UNIVERSITI TEKNOLOGI MARA

E-PROCEEDINGS

INTERNATIONAL TINKER INNOVATION & ENTREPRENEURSHIP CHALLENGE (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

23 January 2025
PTDI, UiTM Cawangan Johor
Kampus Pasir Gudang

e ISBN 978-967-0033-34-1

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ORGANIZED BY:

Electrical Engineering Studies, College of Engineering
Universiti Teknologi MARA (UiTM) Cawangan Johor
Kampus Pasir Gudang
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A-ST007 - A-ST159

A-ST009: ADVANCED SOLAR TRACKING SYSTEM WITH TEMPERATURE CONTROL AND REAL-TIME MONITORING

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ABSTRACT

The increasing demand for renewable energy has highlighted the inefficiencies of conventional static solar panels, which fail to maximize energy capture due to their inability to adapt to changing sunlight angles and environmental conditions. Addressing this challenge, this work presents the development of a Smart Solar Tracker system featuring wireless monitoring, temperature optimization, and real-time visualization utilizing the ESP32 microcontroller. The system integrates key components such as a humidity sensor, light-dependent resistor (LDR) sensor, servo motor, relay module, and LCD display, working in unison to optimize solar panel performance. The incorporation of a Wi-Fi module transforms the setup into an Internet of Things (IoT) device, enabling remote monitoring and control capabilities. The LDR sensor detects variations in light intensity, allowing precise adjustments of the solar panel's position via the servo motor to maximize solar energy capture. Meanwhile, the temperature and humidity sensors provide critical environmental data to ensure efficient system operation. Leveraging the Wokwi simulation platform, the Arduino microcontroller processes sensor inputs and executes intelligent decision-making algorithms. These algorithms dynamically control the servo motor, relay module, and LCD display, adapting the system based on environmental conditions. The use of IoT technology enables enhanced accessibility through remote connectivity, offering real-time data visualization and system management. This scalable and versatile solution advances solar tracking by combining automation, wireless monitoring, and IoT integration, paving the way for improved energy efficiency and user accessibility.

Keywords: Smart Solar Tracker, Wireless Monitoring, Temperature Optimization, ESP32, IoT, Wokwi Simulation Platform.

1. Product Description

The Smart Solar Tracker is an innovative system designed to optimize solar energy capture through automated panel alignment and real-time monitoring. This system integrates a servo motor for precise solar panel positioning, an LDR sensor to detect light intensity, and temperature and humidity sensors to ensure optimal operating conditions.

Equipped with an ESP32 microcontroller and a Wi-Fi module, the tracker transforms into a versatile IoT-enabled device, offering remote monitoring and control capabilities. Data from the sensors is processed via intelligent Arduino code, which dynamically adjusts the panel's position and displays real-time information on an LCD screen. The inclusion of Wokwi's simulation platform enhances development and testing, ensuring robust performance. The system features wireless connectivity for convenient remote access, enabling users to monitor and manage solar panel conditions from anywhere. Its efficient design maximizes energy output while ensuring reliability and scalability for various applications. This IoT-integrated solar tracker provides an advanced, user-friendly solution for sustainable energy management.

2. Block diagrams and Flow Charts

Figure 1 presents the block diagram of the advanced solar tracking system, showcasing the integration of key components and their interconnections. At its core, the ESP32 microcontroller serves as the central processing unit, interfacing with input sensors (LDR and DHT for light, humidity, and temperature) and output devices such as the servo motor for solar panel adjustment, a relay module for power control, an LCD display for real-time visualization, a buzzer for alerts, and a Wi-Fi module for IoT connectivity via the Blynk server. The flow of data and commands highlights the system's modular and scalable architecture, emphasizing its efficiency in monitoring and automation.

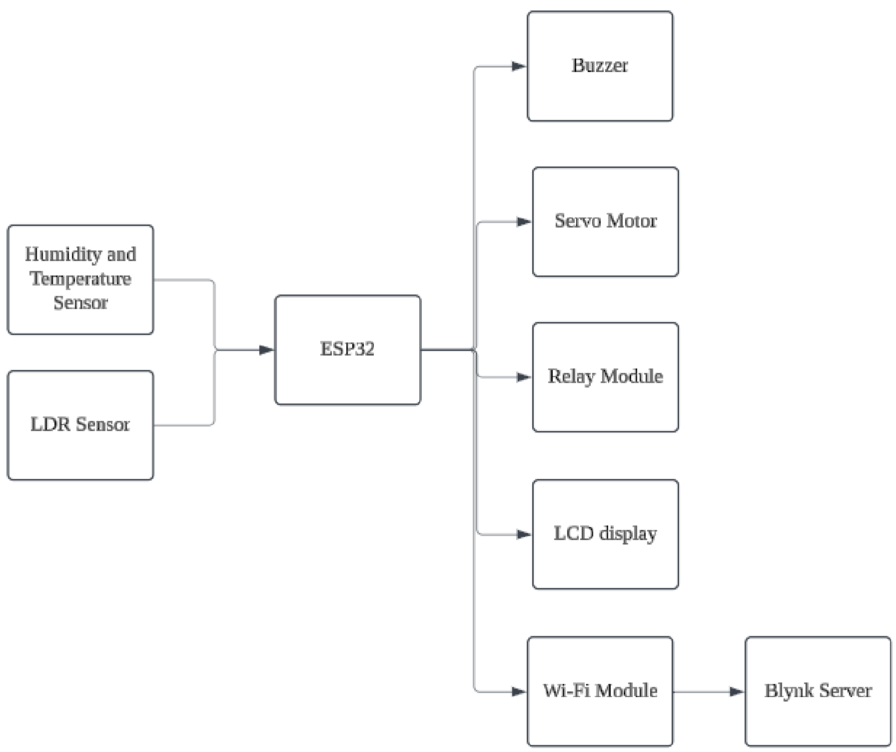

Figure 1. Block Diagram of Advanced Solar Tracking System with Temperature Control and Real-Time Monitoring

Complementing this, **Figure 2** provides a detailed flowchart that outlines the operational logic of the system. It begins with the initialization of components and proceeds through stages of environmental data acquisition, validation, and transmission. Key decision-making processes ensure optimal solar tracking by adjusting the panel's orientation based on LDR readings, controlling the servo motor, and triggering alerts if temperature thresholds are exceeded. The system collects and updates data in real time, adapting dynamically to environmental changes while providing user feedback via the LCD display and Blynk platform. Together, these figures illustrate the seamless integration of hardware and software in achieving an energy-efficient, IoT-enabled solar tracking solution.

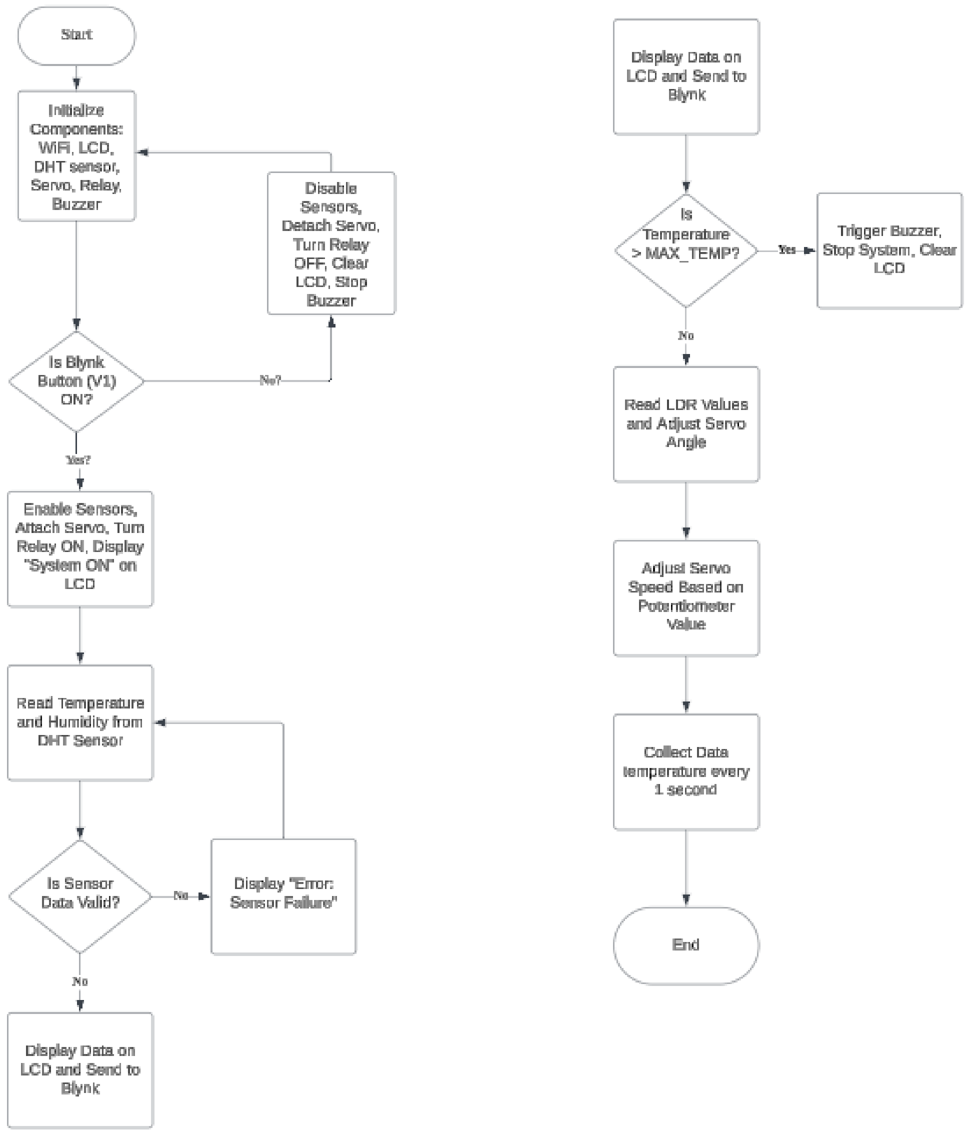

Figure 2. Flowchart of Advanced Solar Tracking System with Temperature Control and Real-Time Monitoring.

3. Novelty and uniqueness

A unique feature of this project is the incorporation of temperature monitoring and automatic system shutdown when high temperatures are detected, enhancing safety and preventing potential damage to the hardware. Furthermore, the use of a potentiometer to control the servo motor speed adds adaptability, allowing the system to perform efficiently under varying environmental conditions.

The system is also integrated with the Blynk IoT platform, providing real-time monitoring and remote-control capabilities. This distinguishes it from traditional solar trackers by offering live performance data, including temperature, humidity, and system status, directly to the user’s mobile device.

From a performance perspective, the combination of servo motors, LDR sensors, and real-time feedback ensures precise tracking of the sun’s position, resulting in improved energy output compared to static solar systems. Additionally, the project's modular design and scalability allow for further enhancements, such as dual-axis tracking or predictive algorithms, making it adaptable to future advancements in solar technology.

4. Benefit to mankind

The Smart Solar Tracker enhances energy efficiency by dynamically adjusting solar panel positioning to maximize sunlight capture. This leads to increased renewable energy production, reducing reliance on non-renewable sources and lowering electricity costs for consumers. By improving energy self-sufficiency, especially in areas with unreliable grids, it supports both economic growth and quality of life. On a global scale, the project contributes to environmental sustainability by reducing greenhouse gas emissions and promoting the use of clean, renewable energy. The inclusion of safety features, like temperature monitoring, ensures long-term reliability and durability of solar systems. By optimizing solar energy harvesting, this system fosters energy conservation, supports efforts to combat climate change, and promotes a sustainable future. Ultimately, the Smart Solar Tracker helps create a more resilient and eco-friendly energy infrastructure, benefiting individuals, communities, and society at large.

5. Innovation and Entrepreneurial Impact

The Smart Solar Tracker fosters innovation by utilizing real-time data from sensors and adaptive control mechanisms to optimize solar energy capture, outpacing traditional static systems in efficiency. Its scalable design makes it suitable for residential and commercial applications, with the potential for future enhancements. This project encourages entrepreneurship by offering a market-ready solution that can be integrated into existing solar infrastructure, opening opportunities for startups in the renewable energy sector. In academia, it provides hands-on experience with IoT, automation, and energy management, bridging the gap between theoretical knowledge and industry practices. By inspiring the development of practical solutions for global energy challenges, the project promotes a culture of innovation and entrepreneurial thinking, encouraging students and researchers to create sustainable, impactful technologies.

6. Potential commercialization

The Smart Solar Tracker system has strong commercialization potential in the renewable energy market. By partnering with solar panel manufacturers or energy providers, it can be marketed as an advanced add-on to enhance solar energy capture and efficiency. With IoT integration, the system enables remote monitoring and real-time data visualization, making it ideal for both residential and commercial applications. Offered as a Software-as-a-Service (SaaS), the system can be easily customized with regular updates for optimal performance across various environmental conditions. Its scalability allows it to be adapted to different market segments, from small residential setups to large-scale commercial solar installations. This cost-effective solution maximizes solar energy output, making it an attractive offering in the growing global renewable energy sector.

7. Acknowledgment

The project is financially supported by the Electrical Engineering Studies, College of Engineering, Universiti Teknologi MARA Johor Branch, Pasir Gudang Campus, Masai, Malaysia

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Shohibul Syahmi Bin Mahmuddin is a student of Electrical and Electronic Engineering at Universiti Teknologi MARA (UiTM). His final year project focuses on developing a solar tracking system with temperature control and Real-time monitoring. Combining innovation with practical engineering solutions, Shohibul aims to contribute to sustainable energy systems and renewable technology. His project highlights the importance of optimizing energy generation through automation and smart systems, bridging academic research with real-world applications.

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