Arduino-based Dual Axis Solar Tracking System Prototype

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Abstract. . Since solar energy is an infinite source of energy, it can be used as a suitable alternative energy source. One of the technological attempts to utilize solar energy is the use of solar panels. A solar panel is a device consisting of a series of solar cells that can convert sunlight energy into electrical energy. The generated electrical energy adjusts the intensity of the received sunlight. However, in its application, most solar cells are statically placed (not following the movement of the sun), where the position of the solar panels only leads to one specific preventing optimal absorption of the intensity of sunlight and resulting electrical energy generation. Therefore, we need a solar tracking system that can automatically control the solar panels to track the movement of the sunlight so that they can absorb the sunlight optimally. The solar tracker created in this research consists of monocrystalline solar panels, LDRs, INA219 sensor, Arduino board, and servo motors. Data collection was carried out for six hours on three consecutive days. According to this study, the greatest difference in power generated by solar panels occurs between 12:00 and 13:00 WIB, with an average value of active solar tracker power of 0.5 W and static solar tracker value of 0.34 W.

Keywords. Solar Energy, Solar Panel, Solar Tracker System, Static Solar Tracker, Active Solar Tracker

1 Introduction

Solar energy is a non-renewable source of energy and is widely used today due its abundance of energy sources [1]. Solar energy is an effective sustainable natural resource due to its existence, availability and sustainability, which are adequate and non-polluting [2]. Solar energy can be used to generate electrical energy using solar panels. A solar panel is a device made up of solar cells that can convert sunlight energy into electrical energy. Solar panels have been widely applied to harness solar energy as a generator. However, solar panels installation is still fixed or static and does not follow the movement of the sun [3]. This condition prevents the solar panels from capturing the maximum amount of sunlight throughout the day, resulting in inefficient electrical energy generation. To address this issue, a solar tracking system is required, which is designed to automatically move the solar panels so that they can follow the movement of the sun and absorb sunlight optimally. In a solar tracking system, solar panels are attached to a movable configuration to track the path taken by the sun throughout the daytime [3]. Of all the solar trackers on the market, those that work on two axes are the most effective [4]. Many previous studies had reported that dual-axis solar tracking is still preferential due to its high efficiency and performance, given the elaborate mechanism, high investment and extensive maintenance necessity [5]. Dual-axis tracking systems offer solar panels maximum efficiency because they can shift and track sunlight vertically and horizontally regardless of the sun's position in the sky. Compared to single-axis solar trackers, dual-axis trackers can be tilted to absorb sunlight [4]. What is more, the major benefit of dual-axis tracking over single-axis tracking is the ability to track the sun's movement throughout the year, not simply throughout the day [6].

The goal of this research was to create a prototype of a dual-axis solar tracking system based on Arduino Uno. An LDR sensor was used as a sunlight detector in the prototype solar tracking system, as well as a monocrystalline solar panel, an INA219 sensor, an Arduino board, and a servo motor as a solar panel driver.

2 Method

2.1 Prototype Design

As already mentioned, the objective of this study is to develop a dual-axis solar tracking system prototype. The prototype is made up of several major components, including LDRs (light-dependent resistors), an Arduino controller, a servo motor, a solar panel, and an INA219 sensor.

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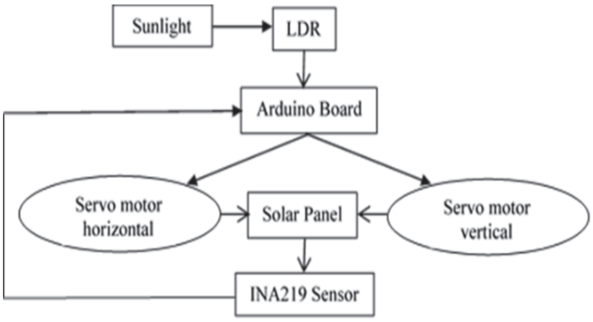

Fig. 1. Block diagram of Arduino-based dual axis solar tracking system prototype.

Figure 1 portrays a schematic diagram of the prototype Arduino-based dual-axis solar tracker system for this extend. Arduino as the main controller acquires analog signal from LDRs and transforms it to a digital signal with the help of an analog-to-digital (A-D) converter [7]. The signal is then sent from the controller to the servo motor to figure out the position of the solar panel. In contrast, the INA219 sensor measures the current and voltage produced by the solar panel. This section covers the details of the components utilized.

1. Light Dependent Resistor (LDR)

Light dependent resistors, moreover broadly recognized as LDRs or photoresistors, are electronic components that are habitually utilized in electronic circuit designs to detect the existence or light intensity. It operates on the photoconductivity principle, in which the resistance of the LDR changes when light is detected. A clear drop in resistance occurs as the light intensity increases [8]. When the light is weak, the LDR becomes a poor current conductor, or it can also be called the LDR has a high resistance when it is dark or dim. When the light is bright, the LDR becomes a conductor or has a low resistance [9]. In this work, LDRs are used to assess the brightness of solar illumination by sending signals to the controller that can adjust the direction and rotation of servo motors [10].

2. Arduino Board

Arduino is an open-source electronic prototyping platform primarily based on small and simple hardware and software [11]. There are several Arduino boards available on the market, including the Arduino Nano, Arduino Mega, and Arduino Uno. The Arduino board used in this lab is the Arduino Uno R3.

3. Servo Motor

A servo motor is a high torque motor that spins the motor rapidly and smoothly [12]. As a motor, a servo motor comprises of a DC motor, a gearbox, a potentiometer and a control system circuit. A servo motor might wait for predetermined positions in instructions and then maintain them, enabling it to operate in a closed loop. When it turns to the desired position, it consumes power; otherwise, no energy is consumed [13]. The servo motor is controlled by sending a variable-width electrical pulse or pulse-width modulation (PWM) over the control wire. The PWM sent to the motor decides the shaft position, and the rotor rotates to the required position according to the duration of the pulses transmitted over the control wire [14]. The servo motor was selected because it does not oscillate during operation and the rotational accuracy can be adjusted depending on the encoder used. Here, a servo motor is applied as the main driver of the solar tracker. When the motor receives an input signal from the LDR sensor that has previously been processed on the Arduino, it will move in the direction that has been programmed [10].

4. Solar Panel

A solar panel is an electrical device that employs the photovoltaic effect to convert energy from the sunlight into electricity. Solar panels' electrical parameters, such as voltage, current, and resistance, change as they are exposed to sunlight [8]. There are multiple different kinds of panels available, including monocrystalline, polycrystalline, amorphous and hybrid [15]. This project used monocrystalline solar panels.

5. INA219 Sensor

INA219 is a sensor module that can measure voltage and current in a circuit [16]. The INA 219 is supported by an I2C or SMBUS compatible interface and the device can monitor shunt and bus voltage supplies with time and filter program conversion. With a maximum input amplifier of 320mV, the INA 219 can measure currents of up to 3.2A [17, 18].

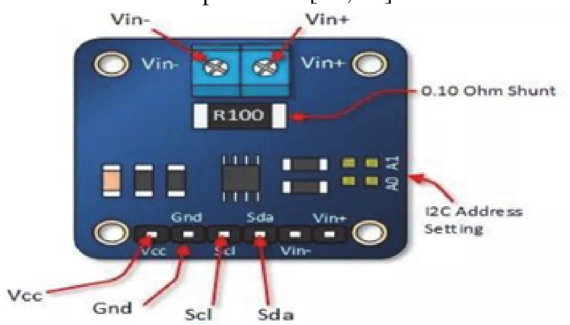

Fig. 2. Sensor INA219 [19].

2.2 The Data Collection Technique

The data is gathered through direct measurements of the active solar tracker system and the static solar tracker system. A monocrystalline solar panel with dual axis solar tracking system will be installed outdoors for three consecutive days from 09:00 WIB to 15:00 WIB. The output value of the current and voltage data is obtained by reading the solar tracker system. The data generated by the solar panel test is then processed to calculate the power value in both the static and active systems. Power is written using the equation: $P = I \times V$.

3 Results and Discussion

3.1 Mechanical Design Results of Dual Axis Solar Tracking System Prototype

Figure 3 depicts a working prototype of a dual axis solar tracking system

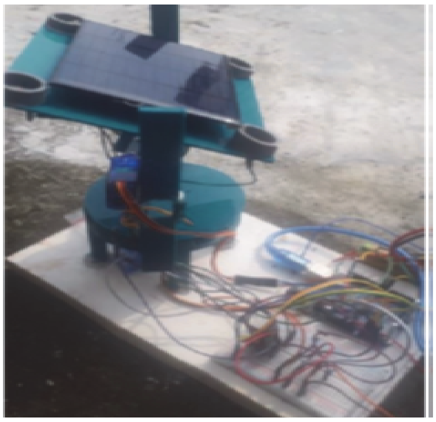

Fig. 3. Arduino-based dual axis solar tracking system prototype

The mechanical part of this solar tracker employs a servo motor that is mounted vertically on the left side of the body handle, while the horizontal is mounted on the underside of the pedestal of the solar panel body used. In the left and right corners are four LDR sensors that act as sunlight detectors. Moreover, the vertical and horizontal servo motors act as mechanical drivers, ensuring that the panel is always precisely aligned with the direction of the sun's rays. In the next step, the INA219 sensor reads the output value of the solar panel in the form of current and voltage. This value will be sent to the Arduino for processing to get the power value. The power value derived from this static and active panel will be compared to the power difference formula (ΔP), as shown in the equation below.

$$\Delta P = P_{active\ solar\ panels} - P_{static\ solar\ panels}$$

3.2 Results and Analysis of Solar Tracker System Test

As previously stated, the data collecting was conducted from 6 am to 3 pm for three consecutive days. Hereby, the graphs of output voltage, output current, and output power for both active and static dual axis solar tracking system prototype are shown.

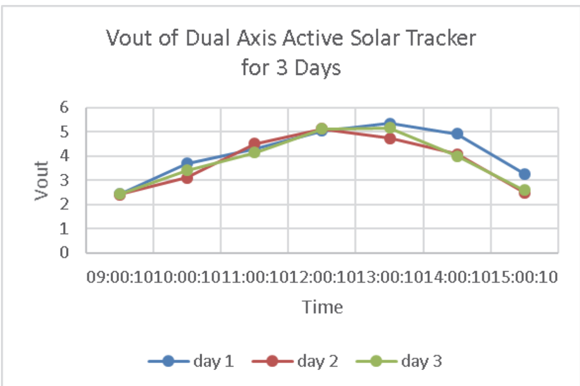

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Fig. 4. The output voltage of the dual axis active solar tracker for three consecutive days.

Figure 4 illustrates the changing of output voltages in active solar tracking system for 3 consecutive days. We can see that among the three coloured pattern of output voltages, the blue pattern has the highest value. The highest point of the blue pattern (day 3) about 5.34 is obtained at 13:00:10

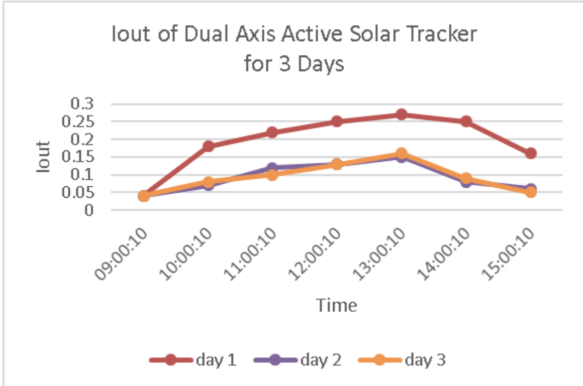

Fig. 5. The output current of the dual axis active solar tracker for three consecutive days.

The output current of the dual axis active solar tracker in day 2 and day 3 has almost the same range of values as seen in Fig 5. This is because the weather conditions during data collection on the second day and third day are the same

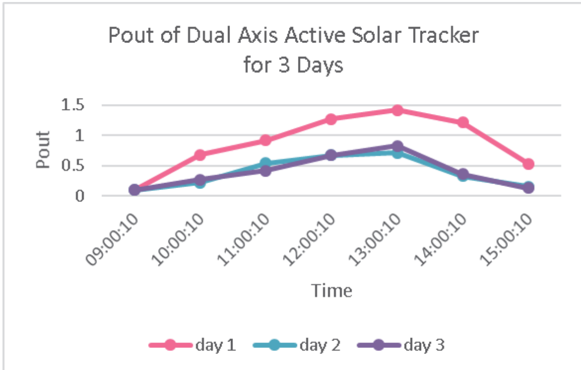

Fig. 6. The output power of the dual axis active solar tracker for three consecutive days.

The same pattern is also repeated in the graph of the output power of the dual axis active solar tracker. The graph in Figure 6 shows that the value of the output power generated by the dual axis active solar tracker on the second and third days is almost the same

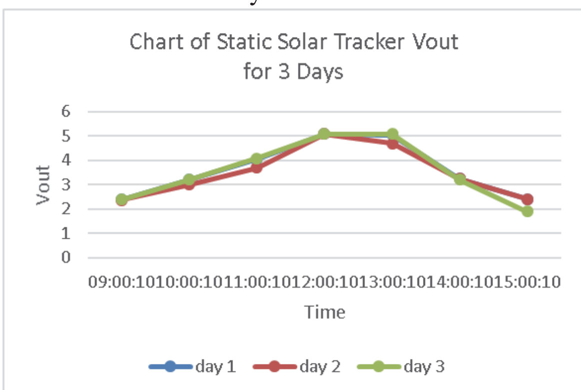

Fig. 7. The output voltage of the dual axis static solar tracker for three consecutive days

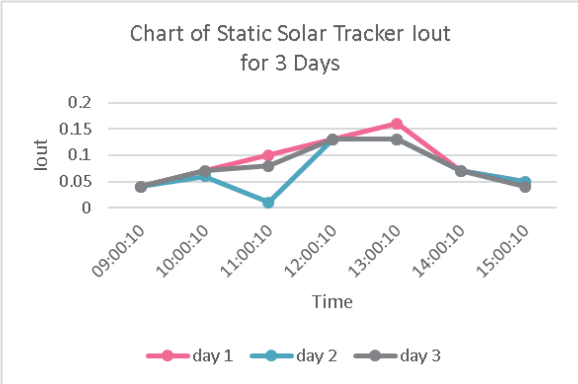

Fig. 8. The output current of the dual axis static solar tracker for three consecutive days

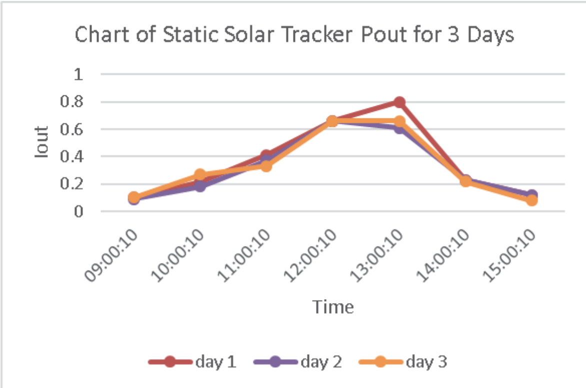

Fig. 9. The output power of the dual axis static solar tracker for three consecutive days

Meanwhile, the values of output voltage and output power of the dual axis static solar tracker for three consecutive days depict the same pattern (Figures 7 and 9). At 6 am until 12 pm, there is increase number of output voltage and output power, but afterward the voltage and power decrease. Figure 8 also shows that the maximum output current occurs at 13:00:10 on the third day, with a value of 0.66.

From Figures 5 and 8, one can tell that the solar position not only has greatly impact on the power but also the induced current. Indeed, current tracking contributes substantially more than voltage tracking. It appears that the greater the induced current, the closer the panel's trajectory is to the sun's trajectory [20]. However, the active tracking panel produces highest power output than the static panel is precisely at 11.00 pm (Figures 6 and 9). As a result, tracking solar panels can provide consistent power output throughout the day, whereas fixed panels are highly dependent on solar radiation and their solar position [21].

4 Conclusion

This study yielded in several conclusions. Among them is an increase in the value of output voltage and output power for three consecutive days on the dual-axis static solar tracking system. Furthermore, on the second and third days the output current and output power generated by the dual-axis active solar tracking system have nearly the same extend of values.

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