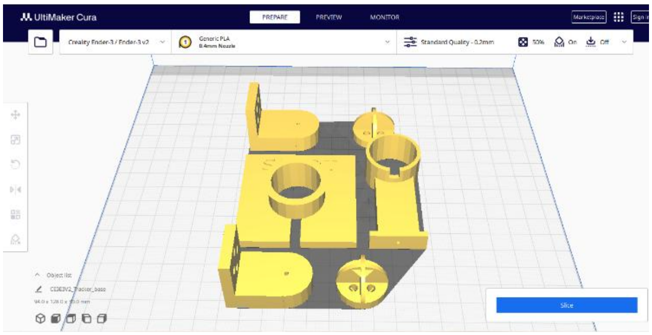

Figure 3.1: Designed solar tracker body parts STL file being transferred into UltiMaker Cura.

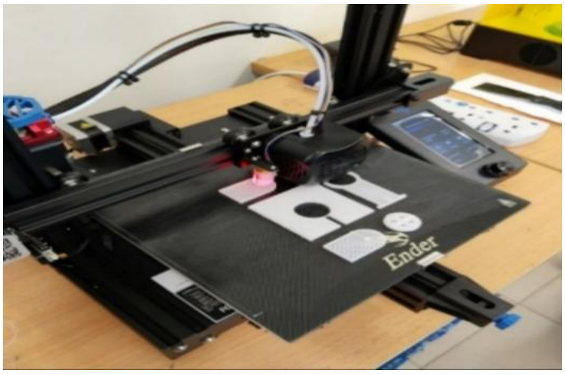

Figure 3.2: Solar tracker body parts printing process

4. RESULT AND DISCUSSION

The performance of the dual-axis solar tracker system is illustrated in Figure 4.1, which shows the system's real-time power output and energy generation. The tracker effectively captured solar energy throughout the day by continuously adjusting its orientation according to the changing position of the sun. This real-time adjustment resulted in visible fluctuations in power output, reflecting the system's responsiveness in maximizing energy collection under different sunlight conditions

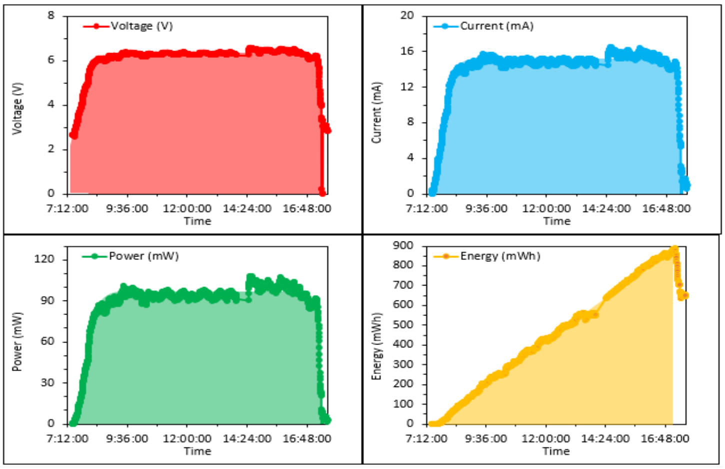

Figure 4.1: Dual axis solar tracker performance

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Throughout the testing period, the total energy produced by the system was 892 mWh. Voltage readings varied between 2 to 8 volts, depending on the intensity of solar irradiance at different times of the day. The current output peaked at 16 mA, indicating efficient current flow during periods of high sunlight exposure.

These findings confirm that the dual-axis tracking mechanism significantly enhances solar panel alignment and overall energy production. The system's continuous tracking of the sun's movement in both azimuth and elevation contributes to its high performance and makes it suitable for applications that require reliable and efficient solar energy generation.

The integration of Internet of Things energy monitoring into this study successfully provided data in real time regarding the operation of the solar energy system and the amount of energy it generates via ThingSpeak (Figure 4.2). IoT devices, such as sensors and smart metres, have the capability to gather and communicate data on a variety of factors, such as solar irradiance, panel tilt angles, energy output, and system efficiency (Gupta & Kumar, 2020).

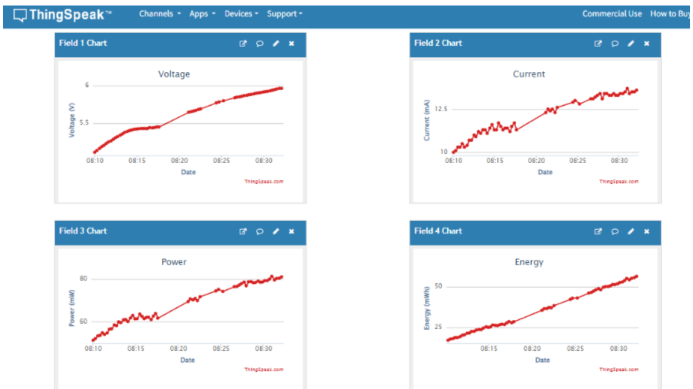

Figure 4.2: Real-Time IoT monitoring of dual axis solar tracker using ThinkSpeak

5. CONCLUSION AND RECOMMENDATION

In conclusion, integrating IoT-based energy monitoring with a dual-axis solar tracking system presents a significant advancement in solar energy harvesting. This combination enables real-time remote monitoring and enhances energy output by up to 40% compared to fixed systems. The incorporation of a 3D-printed structure further contributes to the system's portability, cost-effectiveness, and ease of deployment, making it suitable for use in remote or mobile environments. These innovations support the broader adoption of solar energy, contributing to cleaner and more sustainable energy solutions.

For future improvements, research could explore the potential of origami-inspired designs to develop lightweight, foldable, and adaptable solar trackers that offer greater flexibility and ease of deployment. Additionally, the integration of self-cleaning technologies such as hydrophobic coatings or retractable wipers could help minimize dust accumulation on solar panels. Incorporating remote maintenance and diagnostic features may also reduce the need for manual intervention and extend the system's operational lifespan. These developments could further enhance the efficiency, autonomy, and practicality of portable dual-axis solar tracking systems with IoT integration.

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