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SOLAR TRACKER UTILIZING IOT FOR ENHANCED POWER GENERATION

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Abstract
Sunlight based energy is acquiring prevalence as a possible wellspring of environmentally friendly power. However, there are insufficient specialists to monitor the solar panels' condition. Dust, partial shadowing, fractures, delamination, and other factors have the potential to lower the efficiency of solar panels when they are exposed to the elements.
The essential objective of this task is to fabricate a sun-oriented tracker and communicate information through IoT. In this work, the area of the sun was detected in two phases: secondary and primary. The sun-Earth relationship is used in the first stage, and a group of LDR sensors are used in the second stage. The amount of solar irradiance is what determines how much energy can be recovered from a solar collector.
The solar collector panel should always be parallel to the incident radiation for maximum energy extraction. Sun oriented global positioning frameworks fundamentally further develop the energy productivity of photovoltaic (PV) boards. A solar panel, two servo motors, an LDR sensor module, and an electronic circuit are typically the project's hardware. The system's way of thinking is represented by the software component. In this project, an autonomous solar tracking system is built on top of a mechanical framework with servo motors and a Light Dependent Resistor (LDR). It is carried out utilizing an Arduino UNO regulator. Utilizing ThingSpeak (Web and Database Server), voltage and current sensors, and a NodeMCU, the data is periodically uploaded to the mobile application. After that, monitoring the installed plant can be done with the data that has been uploaded. The results demonstrate that autonomous solar tracking systems outperform fixed ones in terms of effectiveness and dependability.
Keywords: NodeMCU, ThingSpeak, Light Dependent Resistor, Internet of Things, Sensors.

I. Introduction

In India, there is immense potential for renewable energy generation from multiple sources such as wind, solar, biomass, small hydro, and cogeneration bagasse. As of March 31, 2022, the total estimated potential for renewable power generation across the country stands at 14,90,727 MW. Notably, solar power holds a significant share in this potential, accounting for 7,48,990 MW, which represents approximately 50.24% of the total renewable energy potential [1].
The adoption of solar energy in households has been steadily increasing, driven by several factors including government incentives, decreasing costs of solar technology, and rising awareness of environmental sustainability. With abundant sunlight throughout the year, solar energy presents a viable solution to address the country's growing energy needs while reducing dependency on fossil fuels. From urban apartments to rural villages, households are increasingly installing rooftop solar panels to harness the sun's energy and power their daily activities.
Solar trackers are innovative devices used to increase the efficiency of solar panel systems by orienting them to track the sun's path throughout the day. By continuously adjusting the angle and position of solar panels, trackers maximize the amount of sunlight captured, optimizing energy production. Solar trackers are particularly beneficial in regions with high solar irradiance or where space is limited, as they allow for greater energy yield from a given area of land.
Single-axis trackers rotate panels along one axis, typically following the sun's east-west movement, while dual-axis trackers can also adjust for the sun's north-south variations.

In paper [3], the researcher had compared the dual-axis solar tracking system with fix-angle solar tracking system and the result show the electricity generated by dual-axis solar tracker has an overall increase of 8% until 25% more than the fix-angle solar tracker.
The Internet of Things (IoT), sometimes known as the Internet of Everything (IoE), is a network of web-enabled objects that gather, send, and act on data from their surroundings using embedded sensors, processors, and communication gear. These gadgets, also known as "associated" or "brilliant" devices, may communicate with other devices that are connected to them through a process known as machine-to-machine (M2M) communication and follow up on the data they receive from one another. Humans can set up the devices, give them orders, or grant them data access, but they usually function on their own. All of the commonly available little portable pieces, as well as our house and business's regular accessibility.
The integration of IoT technology into solar trackers can vastly improve their efficiency and functionality. The utilization of dual-axis systems in solar trackers via IoT implementation enables instant movement following of the sun, thereby leading to increased efficiency in solar tracking. The IoT technology not only improves solar tracking but also reduces the amount of CO2 emissions from the environment, resulting in a more sustainable energy source. Moreover, the IoT technology allows for live data feed in solar trackers, enabling real-time monitoring and data collection of the system performance. The system exhibited the ability to execute and monitor the real-time operations of the photovoltaic (PV) module, indicating that it has potential to optimize the performance of the solar PV system. The dual-axis system was able to follow the movement of the sun instantly, which is crucial in maintaining efficiency and maximizing energy output.

II. Literature Review
This section presents a summary of previous research carried out in the same field, providing an extensive literature review that places the current study into context.
[2] emphasizes on the advantages and disadvantages of Internet of Things (IoT), which connects hardware and software to connect actual items to the internet, allowing for interaction and communication between them. This change makes it easier for individuals to engage with items, has the potential to completely change daily life and communication patterns. However, there are a number of obstacles and problems that must be overcome before IoT can reach its full potential. The paper includes explanations of sensors, actuators, and their intelligent communication, as well as subjects like IoT definition, architecture, problems, and issues.
[5] The project's main goal is to leverage Arduino technology to create a dual-axis solar tracker with an Internet of Things monitoring system. Solar tracking systems improve the efficiency of using solar energy, a renewable resource. The solar panel's position is adjusted by the system using two servo motors in response to variations in the sun's movement and light-dependent resistors (LDRs) for sunshine sensing. Data is saved on an Internet of Things monitoring website, which is facilitated by an ESP8266 chip.
[6] This paper describes the design and implementation of a dual-axis solar programmable logical controller (PLC) based automatic tracking system, together with its supervisory and control system. In order to maintain the solar panels' constant perpendicularity to the sun, the elevation and orientation angles are controlled by the suggested automatic tracking system. The automatic solar tracking system is inexpensive, dependable, and effective, according to the results.
Authors of [10] presented research on Solar Panel's quality, when solar panels are exposed to the elements, their efficiency may decrease as a result of dust, partial shading, cracks, delamination, and other factors. This project compares the performance of the panels under normal and problematic conditions using tools like a PV analyzer, solar power meter, and thermal camera. Using NodeMcu, the acquired data is routinely transferred to the cloud. From there, it may be utilized to monitor the installed plant.

[12] presents a dual-axis solar tracker (DAST), which enables exact alignment with the sun's position throughout the day, is suggested as a way to increase the efficiency of solar panels. The system aims for fast response times (less than 0.2 seconds) in order to store data in a database and enable thorough study of solar panel performance over the course of a day. The panel is positioned by a microcontroller in response to changes in the sun, and the tracker's performance is monitored by a Wi-Fi-connected Internet of Things system to guarantee maximum energy output.

[13] This chapter looks at how IoT technology can be used to monitor and manage a smart dual-axis solar tracker system at a reasonable price. The solution makes use of developments in hardware, software, and network technologies to allow for remote control and monitoring of the solar tracker over an online Internet of things platform. Sending and receiving different sorts of data as well as sending alert alerts when predetermined events take place are important features. With an emphasis on accessibility, affordability, and simplicity, the solution makes use of inexpensive hardware and open-source software. The system's capacity to send data efficiently, enable remote monitoring, and receive commands from the IoT monitoring application is confirmed by the test results.

[15] A study on the working and feasibility of an Automatic Solar Tracker are carried out in this paper. To maximize solar exposure all day, these trackers move the solar panels around to follow the sun's path across the sky. It summarizes the strengths and weaknesses of a solar tracker, sensors used to develop an automatic solar tracker.

Authors of [16] developed a solar tracker using the sun-earth relationship. Hardware for the project includes solar panels, motors, sensors, and electronic circuits; software controls how the system behaves in different weather scenarios. The study's findings show that the automatic sun tracking system based on LDRs and DC motors, when implemented with an Arduino UNO controller, is more dependable and effective than fixed configurations.

[17] This study examines how changes in solar irradiation throughout the day and seasons contribute to a decrease in the power generation of stationary flat-plate photovoltaic (PV) systems. The research suggests a low-cost, autonomous dual-axis solar tracker system to improve solar power generation. For active tracking, this system uses Light Dependent Resistor (LDR) sensors in a closed-loop control configuration. The sensors in the tracking method spin around the primary (north-south) and secondary (east-west) axes using a digital logic design. A comparison of the suggested tracking system with a fixed flat-plate system using experimental assessment revealed an average 44.89% gain in electrical energy efficiency. The study also offers a cost estimate of the suggested tracking system.

[19] Developed an automated solar tracking system utilizing comprising an Arduino Microcontroller, four Light Dependent Resistors (LDRs), and three stepper motors. Hardware and firmware programming are combined to operate the system. LDRs are employed to capture maximum incident light, while stepper motors adjust the solar panel's position accordingly. Software controls both vertical tilt angle and horizontal rotation of the panel, enabling it to track the sun's direction. This system optimizes illumination, reducing energy generation costs by minimizing the required number of solar panels.

III. Methodology

3.1 Requirements

Microprocessor- Arduino UNO, Node MCU

Well known microcontroller board called the Arduino Uno depends on the ATmega328P microcontroller. It is frequently utilized for a variety of projects in the maker and electronics communities due to its adaptability and simplicity.

Figure 1: Arduino UNO

NodeMCU, an open-source development board called NodeMCU is based on the ESP8266 Wi-Fi chip. For IoT (Internet of Things) prototyping and development, it offers a low-cost platform. Hub MCU consolidates the abilities of an Arduino board with Wi-Fi network, making it reasonable for building associated projects.

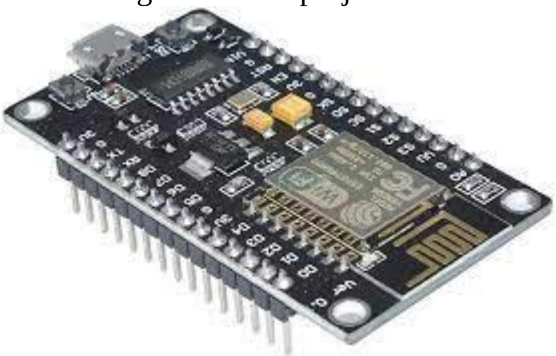

Figure 2: NodeMCU

Sensors- Current, LDR sensors

A current sensor is a device that produces a signal that corresponds to the electric current passing through a wire. Computerized yield, simple voltage, or current are potential kinds of made signals. The created sign can then be utilized to control the gadget, be put away for additional examination in an information gathering framework, or be utilized to show the deliberate current in an ammeter.

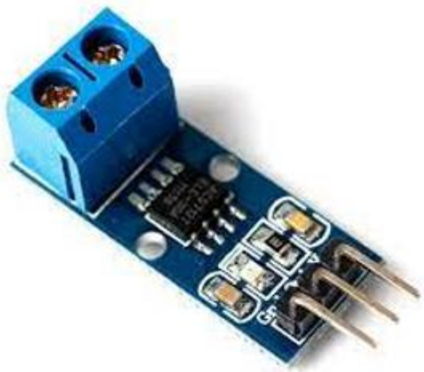

Figure 3: Current Sensor

LDR (Light Dependent Resistor) is a one-of-a-kind kind of resistor that, as its name suggests, alters its resistance in response to the intensity of light. It is based on the idea of photoconductivity. Its resistance decreases as the intensity of the light increases. It is oftentimes utilized as a light sensor, light meter, programmed streetlamp, and in different circumstances where light responsiveness is required. One more name for itis a light sensor.

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Figure 4: LDR Sensors

Servo motors

The rotational actuator or straight actuator known as a servo engine empowers exact control of rakish or direct position, speed, and speed increase. It consists of a position feedback sensor and a suitable motor. Additionally, it requires a rather complex controller, frequently a specialized module designed specifically for servomotor use. Even though the term "servomotor" is frequently used to refer to a motor suitable for a closed-loop control system, servomotors are not a specific kind of motor.

Figure 5: Servo Motor

Resistor

A resistor, a passive electrical component with two terminals, is a circuit element that uses electrical resistance. In electronic circuits, resistors are used for a variety of things, such as reducing the flow of current, altering signal levels, dividing voltages, biasing active components, and terminating transmission lines. Test loads for generators, power distribution systems, and motor controls can be high-power resistors that can generate many watts of heat rather than electrical energy.

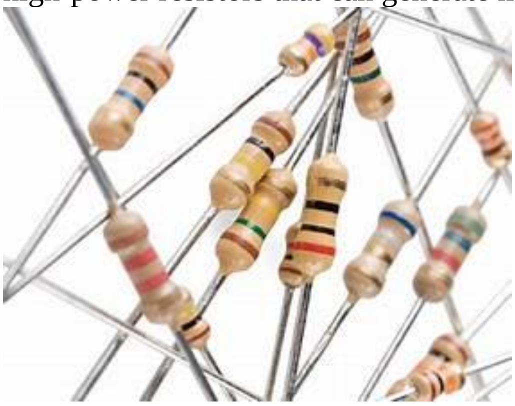

Figure 6: Resistors

3.2 Methodology

The below framework engineering depicts how multiple framework modules are linked to one another. The project can be divided into two parts: Implementation of Dual Axis Solar Tracking System, monitoring the Solar Tracker through a mobile application.

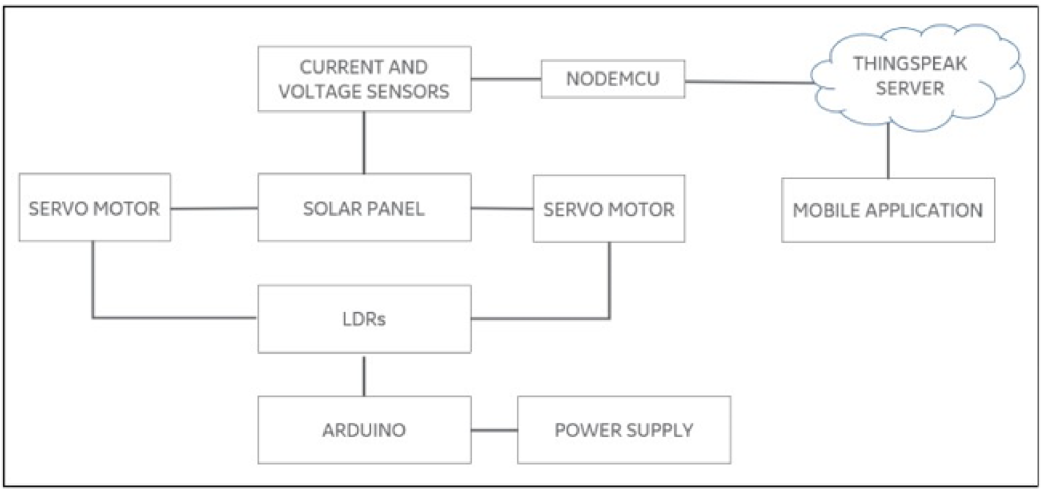

Figure 7: System Architecture

3.2.1 Dual Axis Solar Tracker

The dual-axis solar tracker contains a set of four LDRs implementing 2 axes, and intensity is calculated in all required directions and the solar panel is rotated in whichever direction more intensity is recorded, i.e., LDRs are placed at four corners of the solar panel: Top-Right, Top-Left, Bottom-Right, Bottom-Left. Intensity is compared on left and right directions and panel is rotated on vertical axis, similarly intensity is compared on top and bottom of the panel and is rotated on horizontal axis. Hence, two servo motors are used to rotate the panel in two directions: horizontal and vertical directions respectfully. Communication between LDRs and servo motors is through Arduin UNO micro-controller. Arduino IDE is used to control the sensors, motors and micro-controller.

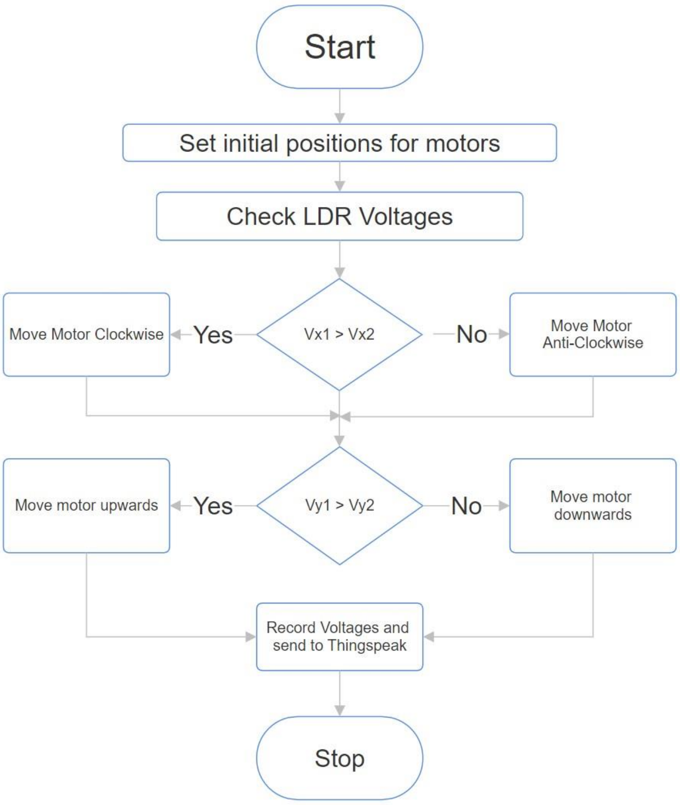

Figure 8: Dual Axis Solar Tracker

3.2.2 Monitoring the Solar Tracker

The second part consists of monitoring the dual axis solar tracker in order to keep it safe and efficient. Solar panels are connected to current and voltage sensors, these current and voltage sensors read from the solar panel. Current and voltage sensors are connected to NodeMCU, it consists of a Wi-Fi module used to connect over the internet. NodeMCU can be used to receive data from sensors and view it over net- work. Readings read are transported and stored in a webserver known as Thing- Speak. To connect NodeMCU and web server, the first prerequisite is that both should be connected to the same network, and with the unique API key provided to our ThingSpeak channel. Arduino IDE software is used to implement the program to connect NodeMCU to the server. A mobile application is developed to monitor the performance of the solar panel using MIT App Inventor. The application is connected to a web server and receives data from it and displays in the application. Hence, a user can easily monitor the solar panel through the application.

IV. Implementation

4.1 Dual Axis Solar Tracker

The below circuit diagram shows the construction of a Dual Axis Solar Tracker. Four LDRs are connected to Analog Input Pins and two servo motors for dual axis are connected to Digital Output pins of Arduino UNO microcontroller.

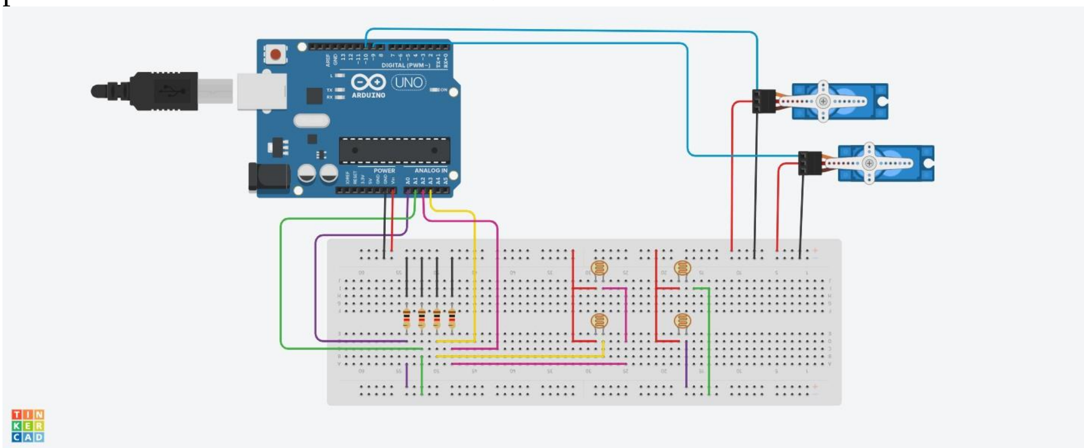

Figure 9: Circuit Diagram

4.2 Connect to Thingspeak Server

Create a ThingSpeak account and channel with a distinct Channel ID and Write API Key. Initialize the ThingSpeak client using your Channel ID and Write API Key, and the Wi-Fi connection with your network credentials in the code. Utilizing the ThingSpeak client, read sensor data and send it to your channel. Upload the code to your NodeMCU and the NodeMCU will continuously transmit data via Wi-Fi to the designated ThingSpeak channel.

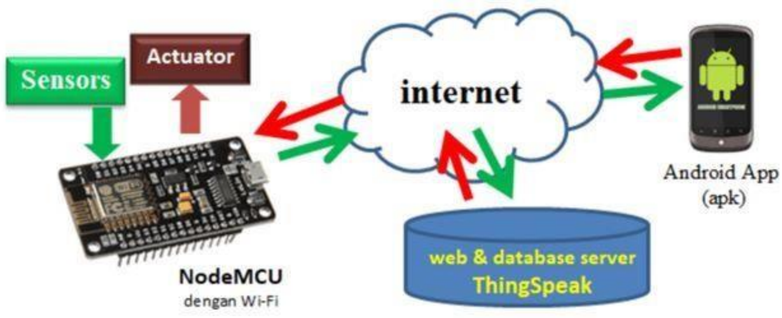

Figure 10: Connecting to the Server

4.3 Mobile App Development

Use the ThingSpeak API to send and receive data between the two platforms in order to integrate ThingSpeak with MIT App Inventor. To update or obtain data from your ThingSpeak channels, use the Web component in App Inventor to submit HTTP calls to the ThingSpeak API. This will help us view the sensor values on the application and also monitor the system.

V. Results

The mobile application contains two screens: the first screen displays the voltage, current and power values over time, specified with date and the value generated, whereas the second screen displays the values of voltage, current and power numerically and some options to redirect the power generated. Some basic applications mentioned are using the power by directly connecting them to home appliances or storing it for later usage or using it for charging electric vehicles. This type of application allows users to easily monitor their solar tracking system.

This mobile application provides periodic monitoring; hence the performance of the solar panel and the tracking system can be analyzed, which will help to improve the whole system.

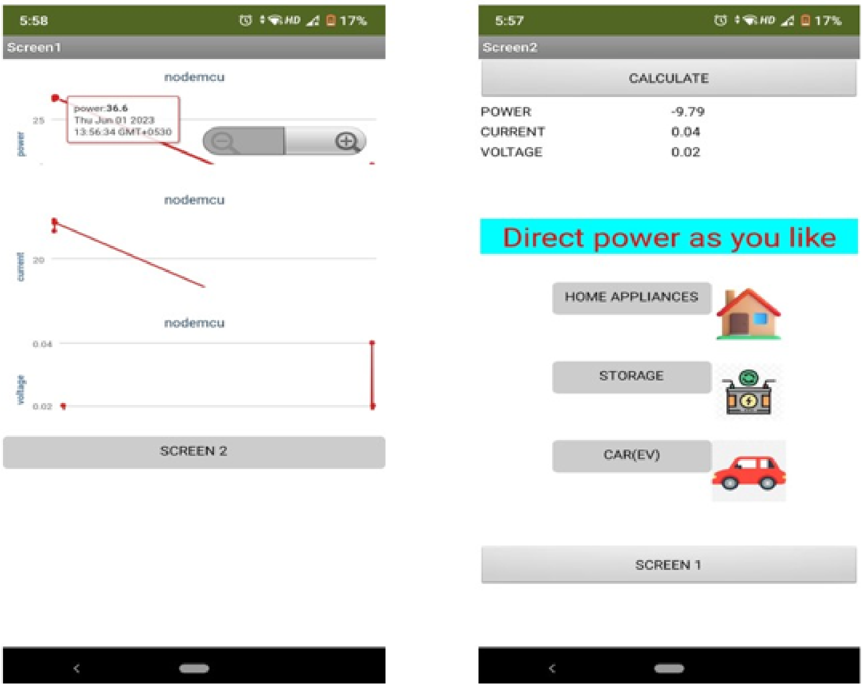

Figure 11: Application Results

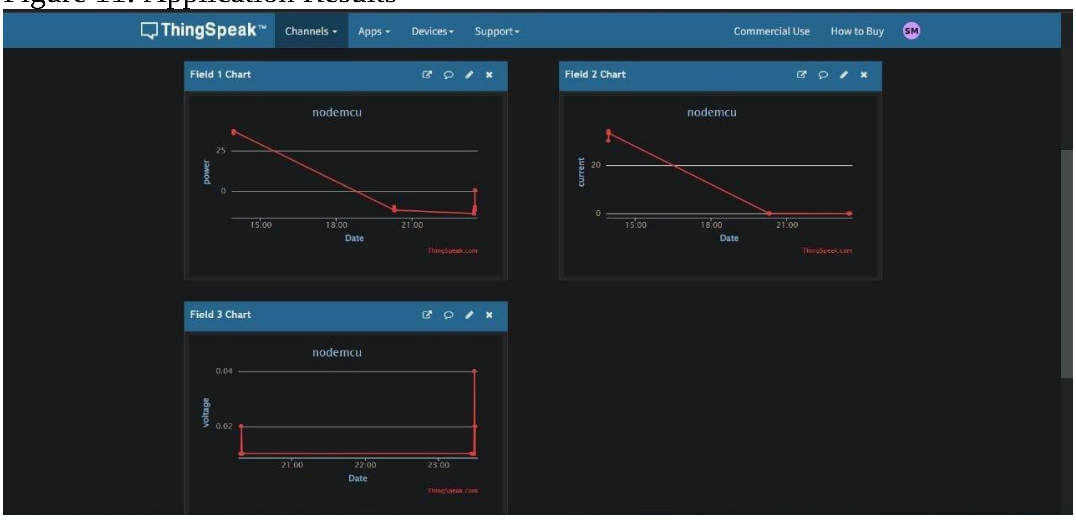

Figure 12: Thingspeak Results

VI. Conclusion

In any area, a programmed sun-powered global positioning framework frequently accomplishes the best energy gain. As a result, it is the system with the greatest degree of adaptability because it can be set up anywhere and generate a lot of energy. Solar trackers are always recommended everywhere because they always increase the amount of energy, they collect from an energy perspective. Because it can be used independently with a computer or mobile device and connect wirelessly, the system is reliable and observable. LDR sensors and voltage and current sensors with high accuracy ensure an improved tracking system. The user now has internet access to the sensor parameters. This guarantees the most powerful result while making remote checking of planetary groups moderately straightforward. With a tracker that only moves along a single axis, it is generally impossible to track the maximum solar energy. when dual-axis trackers have solar beams that are always perpendicular to the panel. As a result, the maximum amount of energy is stored throughout the day and year. In this way, the result increments demonstrating that proficiency in excess of a decent sun-powered charger (around 30- 40% more) or a solitary hubs-based tracker (around 6-7% more).

Using only the electricity generated by the solar panel can eliminate the system's need for an external power supply of 5 volts and 3.3 volts. Using a motor and control system, it is also possible to improve power production by tracking the sun. In addition to the other advantages, a system's intelligence can be enhanced through the use of a variety of machine-learning models and techniques.

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