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Simulation of Automatic Solar Tracker Control System Using Proteus Application

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***Abstract*— As a tropical country, Indonesia possesses significant renewable energy potential, particularly from solar and wind sources. However, seasonal variations—such as high solar intensity during the dry season and increased wind speeds during the rainy season—pose challenges to optimizing solar cell utilization. While solar energy presents an ideal solution for clean energy transition, static photovoltaic (PV) systems suffer from efficiency limitations due to their inability to track the sun's movement. Dual-axis solar trackers can enhance energy efficiency by 25–35% compared to fixed systems, particularly in tropical regions with dynamic solar positioning. However, large-scale physical implementation requires substantial investment, making simulation tools like Proteus essential for computational validation prior to real-world deployment. Proteus facilitates comprehensive modeling of LDR sensors, servo motors, and microcontroller-based control algorithms (e.g., Arduino) in a precise virtual environment. This approach also evaluates the impact of tropical conditions (e.g., humidity, rainfall) on system reliability while optimizing designs to reduce costs. Integrating current research with Proteus simulations offers a robust methodology to accelerate solar tracker adoption in Indonesia.**

Keywords: ***Solar tracker, LDR, Proteus simulation, renewable energy,***

I. Introduction

Indonesia as a tropical country has great renewable energy potential, especially from sunlight and wind. However, seasonal variability such as the dry season with high solar intensity and the rainy season with increasing wind speeds pose challenges in optimal utilization of solar cells [1]. Indonesia's potential for high solar energy makes it an ideal solution for the clean energy transition, but the efficiency of static photovoltaic (PV) systems is often limited due to the inability to optimally follow the movement of the sun [2], [3]. Dual-axis solar trackers can theoretically increase energy efficiency by up to 25-35% compared to static systems, especially in tropical areas with significant variations in the position of the sun throughout the day [4]. However, direct physical implementation requires large investments, so simulations using software such as Proteus are a critical stage to validate system performance computationally before realization in the field [5].

Proteus enables comprehensive modeling ranging from LDR sensors, servo motor actuators, to microcontroller-based control algorithms such as Arduino or PIC in a precise virtual environment [6]. This simulation approach also enables analysis of the impact of Indonesia's tropical environmental factors such as high humidity and rainfall on system reliability, while optimizing the design to reduce production and maintenance costs [1]. Thus, the integration of current literature studies and Proteus-based simulations offers a methodological solution to accelerate the adoption of solar tracker technology in Indonesia.

II. Methods

Some of the main components that make up a solar tracker include:

A. Arduino UNO

Arduino is an open-source electronic platform based on microcontrollers that is widely used for prototyping projects, including in control and automation systems. This platform is popular because of its ease of programming using C/C++ language and its flexibility in interacting with various sensors and actuators. Arduino is often used in renewable energy research, such as solar trackers, because of its ability to process sensor data and control servo motors in real-time [6][7][8] [9].

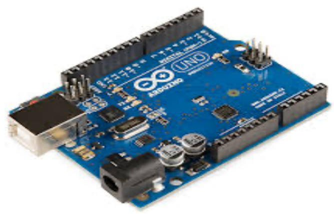

Fig.1. Arduino UNO

B. Solar Cell

The Solar cells are semiconductor devices that convert sunlight energy into electrical energy through the photovoltaic effect. This technology is an important solution in the renewable energy transition because it is environmentally friendly, abundantly available, and has the potential to reduce carbon emissions. The efficiency of solar cells continues to be improved through various material innovations, such as the use of single crystal silicon, thin-film, or perovskite, which offer higher energy conversion at lower production costs [5], [10], [11].

Fig.2. Solar Cell

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C. Light Dependent Resistor (LDR)

Light Dependent Resistor (LDR) is a light sensor component whose resistance changes significantly based on the intensity of light it receives. When exposed to light, the resistance of the LDR decreases, while in dark conditions its resistance increases. This property makes LDR widely used in applications such as automatic lighting systems, solar trackers, and light intensity meters [12], [13].

Fig.3. LDR

D. Servo Motor

Servo motors are precision actuators capable of controlling position, speed, and torque with high accuracy through a feedback loop. These motors are widely used in robotics applications, solar trackers, and industrial automation systems due to their ability to respond to control signals quickly and stably. Servo motor performance is highly dependent on controller design, such as PID or fuzzy logic, to reduce position and oscillation errors [14].

Fig.4. Servo Motor

E. Proteus

Proteus is one of the electronic simulation software that is widely used to design and analyze electronic circuits, including microcontrollers and PCBs. This application allows users to perform real-time simulations before physical implementation, thereby reducing the risk of errors and development costs. Proteus also supports a variety of electronic components and microcontroller programming, making it an efficient tool for education and research in electrical engineering[5], [8], [15].

F. Langkah Kerja

The following are the steps taken in this study:
1. Create a simulation design on proteus using Arduino, Solar Cell, LDR and Servo Motor components.
2. Program Arduino on Arduino IDE.
3. Compile the program code.
4. After successfully importing the ".ino.hex" file, the result of compiling the Arduino components on proteus.

III. Results and Discussion

Based on experiments with Proteus software, the results of the servo motor position are as follows:

Sunlight Conditions	LDR 1	LDR 2	LDR 3	LDR 4	Servo X	Servo Y
Moving Right (Morning)	400	800	400	800	70	90
Sun Above (Afternoon)	800	800	200	200	90	60
Sun To The Left (Evening)	300	600	200	900	50	80

The dual-axis solar tracker system with four LDRs and two servo motors shows an effective response to the variation of the sun's position throughout the day. In the morning when the sun moves to the right, the right LDR (LDR2 & LDR4) detects a higher light intensity (800) than the left (400), causing the X servo to move to 70° to direct the panel to the dominant light source, while the Y servo remains at 90° because the top-bottom readings are balanced. When the sun is directly overhead (noon), the upper LDR (800) detects stronger light than the lower (200), causing the Y servo to move up to 60° to optimize light absorption, while the X servo remains at the neutral 90° position because there is no significant difference between left and right. In the afternoon when the sun moves to the left, the lower right LDR (900) shows the highest intensity while the left (300-200) is lower, causing the system to respond by moving the X servo to 50° (right) and slightly lowering the Y servo to 80° to adjust for the lowering sun angle. These results prove the system's ability to dynamically follow the sun's movement, although it still requires improvements such as the addition of dead zones to reduce oscillations and predictive algorithms to improve accuracy in unstable light conditions, while also showing great potential for renewable energy applications in tropical areas such as Indonesia with significant variations in sun intensity throughout the day.

IV. Conclusion

The solar tracker simulation based on four LDRs and two servo motors successfully proved the effectiveness of the system in dynamically following the movement of the sun throughout the day, where in the morning the X servo responds to the difference in right-left light intensity by moving to 70°, during the day the Y servo adjusts the elevation to 60° to capture sunlight at the zenith, and in the afternoon the system performs a combination correction by moving the X servo to 50° and the Y servo to 80° to compensate for the low position of the sun, demonstrating accuracy in adjusting the angle of the solar panel; however, the simulation also revealed the need for further optimization such as the addition of a PID control algorithm for smoother movement, a filtering system to overcome LDR reading noise, and adaptive tolerance calibration to weather variations, all of which are important foundations for the development of a physical prototype to maximize energy efficiency in locations with high solar intensity such as Indonesia.

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