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Solar Power System: Dual-Axis Tracker & Monitoring System for a Gateway Station using Arduino & NodeMCU

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Abstract: Sunlight is a non-disappearing and atmospheric-free source of renewable energy. The disadvantage of solar energy, however, it relies precisely on the strength of the sun. In order to create the utmost amount of energy, the solar panel has to be perpendicular to the source of light. When the photovoltaic panel is perpendicular to the sun, the solar energy conversion efficiency increases. Therefore, the purpose of this study is to propose an innovative method of tracking the sun using a resistor dependent on light (LDR). It is rational to conclude that the sun position indicates the points of the brightest region in the sky. The sun central location data is sent to the embedded processor to power two servo motors that can move both horizontally and vertically to track the sunlight. The IoT is used in this study purposely for monitoring the performance of the solar power system and the dual-axis solar tracker. The data helps to make the decision to plan operations, repairs, and preventive maintenance.

Keywords: Photovoltaic, LDR, Solar Tracker, IoT, Arduino, NodeMCU, Ubidots

1. Introduction

Nowadays, the cost of solar power equipment per watt has decreased in the last ten years due to the increasing number of renewable energy resources [1]. It is certainly expected to become economical in the coming years and to evolve as better technology in terms of both costs and applications. Photovoltaic solar energy conversion is called the direct conversion of sunlight into electricity. The solar cell in which the photovoltaic effect takes place is an essential component of the photovoltaic system. The sun will produce free power via solar panels that will convert sunlight into electricity without moving parts, zero pollution, and no maintenance. A collection of individual silicon cells that generate electricity from sunlight is the solar panel, the first component of an electrical solar energy system [1]. Solar photovoltaic energy systems are made up of different components. Each component has a specific role

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to play. The type of component in the system is dependent on the system's design and purpose. Direct current (DC) is generated by a solar power system. That is the electricity that travels in one direction. Loads in a simple photovoltaic (PV) network often operate on DC.

The fixed structure and the solar tracking system can define the configuration of the solar panels. For the function of a solar panel, the solar tracking structure is not important, but without it, efficiency is lowered [2]. Solar monitoring can be carried out using one-axis, or two-axis for greater accuracy. Only direct solar radiation will be tolerated by high-concentration photovoltaic (HCPV) systems, and the sun's deviation from the acceptance angle would result in a significant decrease in energy conversion efficiency [2]. Therefore, a highly accurate and reliable solar tracker is required for the HCPV system to obtain full power. However, in cases where solar trackers can improve the energy efficiency of PV arrays, problems can arise, like costs, reliability, energy consumption, weather, and maintenance.

The solar PV system always generates sufficient power, which is why real-time monitoring of its performance is necessary. This is only possible if we have an intelligent system for generation, monitoring, and distribution [3]. In the last decade, the monitoring and control with industrial and university communities have become increasingly common, and the generation of energy from solar cells has also increased significantly and has spread parallel to solar panel systems [3]. Quality control and performance management is an integral part of any solar energy program, but if we are going to save money, it must be sacrificed. The rated amount of electricity is about to be produced by the Solar System. The solar control system can inform users if the system is functioning as planned and even if the system is offline [4].

In the process of generating solar energy, usually, workers or engineers need to go to the site to see the process of the solar system. In today's sophisticated era, manpower still needs to be deployed to examine the quantity of electricity generated by the solar system. The process needs to be carried out regularly to ensure that the solar system is always in good condition and able to produce enough energy. The quantity of the electrical energy produced from the solar system must be observed regularly.

In this study, a solar power system with IoT is designed for remote monitoring and also solar tracking for optimal solar energy. The solar power system in this study is used to supply power to the gateway station of a monitoring platform for gaseous ammonia. The purpose of the monitoring platform is to detect gaseous ammonia and send the data wirelessly to an IoT system that can be observed through a software suitable for the project.

This project uses a 85-115 mm-18 V, 80 mA, and 1.5 W high-efficiency solar panel, 12 V/24 V rated voltage, 10 A rated current, 50 V maximum PV voltage, 130 W(12 V) 260 W(24 V) maximum PV input power solar regulator, and 12 V rechargeable battery. Then, the dual axis solar tracking system is constructed using Arduino UNO, LDR sensor module, servo motor, and 12 V battery. The monitoring system is constructed using NodeMCU ESP8266, current sensor, voltage sensor, and LDR.

2. Literature survey

In [5], Design of a Solar Tracking System Using the Brightest Region in the Sky Image Sensor, in essence, the systems for solar tracking are divided into two groups. The thermal growth of chemicals is the basis of memory alloys for passive solar tracking systems. Usually, this type of solar tracking system is composed of a few actuators that work against each other. The solar tracking device will be balanced under equal illumination. Based on a combination of these three systems, active trackers can be categorized as the microprocessor and electro-optical sensor-based, PC-controlled date and time-based, auxiliary bifacial solar cells. From an active perspective, active solar monitoring systems can be implemented as open-loop or closed-loop control systems.

In [6], The Implementation of Solar Tracker using Arduino with Servomotor, the purpose of the solar tracker is to use the solar panel to consume optimal solar energy. A Solar Tracker is a system on which solar panels are mounted to monitor the position of the sun to ensure that the panels during the day are significantly impacted by the greatest amount of sunlight. The power output from a solar cell is optimum when facing the sun, i.e. the angle between its surface and sun rays is 90 degrees. Solar tracking makes it possible to produce more energy because the solar array is able to remain aligned with the sun. Servo motors, Arduino and LDR are the components used for their design. The active sensors track the sunlight continuously and alternate the sunlight towards the direction in which the maximum sunlight intensity.

In [7], Microcontroller Based Solar Tracking System for enhancing of a Photovoltaic System, as a tool for monitoring, the device uses the concept of thermal expansion of materials. A chlorofluorocarbon (CFC) or sort of shape memory alloy is usually mounted on either side of the solar panel. The two sides are at equilibrium when the panel is perpendicular to the sun. Once the sun moves, one side is heated and allows one side to expand and the other to compress, allowing the solar panel to rotate.

Active Solar Tracking:

- Astronomical: The electronic system calculates the current position of the sun and the tracking motor uses accurate coordinates to move the solar modules at pre-set time intervals perpendicular to the sun.
- Sensor Controlled: Instead of aligning the modules using the sun's astronomical position, a tracking system fitted with a light sensor points the solar panels toward the brightest points in the sky. For instance, the modules will be in a horizontal position under a fully overcast sky.

In [8], Low-Cost Monitoring System for Solar Farm using Agent Technology, the project presents a multi-agent solar farm monitoring system that allows the main indicators of the solar panels to be controlled in order to detect and take steps to resolve early faults. In different science fields, the use of multi-agent systems is widely used because they provide abstraction and intelligence modeling. The use of distributed energy sources, micrograds, smart grids, etc., today requires the use of multi-agent systems to manage the transmission of energy and the exchange of information. Together with multi-layer communication architecture, multi-agent systems are used because they enable better information management.

In [9], Solar Power Remote Monitoring and Controlling using Arduino, LabVIEW and Web Browser, the project proposes an efficient and powerful graphical user interface (GUI) for real-time monitoring and control of solar panel-generated local and remote DC power and DC power consumption. The server and the client are given two GUIs. Server computers need to be mounted near solar panels for local monitoring and control, while the client GUI can be accessed from any part of the world via a web browser, allowing people to track and control all operations. Using LabVIEW and LabVIEW UI Creator, server and client GUIs are built, while Arduino Uno hardware, current and voltage sensors, relays, and charge controllers are created. To prepare electricity, current, and voltage graphs, the monitoring interface uses real-time measurement results and database files can also be recorded and viewed to analyze the history of renewable energy sources (RES) devices.

In [10], Grid Tie Solar Power Plant Data Acquisition System Using Internet of Things, the project describes the design of the solar plant's Internet of Things remote data acquisition system. Solar power plant monitoring will provide real-time data for net energy, net/total power, and irradiance. This data helps to determine the planning of operations, maintenance, and preventive maintenance activities.

3. Methodology

In the process of implementing the Solar Monitoring System, a project plan and schedule is important to accomplish the project effectively. This project planning provides a flowchart representing the project process and workflow. The project schedule is more detailed with the list of tasks that needs to be accomplished by the student to prevent the work process to become sluggish. The flowchart for project planning is shown in Figure 1.

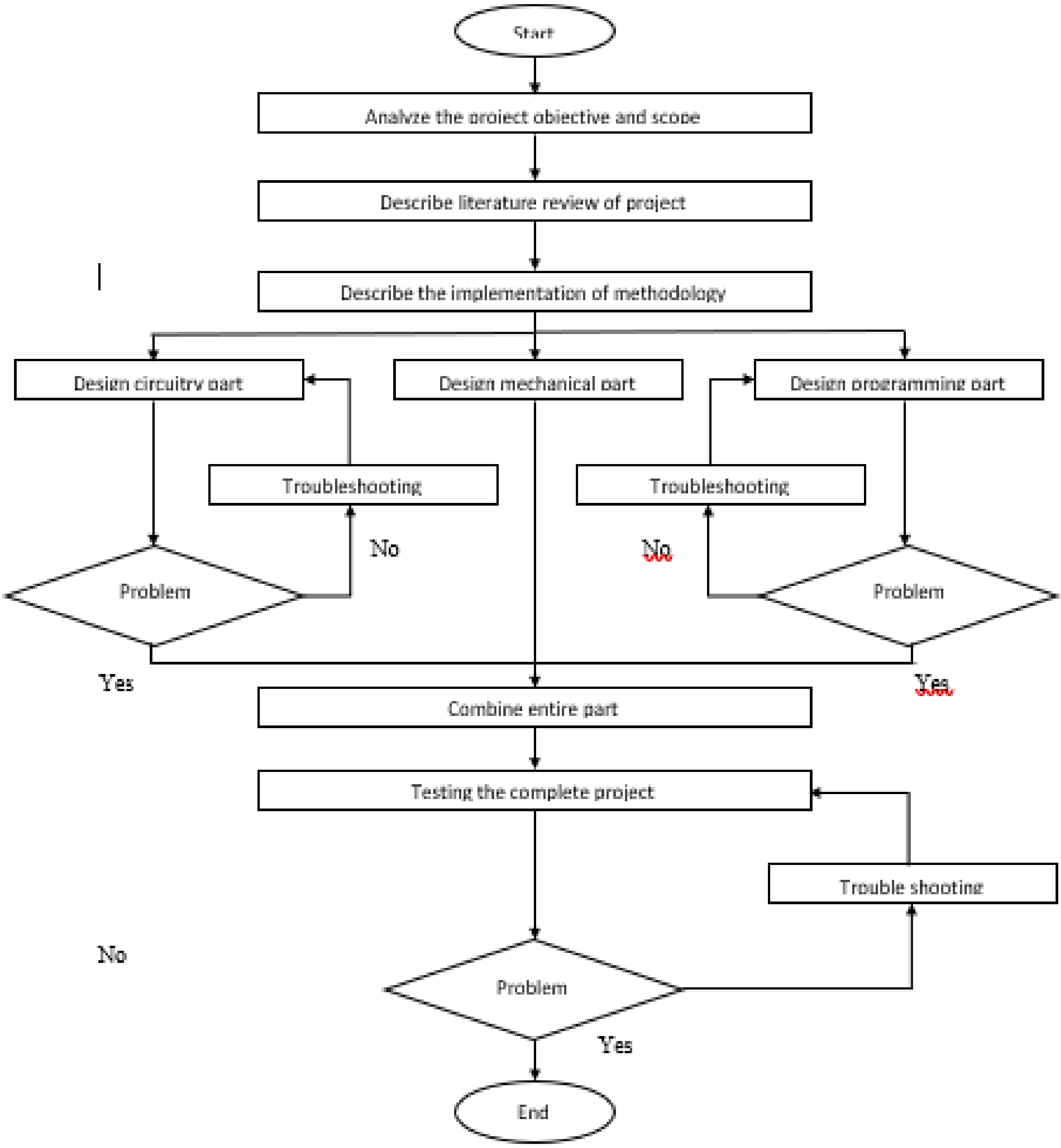

Figure 1: Flowchart of the project planning

3.1 Flowchart of the systems

The programming starts with the flowchart, which is essential for the step-by-step procedure to solve the solution. It was able to show the process flow and instructions for the programmed code to solve the problem through the use of this programming technique. Below is the flow chart for the dual-axis solar tracker and solar monitoring system:

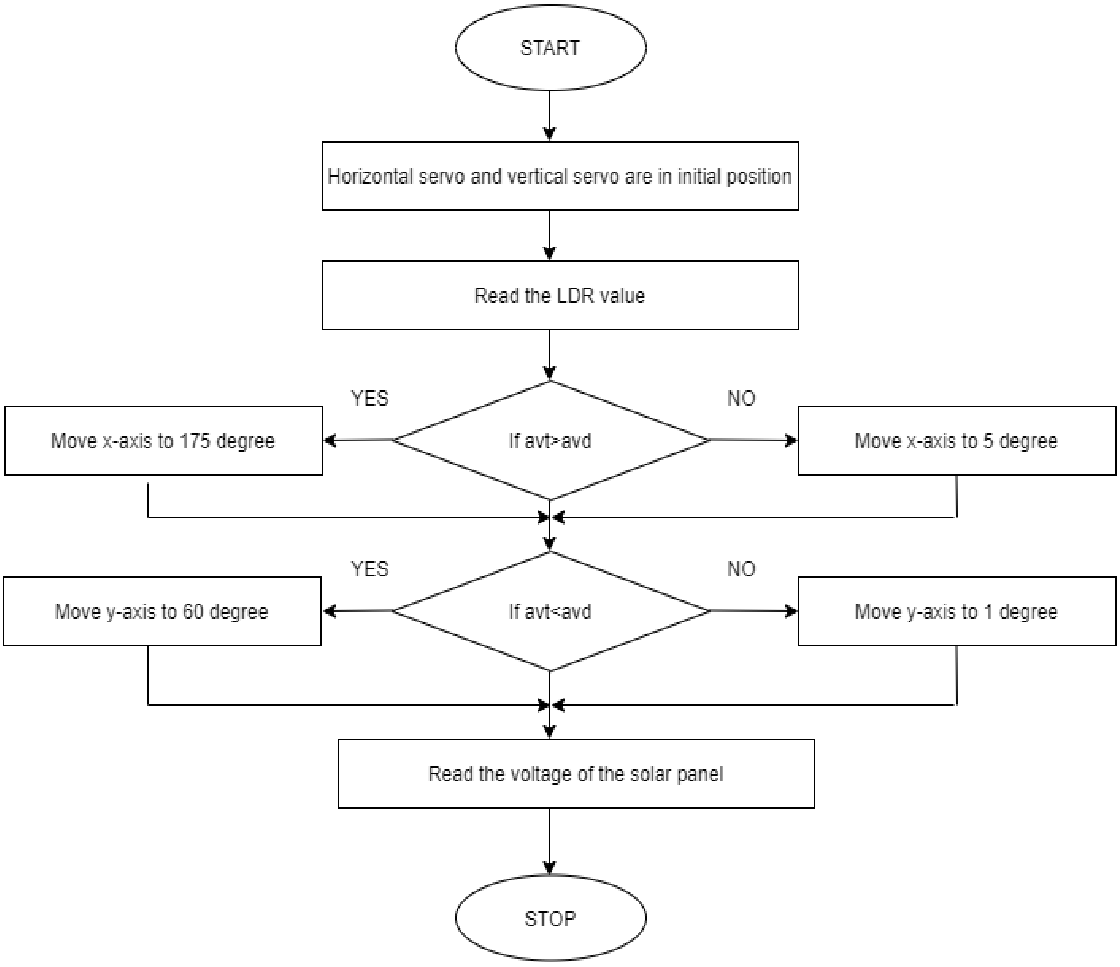

Figure 2: Dual-axis solar tracker flowchart

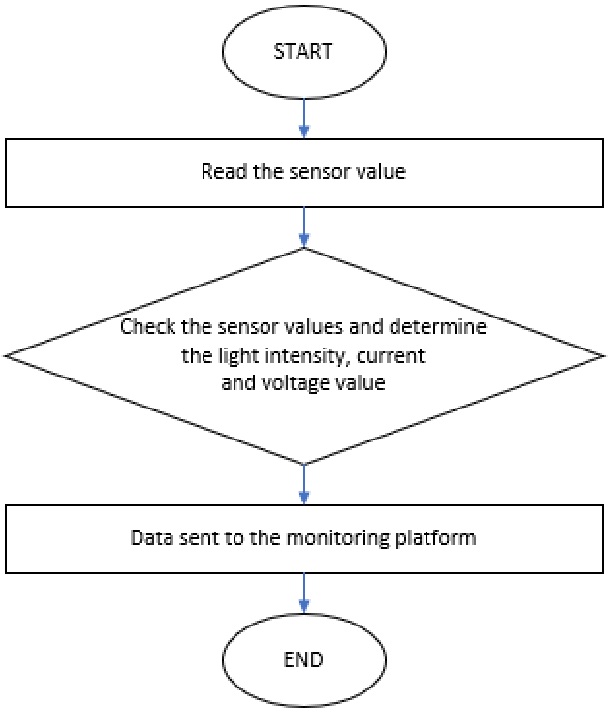

Figure 3: Solar monitoring system flowchart

3.2 Dual-axis solar tracker simulation process

The simulation was implemented by using the Autodesk TinkerCad software. TinkerCad is a free online collection of software tools that help individuals think, create, and develop across the world. It is the perfect introduction to Autodesk, the leader in software for 3D design, engineering, and entertainment. The Solar Dual Axis Tracker simulation using TinkerCad is shown in Figure 4.

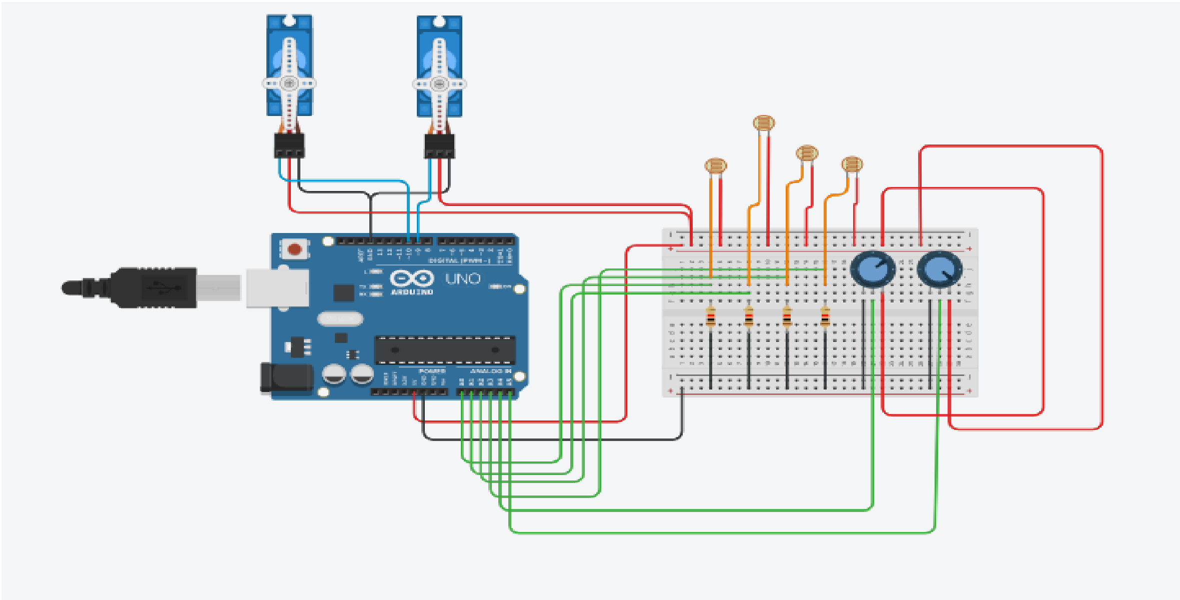

Figure 4: Simulation of dual-axis solar tracker

3.3 Ubidots online software as the monitoring platform

Ubidots is the web-based software used for monitoring the solar power system. Ubidots has provided end-to-end IoT solutions for healthcare customers to remotely monitor, control, and automate procedures. Ubidots users can easily connect, build, and deploy cloud IoT applications with a core architecture focused on data efficiency and an engaging UX (user experience), leaving Ubidots to handle the cloud and end-user UX infrastructure. The signal is from a connection between the sensors and the NodeMCU.

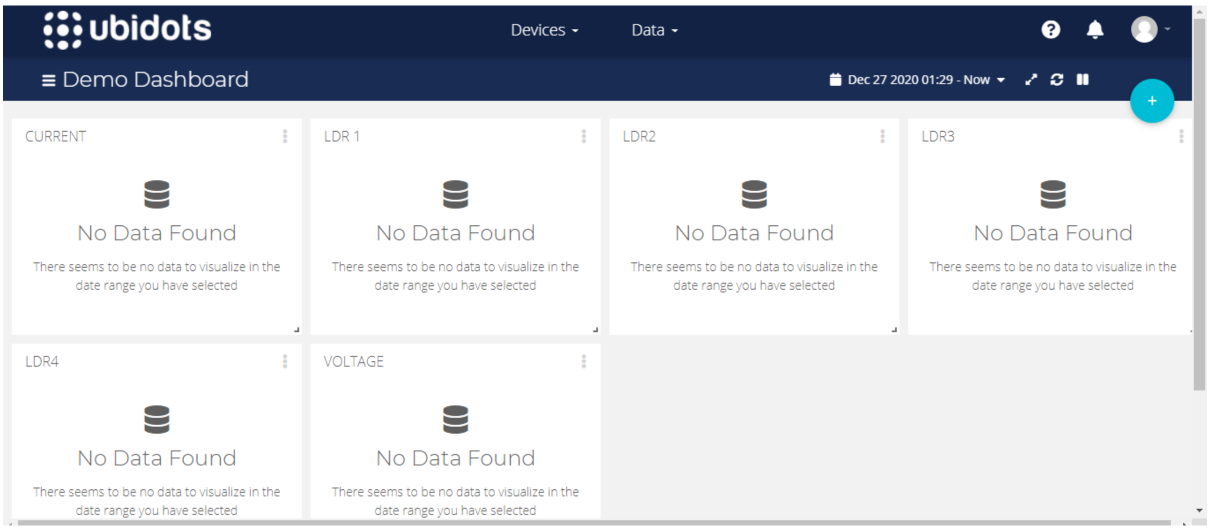

Figure 5: Ubidots online software

4. Results and Discussion

The experiment set up is purposely to find the performances of the solar system with the tracking system. The data is based on the working process for the solar system, dual-axis solar tracker, and solar monitoring system according to the programming code.

4.1 Results

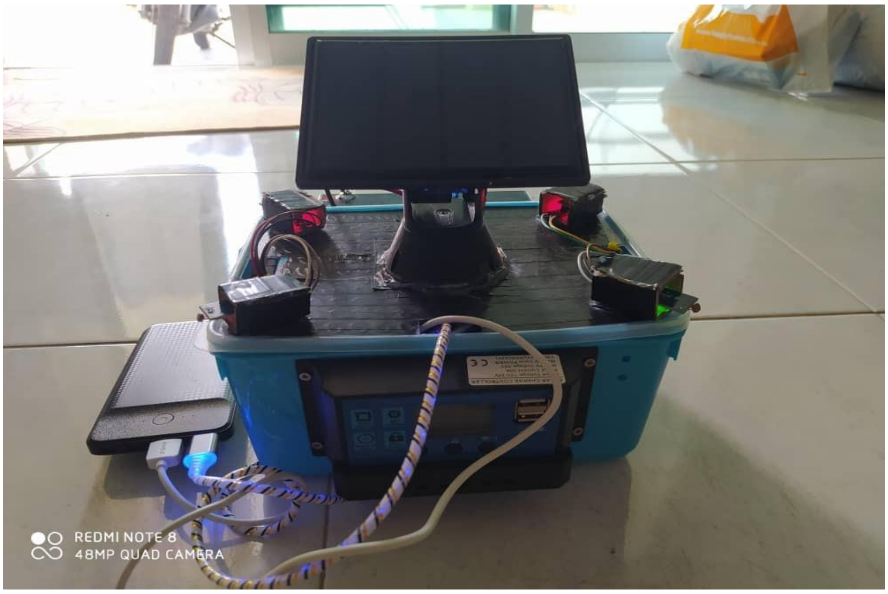

Figure 6: Dual-axis solar tracker in steady state

Table 1: Monitoring system performance at normal state

Data Measured	Results
Time	-
Current	0
Light Intensity (LDR1)	1
Light Intensity (LDR2)	1
Light Intensity (LDR3)	1
Light Intensity (LDR4)	1

In Figure 6, the figure shows the Dual-axis solar tracker in the normal state. The solar panel originally is facing the angle according to the programmed code for the initial state. In Table 1, it shows the value read by the sensor for the initial state or normal state. The current read by the sensor while in the normal state is 0A while the LDR sensor read is 1 for all the LDR sensors.

Figure 7: Dual-axis solar tracker on first day testing

Table 2: Monitoring system performance on first day testing

Data Measured	Results
Time	1.00 PM
Current	8 A
Light Intensity (LDR1)	1
Light Intensity (LDR2)	1
Light Intensity (LDR3)	1
Light Intensity (LDR4)	0

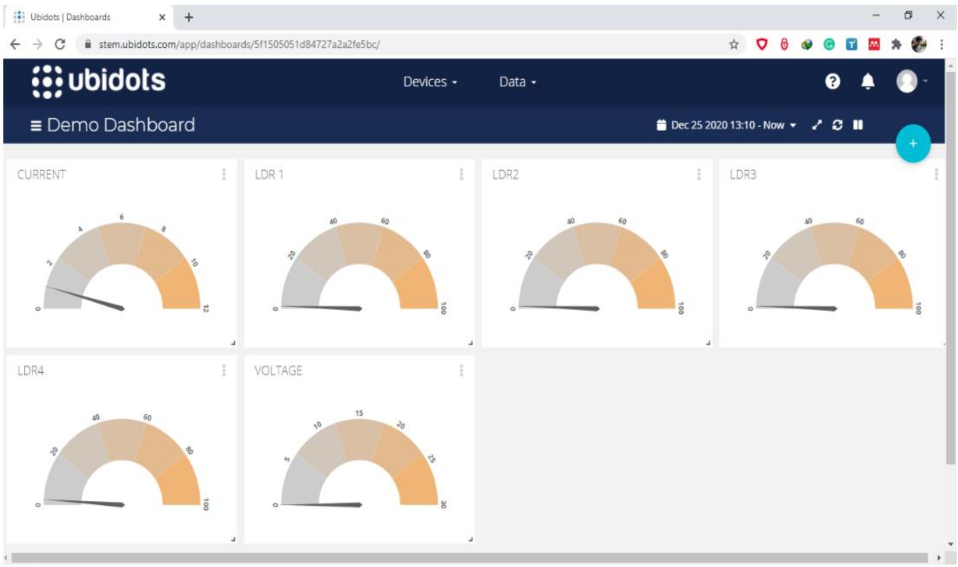

Figure 8: Gauge meter in Ubidots on first day testing

In Figure 7, it shows the position of the solar panel on the first-day testing. The solar panel rotates 90 degrees to the left and 20 degrees downwards from the initial position. Table 2 shows the sensor reading of the current and light intensity during the testing. The current read by the current sensor is 8A, the values of LDR 1 to LDR 3 are 1 while LDR 4 is 0. Figure 8 shows the gauge meter that has been used in the Ubidots as the indicator for the monitoring system. All the data that has been read by the sensors are sent to the Ubidots system and move the pointer to the value that has been read by the sensor through the NodeMCU.

Figure 9: Dual-axis solar tracker position on second day testing

Table 3: Monitoring system performance on second day testing

Data Measured	Results
Time	1.00 PM
Current	2 A
Voltage	0
Light Intensity (LDR1)	1
Light Intensity (LDR2)	1
Light Intensity (LDR3)	3
Light Intensity (LDR4)	1

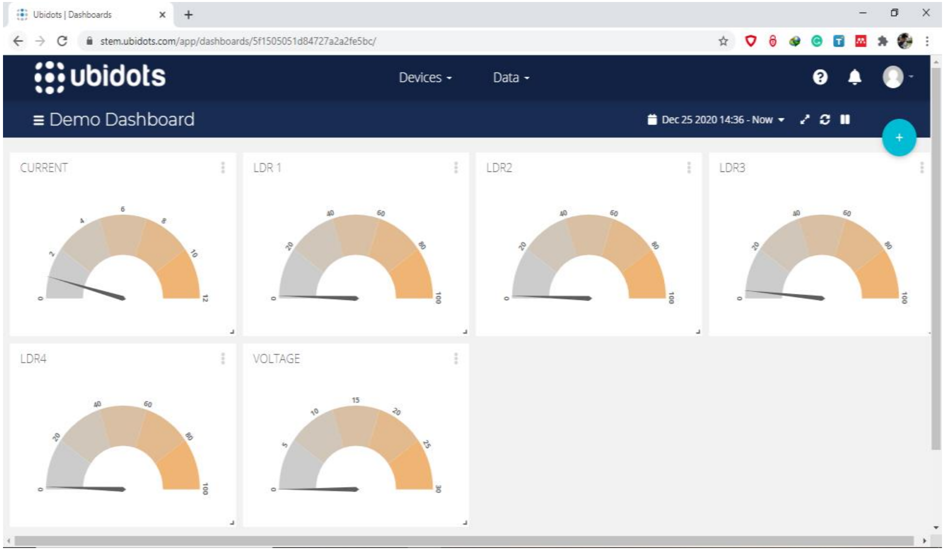

Figure 10: Gauge meter in Ubidots on second day testing

Figure 9 shows the position of the solar panel on the second-day testing. The solar panel rotates 45 degrees to the right and 20 degrees upwards from the initial position. Table 2 shows the sensor reading of the current and light intensity during the testing. The current read by the current sensor is 2 A, the values of LDR 1, LDR 2, LDR 4 are 1 while LDR 3 is 3. Figure 8 shows the gauge meters' indicators point to the value that has been read by the sensors.

4.2 Discussion

The performance of the systems able to work and function but not as expected though the experimental setup is very complicated. The experiment set up was to test whether the Solar Power system, Dual Axis Solar Tracker and the solar monitoring system are working well. The results outcome was not as expected due to several problems. During the performance test, the voltage sensor module has broken suddenly and caused the wire that was used for it burned and the voltage sensor module cannot be used. That is the reason that the value of voltage during the performance test is 0 and not included in the data analysis and result. The performance of the Dual axis solar tracker was functioning in great condition when test using the lamp rather than sunlight. The LDR can read the light intensity of the lamp better than the sunlight. The monitoring system also functioning well but not as expected due to the problems that came from the components used. The problems came from the voltage sensor module that broke during the testing session and the LDR can't read the light intensity of sunlight properly. From the data that has been observed, the LDR is not suitable for the sunlight intensity measurement. Overall, all the systems were working, and functioning based on the objectives of the projects.

5. Conclusion

The solar power system is very compatible and convergence with the dual-axis solar tracker and solar monitoring system. The full performance of the solar power system can be monitored every minute. The dual-axis solar tracker has increased the performance of the solar power system effectively because the LDR can track the position where the direction of the sunlight hits the most. The solar panel follows the direction of the sunlight that makes the solar panel can produce electrical power consistently to power up the gateway station with full performance. The 12 V rechargeable battery used is to power up the gateway station when there is no sunlight presence. The solar charger regulator acts as the charger for the battery during the presence of sunlight. Therefore, the battery is always in good condition when there is no sunlight.

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