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Model Prototype of a Solar Tracking System Supplying Electrical Power for Sensors Used in a Natural Disaster Monitoring System

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ABSTRACT

Sun is the universe main source of energy. This energy can be converted to useful electrical energy by the utilization of solar panels or photovoltaic (PV) during the daytime with the presence of suitable sun irradiation level. It is important that during the energy conversion process, suitable methods are employed to extract as much energy as possible from the PV panels. Some issues affecting PV performance are the accuracy of the panel's orientation and tilt angle with respect to the sun position. This causes PV to operate with lower efficiency, thus generating low output power compared to its rated capacity. One of the approaches to this issue is to constantly maintain a perpendicular profile of PV panels towards the sun direction as to capture the sun energy as much as possible, thus increases the PV efficiency. To do so, the conversion system needs a tracking mechanism to help the solar panel to constantly follow the sun's direction, enhancing the achievement of higher PV efficiency. For this reason, a model prototype has been designed and developed which consists of a dual-axis solar tracking system, with two axis movement direction from east to west and north to south by utilizing the Light Dependent Resistors (LDRs) sensors. This tracking system is developed using Arduino UNO as the microcontroller that allows the PV panel to move optimally towards the high intensity of sunlight via four LDRs and two servo motors. To analyze the PV tracker's performance, a monitoring system is implemented using ThingSpeak platform as the Internet of Things (IoT) platform interfacing with the controller Node MCU ESP8266. This monitoring system records the data of the PV energy parameters from the sensors' output employed in this prototype. To assess the system efficacy, the dual-axis tracking system is compared with the single-axis tracking system. The result showed that the dual-axis tracker has efficiencies of 68.46% which is higher compared to that's of the single-axis tracker. Implementation of the real-time monitoring system has shown a practical and handy way to analyze and monitor the solar tracking system's performance.

Keywords: Renewable energy; LDR; Arduino UNO; IoT; Node MCU ESP8266; monitoring system

INTRODUCTION

In general, power generated by solar panels fluctuates due to the fluctuation of the sun irradiation resulted from the weather condition changes. As a result, the expected power generation from the PV panels could not be obtained. Thus, a system which always extracts the maximum PV power during the daytime in the presence of sun irradiation is indeed needed. This is an important strategy especially for the system that utilizes solar panel as the main energy resource like houses located in remote areas. Thus, to generate sufficient power to the system at this area, solar power with sun tracking system would be the alternative approach.

Since the location of the sun varies during the day and season throughout the year, a solar tracker is a perfect way to improve PV system energy output. In addition, it is a cost-effective alternative rather than adding the additional solar panels in order to get maximum power output. Solar tracking is a device mechanized for monitoring the sun's location and lining up perpendicularly to increase the power output by between 30% and 60% compared to stationary systems (Kumar et al. 2013, Nasir et al. 2022). Nowadays, there are two types of solar tracker which are single-axis (Fatima et al. 2022) and dual-axis (Chien et al. 2022). For single-axis solar tracker, PV panel can only move within one axis that is aligned with North and South. To precisely track the sun, the dual-axis tracker is desired for the sun azimuth as well as altitude angle at all the time, maximizing the full power from the PV system over a day than the non-tracking system. (Aboubakr et al. 2018, Hafez et al. 2017; Jara et al. 2022; Arjun et al. 2023).

To enhance the solar tracker system, the output parameter of the tracker is monitored and analysed using Internet of Things (IoT) platform, thus the PV efficiency can be analysed precisely (Khatoon et al. 2020; Kodali et al. 2020).

SOLAR TRACKING SYSTEM CONFIGURATION

In this work, a model prototype of a dual-axis solar tracker was built to constantly follow the movement of the sun by engaging PV panels axis movements from east to west and north to south in order to increase the amount of solar energy generated. Besides, some portion of this energy is also used to constantly power on the sensors in the PV tracking system. The framework of the solar tracker consists of the Arduino Uno controller, servo motors, Light Dependent Resistor (LDR) sensors and the Internet of Things (IoT) module. The Arduino UNO sends instructions to the servo motor to determine solar panel elevation and azimuth angle so that the solar panel always face toward the sun position. Besides, four LDR sensors are implemented in the tracking system to compensate the altitude and azimuth angle errors. The PV output voltage and the tracking system performance are remotely monitored via wireless module on the monitoring and control program using the IoT platform.

The overall block diagram of the dual-axis solar tracking system is shown in Figure 1.

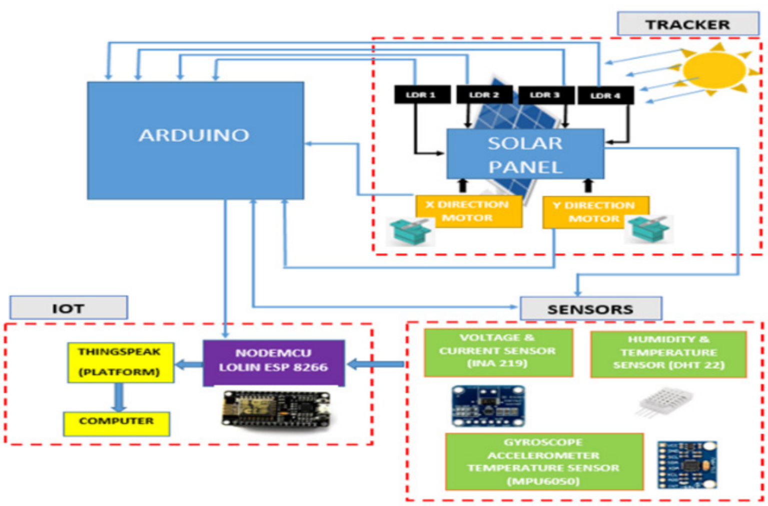

FIGURE 1. Block diagram of the solar tracking system

The dual axis tracking system consists of three blocks which are tracker, sensor and IoT units. The tracker consists of solar panel, light dependant resistor (LDR) sensors and servo motors. In the sensor unit, the sensors act as the PV output parameters monitoring system which consists of voltage and current sensors (INA 219), Humidity Temperature Sensor (DHT 22) and Tilt Angle Sensor MPU 6050. The output parameters from these sensors are used to analysed to monitor the tracker performance. The third unit is the Internet of Things (IoT) that acts as data collector platform and interfaced with the ESP8266 NodeMCU as wifi module.

4.5W 18V solar panel is used in this work due to its high conversion rate and high efficiency output. Table 1 shows the specification of the solar panel.

TABLE 1. Solar Panel Specifications

Parameters	Specifications
Peak Power (Pmax)	4.5W
The voltage a Pmax (Vmp)	18V
Current a Pmax (Imp)	250mA
Open Circuir Voltage (Voc)	20V
Short Circuit Current (Isc)	330mA
Cell Type	Polycrystalline Solar Cell
Weight	0.2Kg
Working temperature	010 °C~ 95°C
Dimension	170x70x3mm

The arrangement of the hardware design of a solar tracking system implemented with all the components for this project is illustrated in Figure 2.

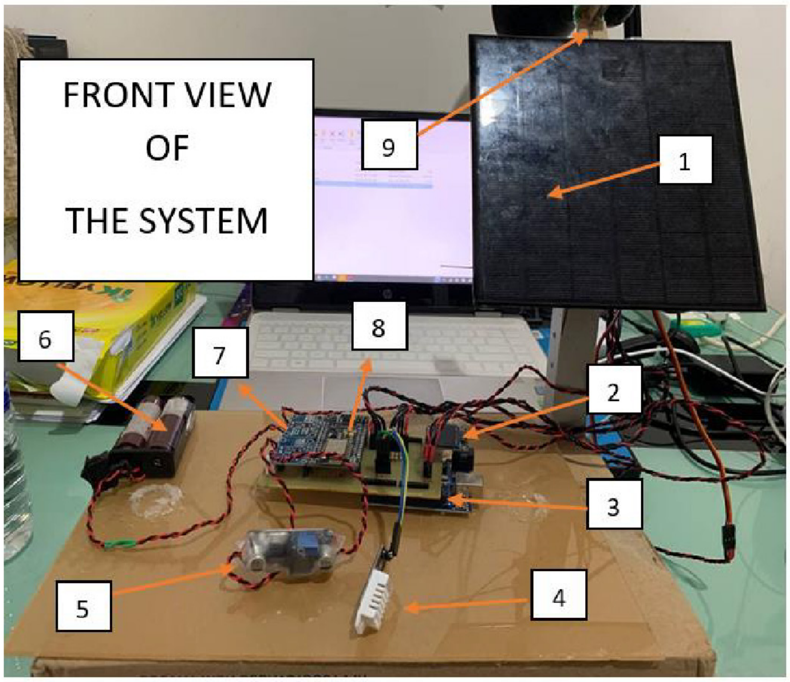

FIGURE 2. Front view of the prototype of the solar tracking system

The system is divided into two parts. The first one is the tracking system that moves the servo motor interface to the Arduino Uno using four LDR sensors. INA219, DHT22 and MPU 6050 are used to monitor the solar panel for the monitoring system, using Node MCU ESP 8266, which acts as a WiFi bridge to the IoT platform. The IoT platform used in the project to record the data is ThingSpeak platform.

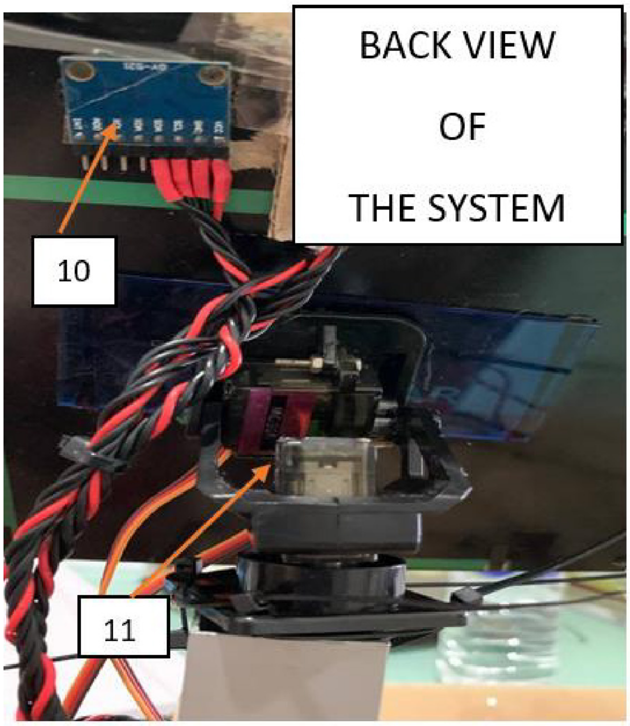

FIGURE 3. Back view of the prototype of the solar tracking system

The components used are organised in this work as shown in Table 2 with the numbering labels.

TABLE 2. Numbering labels indication used in Figure 2 and Figure 3

Numbering	Component
1	Solar Panel Module
2	OLED 12C 0.96Inch 128x64 Blue Display
3	Arduino Genuino Uno Board
4	Humidity and Temperature Sensor (DHT22)
5	LM2596 DC-DC Buck Converter
6	Lithium Battery
7	2 unit of Voltage and Current Sensor (INA219)
8	Node MCU ESP8266
9	4 Units of Light Dependent Resistor (LDR)
10	MPU 6050 Gyro/Accelerometer Sensor
11	2 Units of Servo Motors

For data analysis, the solar monitoring system reports the information gathered by solar panels and feeds the data to web services called ThingSpeak. The data recorded in the ThingSpeak are exported in cloud into an XML file that can be used to analyse the solar tracking system performances. To investigate different factors that affecting the performance of a solar tracking system, the tracking system is placed in different conditions. The Arduino UNO sends an instruction to the servo motor to determine solar panel elevation and azimuth angle so that the solar panel always facing the sunlight. Besides, four LDR sensors implemented in the tracking system to adjust altitude and azimuth angle errors. The output voltage from the solar panel will be supplied to sensors and the tracking system performance are remotely monitored via wireless module on the monitoring and control program using IoT platform.

RESULTS AND DISCUSSION

SOLAR TRACKING SYSTEM PERFORMANCE

The model prototype of the solar tracking system performance was developed and tested to assess its performance. The parameters from the sensors which include LDRs light intensity of the surrounding temperature, humidity from DHT22 sensor, and the tilt angle from MPU6050 sensor are obtained and analysed. These parameters are recorded and exported from ThingSpeak monitoring platform for this tracker system.

Figure 3 shows the graph of the relationship between light intensity output of sensors and the solar output voltage.

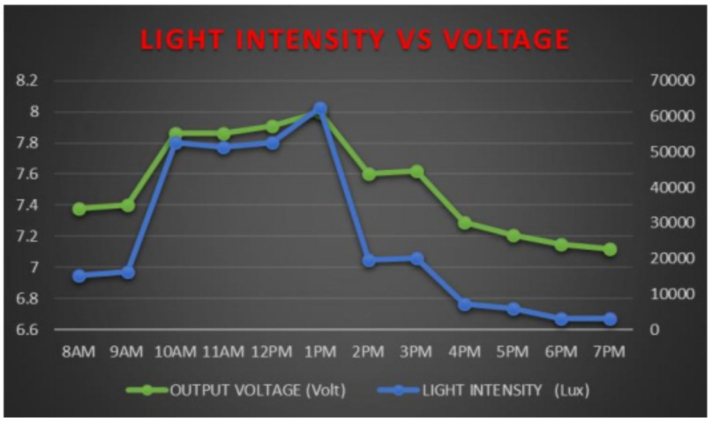

FIGURE 3. Light intensity versus PV output voltage

From the Figure 3, the light intensity (lux) of the LDRs sensor start to increase drastically at 10:00 am and then reaches peak level at 1:00 pm. Currently, the sun irradiation is at the maximum level causing the solar panels to generate maximum peak voltage of 8 volts. These results imply that the four LDR sensors operates effectively in responding to the light intensity which trigger the motor to move solar panel pointing to the correct position toward the sun, producing maximum output voltage.

Figure 4 shows the graph of the relationship between temperature and the output of sensors and the solar output voltage.

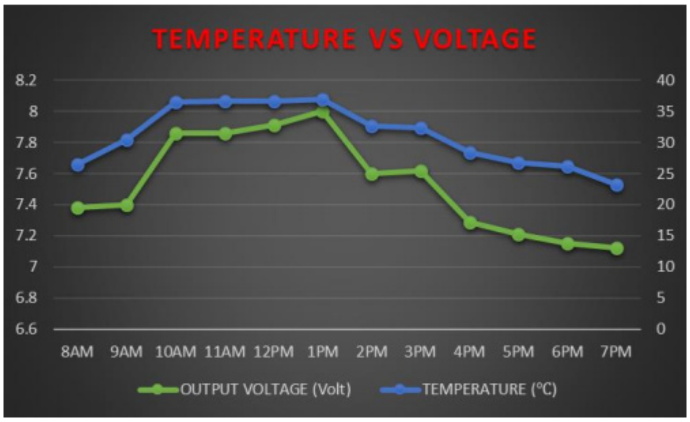

FIGURE 4. Temperature versus solar output voltage

From Figure 4, the solar panel starts to generate higher output voltage at 10:00 am and reaches maximum (8V) in the higher temperature environment, in this case around 35°C.

This implies that temperature is the important factor that contribute to the solar power generation. Other factor that influences the solar power generation is the humidity. Figure 5 depicts the relationship of solar output voltage and the surrounding humidity.

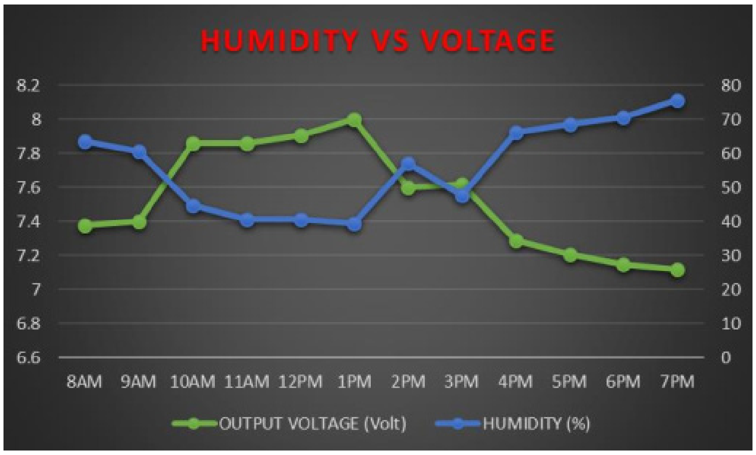

FIGURE 5. Surrounding humidity versus solar output voltage

As the graph shown, the surrounding humidity has the big impact on the solar output voltage generation. This implies that solar panels generate higher output voltage in the surrounding with lower humidity especially during the period from 10 am and 2:00 pm. In this work, the surrounding temperature is approximately 37°C as shown in Figure 4.

Figure 5 shows the relationship between X-axis tilt angle and solar panel output voltage.

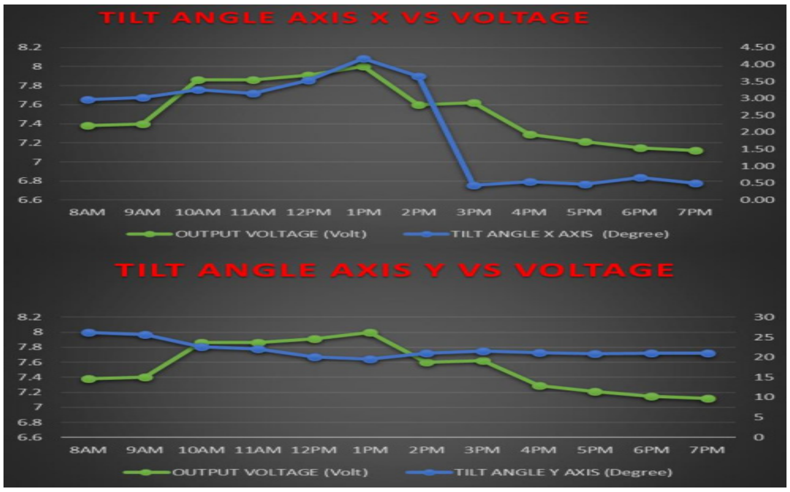

FIGURE 5. Tilt angle of X-axis versus solar voltage output

It shows that, the optimum tilt angle for X-axis (west and east) of the solar panel is between 0.44 to 4.18 degree to generate voltage output. Figure 6 shows the relationship between Y-axis tilt angle and solar panel output voltage.

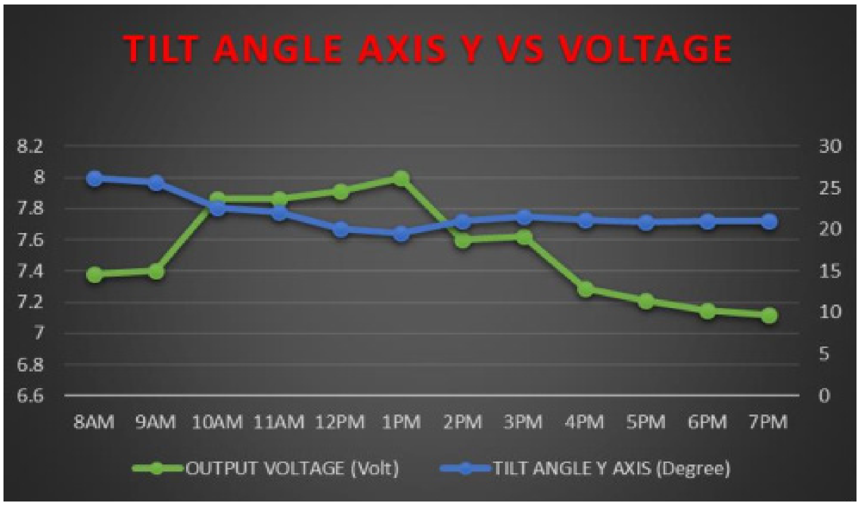

FIGURE 6. Tilt angle of Y-axis versus solar voltage output

From the figure, the optimum tilt angle for Y-axis (north and south) of the solar panel is between 19.61 to 26.24 degree to generate voltage output. Form these results, it can be concluded that the highest output voltage is achieved when the tilt angle is 4.18 degree at X-axis and 19.61 degree at Y-axis.

The output voltages generated by single-axis tracker and dual-axis tracker are recorded from the same solar panel. The single-axis tracker is the tracker that moves only in one axis of direction which is from north to south. The tracker is programmed such that the panel moves only one direction. The voltages obtained are shown in Table 3 and Figure 7.

TABLE 3. Comparison of output voltage from single and dual-axis tracker

Time	Single-axis tracker	Dual-axis tracker
	Voltage (volt)	Voltage (volt)
8AM	5.30	7.38
9AM	5.46	7.38
10AM	5.51	7.86
11AM	5.66	7.86
12PM	5.60	7.91
1PM	5.59	8.00
2PM	5.57	7.60
3PM	5.60	7.62
4PM	5.43	7.29
5PM	5.42	7.21
6PM	4.90	7.15
7PM	4.70	7.12

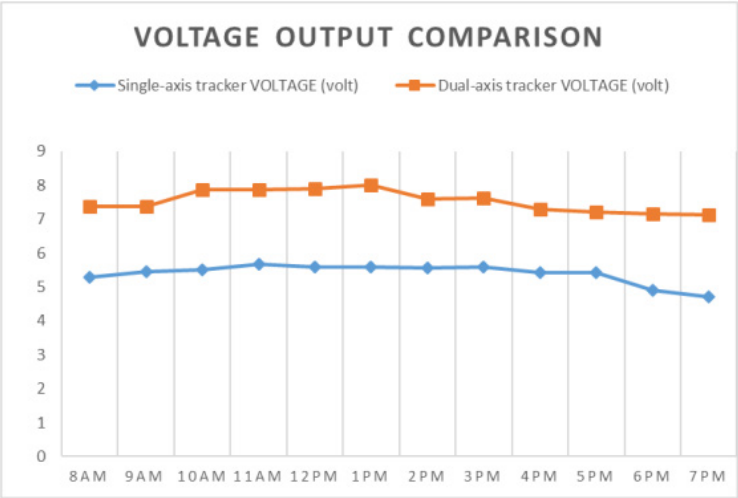

FIGURE 7. Voltage output from single and dual-axis tracker

By referring the output voltage graph from Table 3, the output voltage generated by the single-axis solar tracker is lower than that's of the dual-axis solar tracker. This is due to its limitation in moving the solar panel which only move in one axis of direction (north and south) and unable to constantly follow the sun in other directions like the dual axis tracker. Thus, with the dual-axis tracking mechanism, the solar panel able to generate more power.

With the utilization of ThingSpeak, the parameters for the solar panel and the surrounding factors e.g., voltage, temperature and humidity can be monitored and recorded in real-time. Thus, the performance of the whole tracking can be evaluated. Information from live cloud sources can be tabulated, obtained, and examined from the data recorded using ThingSpeak. By reading the value of INA219 and DHT22 in the form of graphs, ThingSpeak provides instant visualization of the data posted. As a WiFi module, Node MCU ESP8266 is used to connect with ThingSpeak through its particular API key. The example of ThingSpeak field chart collected by INA219 sensor from the solar tracking system is shown in Figure 8 and Figure 9. The values are recorded in real-time and visualized in graphical form.

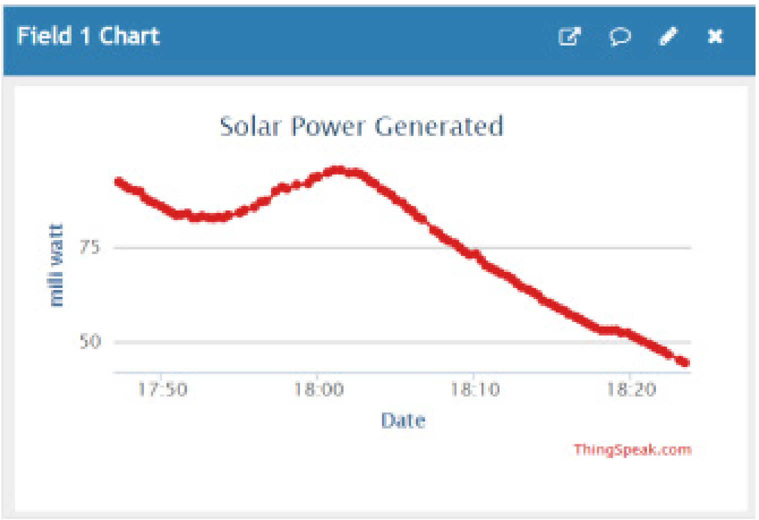

FIGURE 8. PV Power generated data chart.

Figure 8 shows the screenshot of the PV power in miliwatt, generated from ThingSpeak for the time of period from 17:50 hours to 18:20 hours.

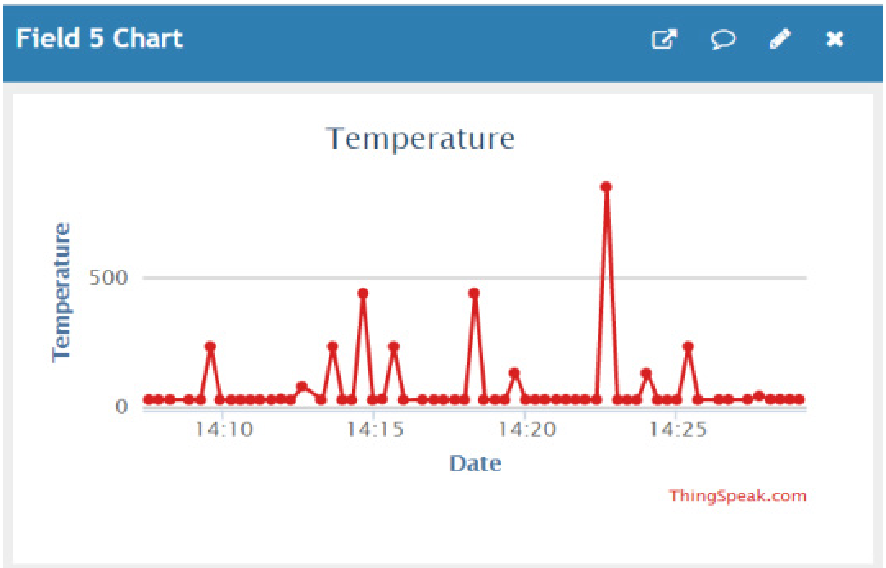

FIGURE 9. Temperature profile

Figure 9 shows that the temperature fluctuates and remains constant from time to time as it depends on the surrounding temperature. This data output is sensed by DHT22 sensor.

CONCLUSION

A dual-axis tracker is developed in this project. A solar tracking system is designed and tested to constantly track the sunlight direction. A monitoring system is created using internet of things (IoT) platform like ThingSpeak to analyses the data and the performance of the solar tracker. The results presented shown that the developed model of dual tracking system generates more power compared to the single axis tracking system. The hardware and software architecture of this system, therefore, is designed to improve the previous system. The output parameters from these sensors, are sent and recorded in ThingSpeak platform in real-time. This work provides accurate and real-time data on the temperature, current and voltage, and angle of the installed solar tracking system. In other words, any incorrect information recorded and collected from the NodeMCU ESP8266 could immediately indicate the inconsistency of the system.

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