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An Evaluation Of Wireless Real-Time Data Of Solar Tracking System

***Abstract**. Sunlight and heat use various continually changing techniques, including solar thermal and artificial photosynthesis. These mechanisms change their orientation throughout the day as the sun maximizes energy absorption. Solar panels are directed towards the sun by the trackers that can increase solar energy compared to the fixed-angle system. Modification efficiency is improved in any solar system when the tracking system is continuously adjusted to the most favorable angle as the sun crosses the sky. The project presents the development of a solar tracking system using Arduino-UNO that allows the panel to move towards high-intensity sunlight via two LDRs. The monitoring system is implemented to record the data of solar energy parameters and factors affecting its deficiencies using ThingSpeak platform. The result shows the tracking system has efficiencies of 54.74% higher than a fixed system. The monitoring system is practical for analyzing the real-time solar panel competent environmental factors.*

Streszczenie.** Światło słoneczne i ciepło wykorzystują różne stale zmieniające się techniki, w tym fotosyntezę termiczną i sztuczną. Mechanizmy te zmieniają swoją orientację w ciągu dnia, gdy słońce maksymalizuje absorpcję energii. Panele słoneczne są kierowane w stronę słońca przez urządzenia śledzące, które mogą zwiększyć energię słoneczną w porównaniu z systemem o stałym kącie. Efektywność modyfikacji poprawia się w każdym układzie słonecznym, gdy system śledzenia jest stale dostosowywany do najkorzystniejszego kąta, gdy słońce przecina niebo. Projekt przedstawia rozwój systemu śledzenia słońca z wykorzystaniem Arduino-UNO, który umożliwia panelowi poruszanie się w kierunku światła słonecznego o dużej intensywności za pośrednictwem dwóch LDR. Zaimplementowano system monitoringu do rejestracji danych parametrów energii słonecznej oraz czynników wpływających na jej niedobory za pomocą platformy ThingSpeak. Wynik pokazuje, że system śledzenia ma wydajność o 54,74% wyższą niż system stały. System monitorowania jest praktyczny do analizy właściwych czynników środowiskowych panelu słonecznego w czasie rzeczywistym.* (Ocena bezprzewodowych danych w czasie rzeczywistym z systemu śledzenia energii słonecznej***)

Keywords: Solar tracker, Arduino UNO, Solar Panel, Servo Motor, Internet of Thing**.**
Słowa kluczowe: śledzenie słońca, panele fotowoltaiczne

Introduction

The solar radiance affects a given point on the earth, concerning the specified observation point that is equivalent to the sun's position in the sky. From this point of view, energy production depends on receiving solar radiance to solar panels. The efficiency of solar energy determines by the amount of power supplied on the panel by the sun's radiation. The electricity generated by a solar panel is not constant for any particular day. It displays variations in parallel with changing the position based on the light intensity from sunlight.

Ritula Thakur from the Department of Electrical Engineering, NITTTR, India designed The Arduino UNO solar tracking system that allows solar panels to move towards total sunlight events. The proposed system consists of developing a cost-effective device using the Bluetooth module to detect voltage using the Arduino Microcontroller-based solar tracking systems for Android apps [1]. The disadvantage of this design is that the Bluetooth module is limited to the short distance and the slow data rate. So, the best method changes it into a Wi-Fi module with a long-range and faster data rate.

Saymbetov, et al. [2] in their paper, is working on comparing different type of dual-axis tracker with an adaptive algorithm. They claimed that their proposed dual axis tracker is 41% more efficient than the other. Another author, Wai Mar Myint Aung in [3] designed a solar PV monitoring system integrated directly into current sensors, voltage sensors, temperature sensors, light sensors, and power supplies using the ATmego328 microcontroller. The method used to display the parameter of the solar panel is using LCD that cannot save data previously. Thus, a Cloud data platform is essential for tracking and storing data to make research more accessible.

In other works by Zhu, et al. [4], expressed new tracking mathematic equation to predict solar irradiation. The authors claimed that their proposed dual-axis mathematical expression has the most advantages over the single-axis module. But this methodology is quite complicated cause it involves a complex mathematical expression to track the solar irradiation.

The controller's design of the sun tracker also is crucial nowadays. Al-Rousan, et al. [5] came up with an efficient single and dual solar tracker design that can accurately affect the sun's trajectory. The author proposed an adaptive neural fuzzy inference system to track the best possible angle of the solar tracker to maximize solar irradiation.

Some researchers described the concept of an IoT device that collects data on physical parameters from different types of sensors via an advanced microcontroller platform and then uploads data to the Internet[6]. The Monitoring Center (MC) receives data from the photovoltaic and other sources of the connected sensor. The MC has a set of tools for monitoring products, detecting failures, and sending alerts through various communication channels[7].
The IoT is an ecosystem of physical objects linked to the Internet. It can also monitor, recognize and understand scenarios or environment devices/things without human assistance. IoT is defined as a data exchange area where objects are connected to cable and mobile networks daily [8]. Computer devices, mechanical and virtual equipment, objects or entities with unique identifiers and the ability to transfer information over a network without human or computer interaction [9].

The IoT is currently implemented in several other areas, such as smart cities, sanitation, home automation, industrial health, and consumer electronics and appliances. The increase in Wi-Fi and 4G-LTE wireless Internet access has shown ideological information and communication networks [8, 10]. In this research, the IoT approach envisages an early future in which everyday objects will equip with digital communications microcontrollers and transceivers.

In this project, a prototype of a single-axis solar tracker was developed to absorb solar energy from the point that it will achieve maximum power. The framework of the solar tracker consists of the Arduino Uno controller, Servo motors, LDR sensor, and the module. Arduino UNO sends an instruction to the servo motor to determine solar panel elevation and azimuth angles to keep the panel always regular to sunlight. Besides, two LDR light sensors were implemented in the tracking system to correct altitude and azimuth angle errors. The tracking system parameters are monitored remotely via the wireless module on the IoT platform's monitoring and control program.

Methodology

To design the best tracking system features with the weather conditions in Malaysia, the solar panel is developed to be a single-axis tracking system. Many electronic systems are self-sufficient and battery-driven. The tracking system must always align the solar panel with the direction of maximum illumination by solar cells to convert solar energy into electricity. Figure 1 shows a block diagram of the solar panel implemented in a single-axis solar tracker.

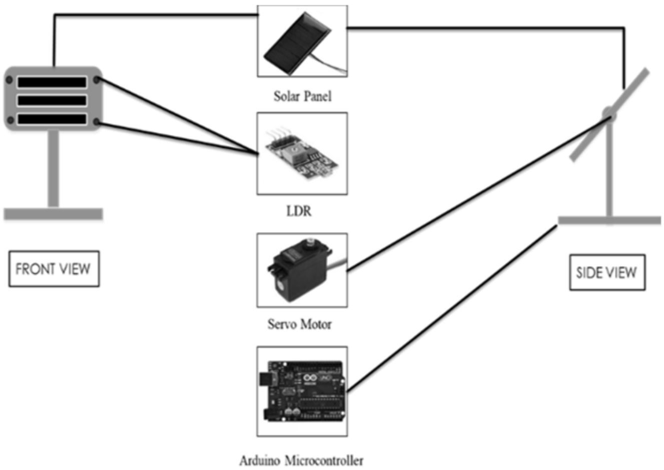

Fig. 1: Hardware design of solar tracking system

The monitoring system of the solar tracking can obtain energy efficiency from the solar panel and track the factor that reduces solar electricity. Solar power systems need this monitoring system to ensure the maximum performance of this solar tracker. In this project, INA219 is used to get the bus voltage, current, and power of the solar panel, while DHT22 is implemented to attain the surrounding temperature and humidity of the solar tracking system. These two sensors are interfaced with WEMOS D1 R2 ESP8266 Wi-FI Module by sending the sensor data into the IoT platform.

The project analyses data analytics to record the performance of the solar tracking system under different conditions. The solar tracking system reports the data collected by solar panels and feeds the data to web services such as ThingSpeak. The data recorded in ThingSpeak cloud could be exported into an XML file that is used to create an analysis of the solar tracking system. The tracking system is placed into different conditions to investigate various factors responsible for affecting the performance of a solar tracking system. Figure 2 shows the complete prototype of this project. The components used in this project is organized with numbers listed in Table 1.

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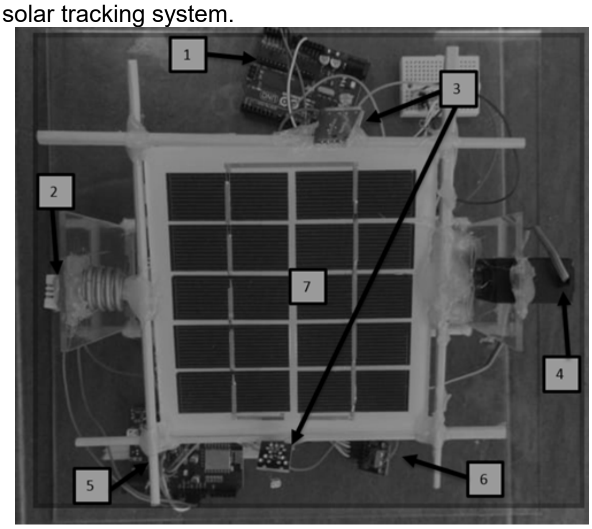


Fig. 2: Complete Numbering and Arrangement of Final Hardware Design

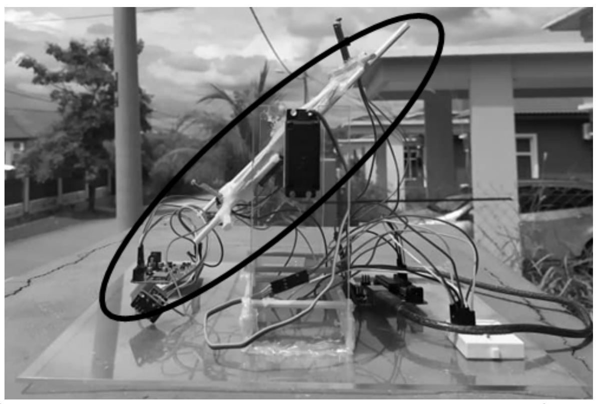
Table 1: Component Numbering for Hardware System Design and Development

NUMBERING	COMPONENT
1.	Arduino Genuino Uno Board
2.	Humidity and Temperature Sensor (DHT22)
3.	Light Dependent Resistor(LDR)
4.	Servo Motor
5.	Arduino WiFi UNO ESP8266 WeMos D1 R2
6.	Voltage and Current Sensor (INA219)
7.	Solar Panel Module

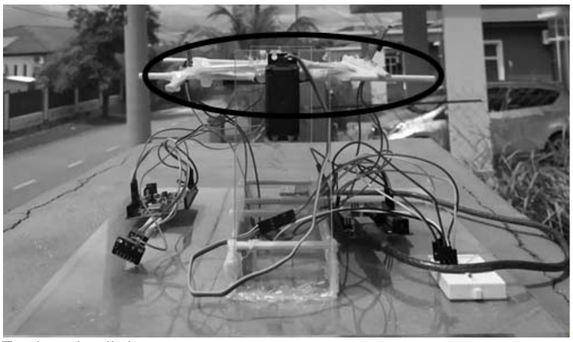
Results, Analysis and Discussion

The intensity of the Solar Tracking System

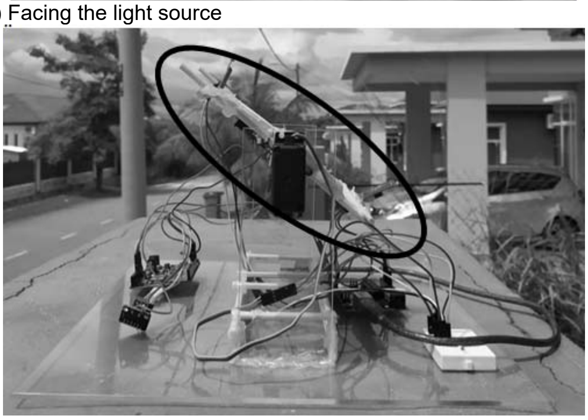
The solar tracking system moves perpendicular to the sun according to the light intensity from the LDR sensor. Two LDRs are used in the solar tracking system to distinguish the light intensity to give the idea to the panel either to move to the right or left. The outputs of the LDRs depend on how **mc**uch light is falling on the surfaces. Figure 3 shows the movement of the solar tracking system.



(a) Rotate counterclockwise, the light source move to the left



(b) Facing the light source



(c) Rotate clockwise, the light source move to the right

Fig. 3: Movement of the solar panel using two LDRs.

The built environment of the Arduino is to communicate with the Arduino board. A code is executed to collect the results that allow data from LDRs to compile after 1 hour. The values of each LDR must be read and recorded using a serial monitor from Arduino IDE software. The values obtained were recorded in table 2 to show the relations of the tilt angle in the solar tracking system.

Table 2: LDR Value and Angle

TIME	LDR 1	LDR 2	Angle of Incidence
9.00 AM	59	25	170°
10.00 AM	26	17	150°
11.00 AM	72	64	140°
12.00 PM	18	15	90°
1.00 PM	18	15	90°
2.00 PM	15	38	80°
3.00 PM	15	48	60°
4.00 PM	16	62	50°
5.00 PM	16	57	30°
6.00 PM	88	110	10°

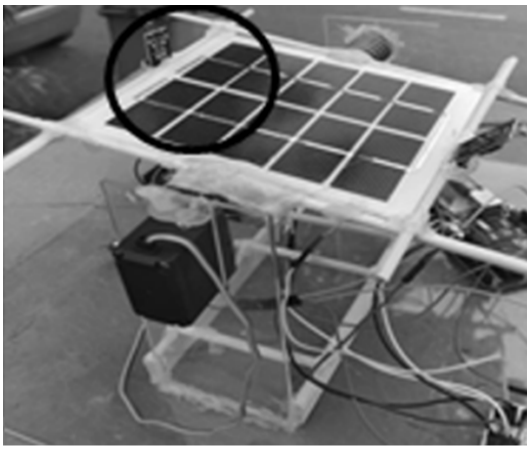


Fig. 4: Shading effect occurs on the system

Maximum insolation is perpendicular to the input radiation when the module is connected to the PV module. The angle of the array (relative to the horizontal surface of the ground) and the azimuth array (from east to west) also can be modified. Single-axis tracking panels have a fixed tilting angle, but continuously azimuth is adjusted to ensure that the PV modules face up to the incoming irradiance as directly as possible.

Tree shades and built structures block direct insolation from PV modules. A slight shading can significantly impact the LDR of the tracking system by altering the flow of light intensity of the light sensor. Figure **4** shows the shading effect that causes the tracking system not to rotate to its desired position.

Factors Affecting Solar Tracking System

Data measurements that are being recorded from ThingSpeak were taken from a wide area with no interference to prevent excessive sunlight on the sensor. The graph is constructed using average output voltages with temperature and humidity. The output voltages are measured from 9 AM to 6 PM.

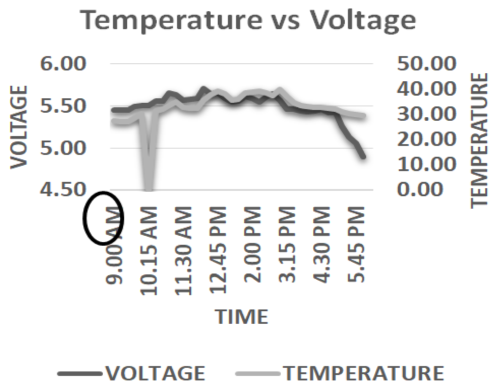


Fig. 5: Data comparison between temperature and voltage on rainy condition

Figure 5 shows the temperature dropped at 10.30 AM. The cause of the temperature drop is the weather surrounding is rainy and cloudy, which reduces the voltage. As temperature increases, the energy of the PV module decreases because it is less efficient at higher temperatures. The solar panel can produce electricity at high ambient temperatures. The solar panel also generates its heat as electricity, which is essential to consider the temperature of the solar panel and the humidity surrounding it.

The result shows in figure 6 that solar panel voltage is affected by humidity. These changes are due to the variable cloud formation that prevents the solar panel from reaching the sunlight, thus affecting its efficiency. The solar panel can reach peak voltage, and the cellular energy is reversed with heat if the outside air temperature is higher.

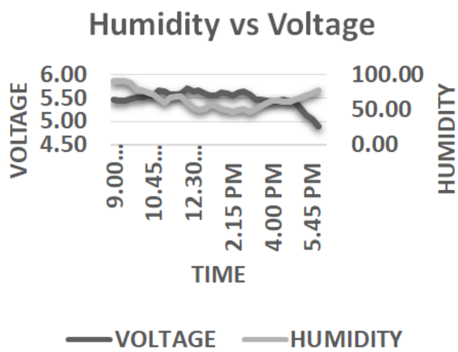


Fig. 6: Data comparison between humidity and voltage rainy condition

The factor that affects the solar voltage can be related to the changes in temperature and humidity. As the temperature is high, the solar energy will produce voltage up to 5V. For moisture, when the changes in humidity are increasing, it will reduce the performance of solar voltage to absorb solar radiance. Figure 7 shows the solar energy when the weather is sunny and bright.

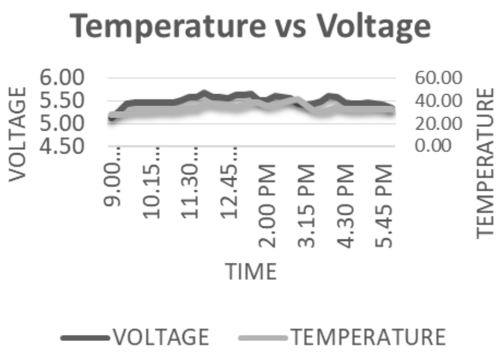


Fig. 7: Data comparison between temperature and voltage on luminescent condition

Figure 8 shows the graph of humidity in sunny and bright conditions. The graph shows solar panels can generate higher energy when temperature changes increase. The humidity changes decrease with the moist surrounding has been reduced with higher temperature. This factor makes the solar panel can absorb more radiance surrounding it.

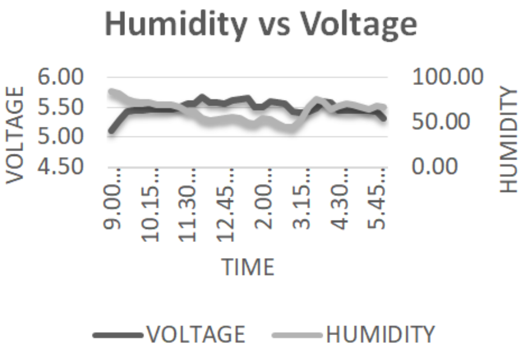


Fig.e 8: Data comparison between humidity and voltage on luminescent condition

Comparison Between Fixed and Single-Axis Tracking Systems

Solar panel readings were measured using a fixed and single-axis solar tracking system. The obtained data given in Table 3 and Figure 9 shows the performance of the data.

Table 3: Comparison of voltage between the fixed and single-axis tracker

TIME	Fixed tracker	Single-axis tracker
	VOLTAGE (Volts)	VOLTAGE (Volts)
9.00 AM	1.62	5.46
10.00 AM	2.10	5.51
11.00 AM	4.26	5.66
12.00 PM	5.42	5.60
1.00 PM	5.15	5.59
2.00 PM	4.95	5.60
3.00 PM	4.34	5.57
4.00 PM	3.86	5.43
5.00 PM	3.23	5.42
6.00 PM	2.24	4.90

Based on the graph in figure 10, the output voltage of the fixed tracking system is lower than the single-axis tracking system. The fixed tracking cannot generate the maximum output voltage due to the sun's movement shading factor, lowering its efficiency. The different results with a single-axis tracking system that can move along with the sun's progress are obtained with the help of two LDR sensors.

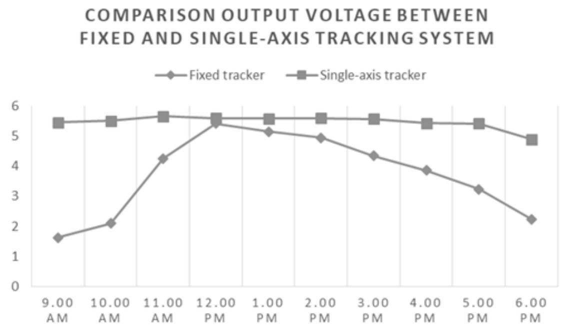


Fig. 9: Comparison of Output Voltage between Fixed and Single-axis Tracking System

In this case, the solar tracking system was placed for 10 hours from 9 AM until 6 PM. Thus, the efficiency of the single-axis is 54.74% higher than the single tracking system, which is only 37.17%.

ThingSpeak Data Analytic

ThingSpeak provides instant visualization of data posted by reading the value from INA219 and DHT22 in graphical form. The data recorded using ThingSpeak can aggregate, access, and analyze data from Live Cloud sources. Wemos D1 R2 was used as a Wi-FI module to connect with ThingSpeak through its specific API key.

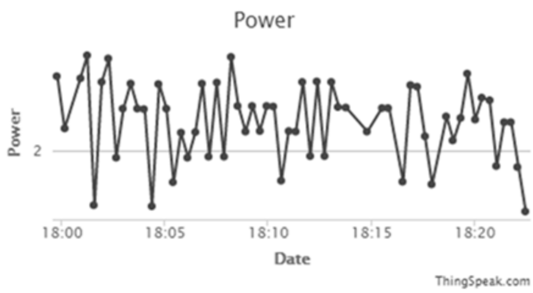


Fig. 10 shows the data chart of power in the ThingSpeak interface. The power is the product of voltage and current collected from the sensor and sent to ThingSpeak cloud.

Fig. 11: Data Chart of Humidity

Figure 10 shows the ThingSpeak field chart for power from the INA219 sensor from the solar tracking system. The value of solar panel from the sensors recorded in Real-Time and visualized in the form of graphical. This figure indicates the data chart of voltage, current and power in the ThingSpeak interface when collecting at rainy and cloudy temperature.

As the INA219 collected the data from the solar panel and sent it to ThingSpeak Cloud, the environmental and weather factor also is received from sensor DHT22. The sensor collects the solar tracker system's temperature and humidity to evaluate the performance.

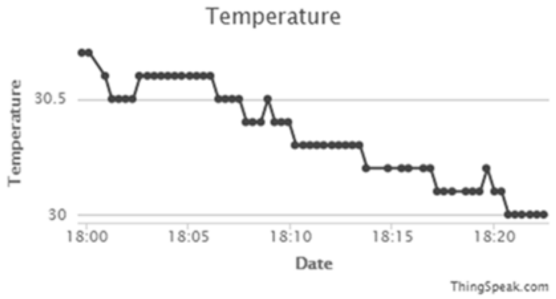


Fig. 12: Data Chart of Temperature

Figure 11 shows the data chart of humidity in the ThingSpeak interface. The data is collected when the weather is rainy and cloudy. The graph in ThingSpeak shows that the moisture percentage is higher than 90%.

The data is then collected when the weather becomes rainy and cloudy. The graph in ThingSpeak in Figure 12 shows that the temperature drops to 30ºC

The merits of this dual solar tracker are emphasized in the succeeding justifications:

(1) The dual solar tracker tends to have superior advantages over the single-axis, with the efficiency of the overall tracker being 54.74%.

(2) The other benefit of this dual solar tracker is it capable of continuously adjusting to the most favorable angle as the sun crosses the sky. This situation could also maximize the solar irradiation emitted directly to the solar plate.

(4) By introducing the monitoring system in this tracking system, it can automatically record the data of solar energy parameters and factors affecting its deficiencies. This is implemented using ThingSpeak platform interfacing with Wemos D1 R2

Conclusion

It is verified that dual-axis solar tracking systems are accurate and are the best way to find maximum solar power from sunlight. The proposed tracking device can detect the incident solar light from the solar panel and force it towards the ultimate solar light event. The weather surrounding impacts the performance of a solar tracking system. To evaluate the tracking system's performance, the monitor system consisting of the parameter of solar panel and environmental factors are displayed and recorded in real-time using ThingSpeak cloud.

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