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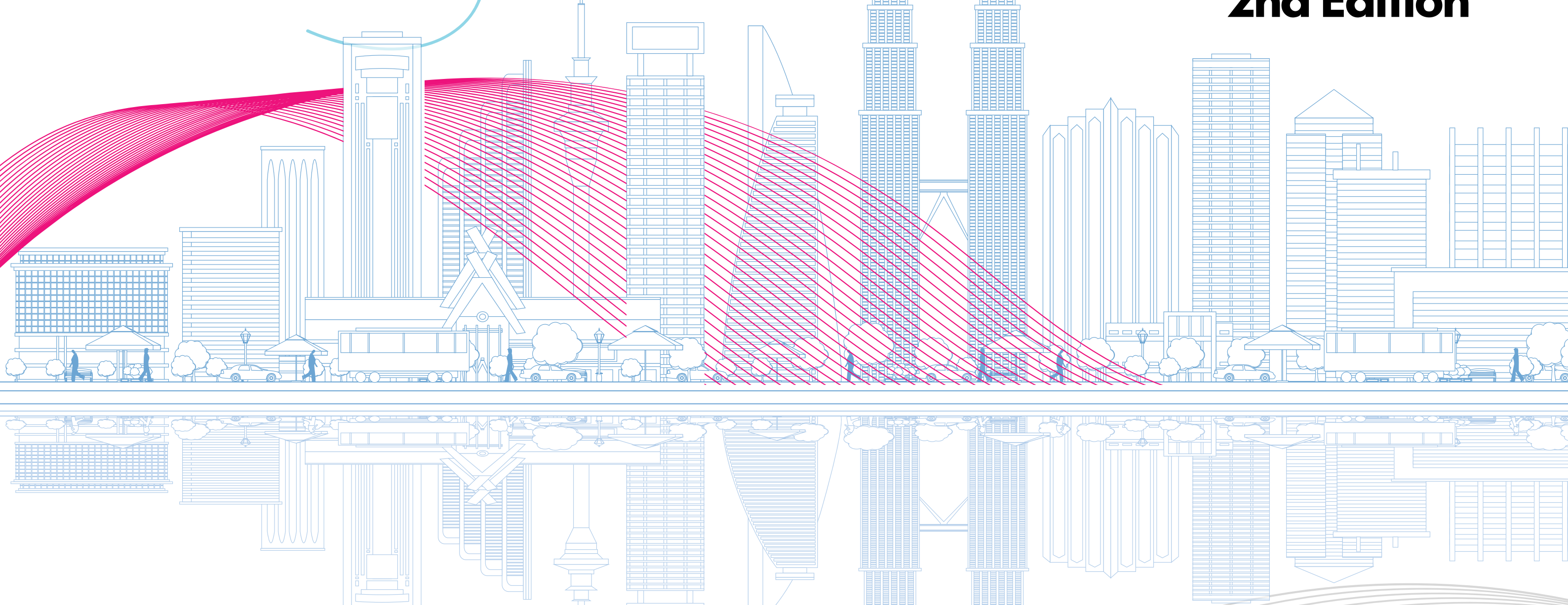

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OPTIMIZING RENEWABLE ENERGY HARVESTING THROUGH THE DESIGN OF A SUSTAINABLE DUAL-AXIS SOLAR TRACKING SYSTEM

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Abstract

Malaysia has significant renewable energy potential, which can be maximized using dual-axis solar tracking systems that maintain optimal alignment with the sun, enhancing energy efficiency. The primary challenge, especially in regions like Bukit Besi in Terengganu with abundant sunlight, is ensuring solar panels remain perpendicular to the sun to maximize energy production, a problem traditional static panels fail to address. This project designs an effective dual-axis solar tracker that continuously adjusts panel orientation for maximum sunlight absorption. The methodology includes mechanical engineering design and simulations using SolidWorks and Tinkercad to ensure structural and circuit functionality. The tracker's performance is verified by measuring the angle of sunlight and input voltage. The result is an optimally designed tracker with a complete electric and control system, significantly boosting solar system efficiency by keeping panels perpendicular to the sun's rays. The design concept and control system have been successfully developed, with future plans for fabrication. This innovation offers commercial potential, providing affordable solutions for integrating renewable energy into the expanding solar market.

Keywords: *Dual-Axis Solar Tracker, Solar Energy Efficiency, Renewable Energy Integration, Solar Tracking System, Mechanical Design and Simulation*

1. INTRODUCTION

Renewable energy sources are crucial due to depletion, rising carbon footprints, and international commitments. “Photovoltaic solar energy, easily available and deployable, produces low energy during the sun's rising and setting hours” (Sharma & Rohilla, 2021). The studies (Mamodiya & Tiwari, 2021) have defined that the inefficiency of current solar technologies, particularly conventional static solar panels, which fail to maintain optimal alignment with the sun throughout the day, results in subpar energy production. This issue is especially pertinent in regions like Bukit Besi, and Terengganu, where sunlight is abundant. To address this problem, the objective of this research is to design a dual-axis solar tracking system that continuously adjusts to maintain solar panels perpendicular to the sun's rays, thereby optimizing solar energy absorption and improving energy efficiency. The project scope includes the design and simulation of the dual-axis solar tracker, with a focus on mechanical design using SolidWorks and circuit simulations using Tinkercad. The functionality of the tracker is verified through measurements of input voltage and sunlight angles, following methodologies demonstrated by (Awasthi et al., 2020) and (Mamodiya & Tiwari, 2023). The comprehensive approach ensures the system's optimal performance, with the expected result being a significant increase in solar system efficiency, making renewable energy integration more feasible in areas with abundant solar radiation.

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The design concept and control system have been successfully developed, with future plans for fabrication, demonstrating the project's potential to provide affordable renewable energy solutions.

2. METHODOLOGY

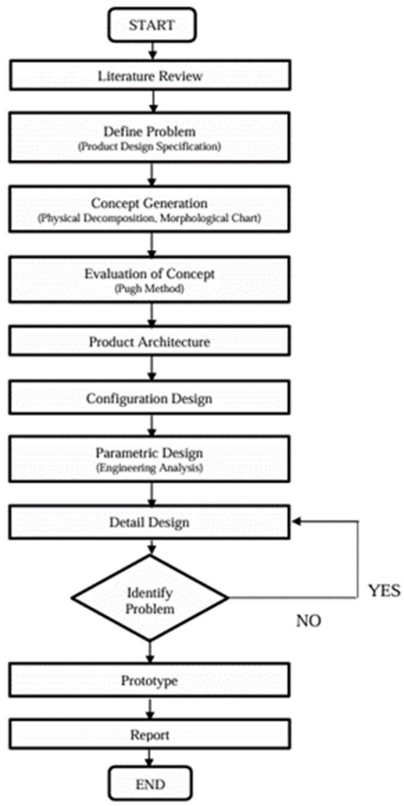
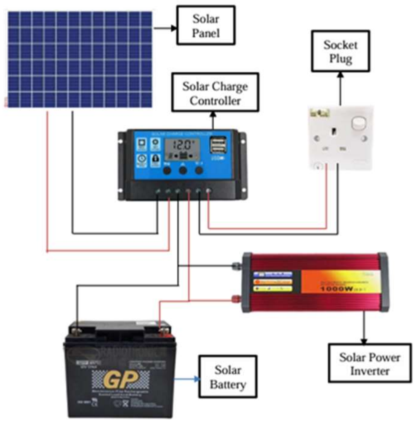


Figure 1. Mechanical Engineering Design Flowchart

Figure 1 outlines the essential processes involved in the design and construction of a Dual-Axis Solar Tracker to ensure its effectiveness and efficiency. Initially, a comprehensive literature review is conducted to identify existing issues with current solar tracking systems. Following this, the problem is clearly defined, and various concepts are generated using morphological charts and physical breakdown techniques. The Pugh method, based on data derived from product design specifications, is then employed to select the most suitable concept. The product architecture is developed to detail the configuration and interconnection of components for optimal energy transfer. Detailed designs, including assembly instructions, component lists, and exploded view drawings, are subsequently prepared. Engineering evaluations are performed to verify the strength and specifications of the components. Finally, a prototype is constructed and assessed against the expected outcomes.

3. RESULTS AND DISCUSSION



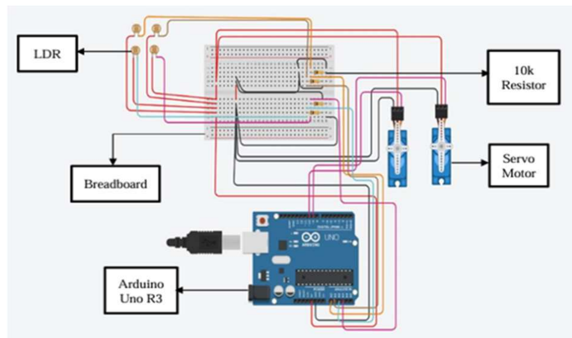


Figure 2. Solar Circuit Diagram

Figure 3. Control System Circuit Diagram

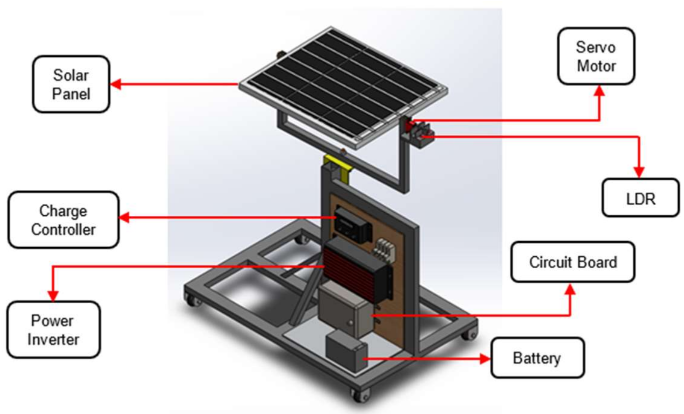


Figure 4. Assembly of Dual-Axis Solar Tracker

Figure 2 illustrates the essential components of the solar circuit diagram, including the solar panel, solar charge controller, power inverter, socket plug, and solar battery. The solar panel generates electricity, which is regulated by the charge controller before being distributed to the inverter and battery. Figure 3 presents the Arduino circuit layout, where two servo motors are connected to pins 9 and 10, and four Light Dependent Resistors (LDRs) are attached to pins A0, A1, A2, and A3. As (Singh et al., 2022) the servo motor moves the solar panel based on LDRs, maintaining consistent light intensity on all resistors, and adjusting intensity based on changes in one or more LDRs. This setup enables precise control of the solar panel's orientation. Figure 4 offers an assembly drawing detailing the configuration of all 16 parts and illustrates the assembly process for the Dual-Axis Solar Tracker.

The tracker's durability is ensured by its robust mechanical design, validated through SolidWorks simulations, and its reliable circuit performance, confirmed by Tinkercad testing. These promising results indicate that this technology provides scalable and cost-effective solutions for integrating renewable energy, with significant potential for solar sector growth in Malaysia, particularly in the Bukit Besi region. Future work will focus on manufacturing and comprehensive field testing to further validate these findings.

4. CONCLUSION

The detailed structure and circuit diagram drawings indicate that this iterative adjustment approach marks a significant advancement over conventional static panels. Although the results are promising, challenges such as potential mechanical wear and initial installation costs remain. Practically, this technology shows great promise for widespread adoption in sun-rich regions like Bukit Besi. Theoretically, it represents a notable advancement in solar tracking technology, offering a scalable and cost-effective solution for integrating renewable energy in developing areas. The successful design and preliminary testing of the dual-axis tracker open the door for further innovations. Future efforts should concentrate on construction and extensive field testing to resolve any functional issues and confirm the system's long-term reliability and effectiveness.

5. ACKNOWLEDGMENT

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