# AN IOT BASED SOLAR PANEL MONITORING AND RECOMMENDATION SYSTEM USING BLYNK CLOUD

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***Abstract*—Most people relocate to urban areas in search of better prospects. Building construction projects are consequently becoming more common in populated areas. As a result, several resources are also being utilized. Due to the globe's expanding population, it is difficult for electric power plants to provide enough electricity, and the world is currently facing electrical issues. These problems have increased the significance of the internet of things in contemporary culture. Several physical devices are connected over the internet for communication. The internet of things reduces living costs and automates all procedures, eliminating manual labor. People use IoT to use solar panels to create electricity from the sun's light, reducing the demand for power plants. Another challenge users run into is controlling their solar stations, mostly physically. Considering all these problems, our project would allow users to use their cell phones to monitor and control the solar system virtually visually. The user won't need to be present physically to use it manually. The customer will effectively reduce their electricity usage while receiving automatic notifications of updates on their mobile device.**

***Index Terms*—Solar Panels, Power Monitoring, Power Consumption Monitoring, Cloud Computing, Internet of Things, Wemos, Batteries, Blynk, Recommendation, Senors**

## I. INTRODUCTION

The Internet of Things is an emerging and futuristic technology that enables the machine to be reportedly controlled by humans [1]. Nowadays, it is widely used in our daily activities, monitoring the system and exchanging data from one physical device to another, controlling these devices remotely. Robots and machines can also be operated remotely [2]. For example, when the water level increases from the given range, the system will alarm the users so the user can then operate accordingly [3]. IoT connects huge things like intelligent car parking, route tracking, smart ecosystem, temperate monitoring, etc. Using IOT, the machines are not dependent on humans for performing their functions [4]. Today the world is dependent on electricity, meaning we can not do anything without electricity. All of our daily life activities and work are on electricity. We can say that electricity is now our backbone [5]. As we know, the consumption of electricity is increasing day by day. Also, the cost of electricity is constantly growing because the higher the electricity consumption, the more we have to produce, and to produce more electricity, we need a lot of machines and new technology, so automatically, the cost of electricity will be increased. The increasing price of electricity effect lower-class people, and they can afford it [6]. We need such systems to produce electricity from natural resources to overcome this problem. The power plants are developed to overcome this problem but monitoring it and consuming it properly is another problem for power plants [7]. The mechanism through which sunlight produces electricity is harmless for humans and the whole ecosystem, but maintenance and keeping a check on all the devices are necessary [8]. Photo voltaic cells are used in these solar power plants; when the rays of sunlight strike these photo voltaic cells, these cells convert the sunlight directly into electricity [9]. Batteries are connected to the solar panel to store electricity and then provide electricity to houses, factories, schools, etc. [10]. Monitoring the power plants is very important; some are nearby and can be monitored daily, but some are far away and challenging to monitor daily [11]. So, this research paper proposes a very efficient IOT-based device to develop a power plant and monitoring system to check all the activities and functions of the power plant from faraway places through mobile. In this research paper, a prototype is developed to examine the results and monitor all the operating temperatures, humidity, voltage, current, etc., through mobile application [12]. Wemos is used as the main component of the system that controls the connectivity of all devices, and the WiFi module for connecting the physical devices to the internet to upload all these parameters on the cloud. We use blink cloud services for storing and analyzing the real-time statistics of the parameters [13]. This prototype also makes an automatic alarm if the battery is complete, the temperature increases or decreases, etc. So the user can control the system according to the environment [14]. The primary goal of this proposed project is to maximize the solar panels' power output. Additionally, any issues with the solar panels' performance will be indicated, and IoT technology is used to monitor and display parameters like voltage and current using sensors [15]. Solar radiation explains this model, specifically, how sunlight from the sun is trapped by solar panels, which convert sunlight into proper energy forms like heat and electricity [16]. The electrical energy is then sensed by sensors, such as voltage sensors, which use the voltage divider principle to measure the voltage produced by the solar panel. Mathematical calculations are then used to determine the current [17]. The system's experimental setup includes solar panels, a regulator power supply, an ESP8266 Wi-Fi module, voltage and current sensors, an LCD (liquid crystal display), and a Wemos D1 R2 microcontroller.

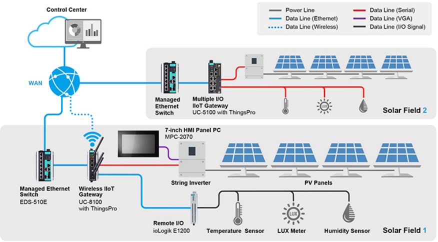


Figure 1: Solar Power Plant Monitoring System

The remainder of the paper is divided into five sections. Part two examines the literature highlighting relevant studies and significant solar system parameters. Section three begins with the system design developed using a block diagram and the system's working flow. This part also depicts the experimental setup. Section four uses graphs to discuss the observed outcomes. Part five ends the paper and outlines the following directions.

## II. LITERATURE REVIEW

The resources through which electricity produces is decreasing daily, for there should be some resources that can be used for a lifetime. One of the primary sources is solar power plants. This system converts sunlight into electricity and store electricity through batteries. Whenever there is no sunlight, the battery provides us with electricity. The Photovoltaic system efficiently improves the solar system's monitoring [13]. The PV system with a low-cost GPRS module and a low-cost microcontroller through which the data will be received from the PV system [17]. This system measures the temperature and also current of the PV system. This system was cloud computing because all the data was stored on the website. The solar panel is one of the non-conventional resources. Due to the decrease in the cost of modern technologies, solar panel also decreases and is cheaply available in the market [3]. But this system should have to monitor regularly. Monitoring methods are necessary for better performance of the system. This helps us to see all the functions of the system and allow us to protect our system from upcoming damage. In another research paper that used raspberry pi to integrate components [18]. This system also stores data via mobile application. The recorded data are about temperature, humidity, voltage, and current and will be monitored accurately. Also, it will notify the user to perform specific actions according to the situation. Kishore et al. have proposed a cloud-based solar system monitoring technique that involves transmitting regular data records to the cloud after a predetermined period [19]. By continuously monitoring the power plant, the analysis of its current status becomes effortless. The advantage of this analysis is that it enables the detection of potential faults in the system and allows for remote monitoring of output from a considerable distance. Rakesh and his colleagues proposed yet another environmentally beneficial solar system [20]. The generated power is monitored in real-time and updated on the server. As the globe faces a scarcity of renewable resources, every country is turning to solar systems, and scientists are working hard to improve their efficiency. Neha Deshmukh discusses the working of photo voltaic cells to present the solar system to meet the ever-growing technological advancements [21]. Dust on solar panels impacts their performance in terms of energy utilization. This research suggests a system that provides a solution and method for monitoring the dust deposition on solar panels [22]. This device monitors the dust on the solar panels and prevents radiation from reaching the panels. For dust detection, this system includes an LDR sensor and a NodeMCU. Solar power facilities should be inspected regularly to ensure maximum production. The parameters in this proposed research article are controlled by an AT mega controller [23]. This technology continuously checks solar plant performance and uploads parameters to the cloud. Another system is available [24], and in this system, several parameters of the solar panels, such as intensity, current, voltage, temperature, and power, are monitored. To measure the intensity of the light, they used an Arduino UNO controller with LDR censors. The load current is measured using ACS712 and LM35. Following that, all of the parameters are presented on the LCD. The article offers a way to enhance solar panels' efficiency when tracking the sun with a two-axis system [25]. A mathematical model of solar panel functioning has been established for the following applications: stationary solar panel installation and a two-axis solar tracker usage. The solar tracker can rotate the solar panel by an azimuth angle of 0 to 170 degrees and a zenith angle of 0 to 90 degrees. The study describes a method for calculating power generation by solar panels using a sun tracker and a stationary solar panel installation variant. Wireless solar panel monitoring system using LoRa technology" by H. M. Alqudah et al. [26]. This paper presents a wireless solar panel monitoring system that uses Long Range (LoRa) technology to communicate the data collected from the sensors. The system is low-power and low-cost, making it suitable for remote and off-grid applications. PV power plant monitoring using ZigBee technology has also been proposed. Which method uses the ZigBee technology to upload the incoming data to the cloud via a 4G communication network [27].

TABLE 1: Comparison of Features

| Research Papers | Micro-controller | Live Monitoring | App | Charging Module | Backup Monitoring | Notification System | Relay Module |
|---|---|---|---|---|---|---|---|
| An IOT Based Approach for Monitoring Solar power Consumption with Adafruit Cloud | Arduino Mega 2560 | *Yes* | *Yes* | *No* | *No* | *No* | *No* |
| Design and Implementation of Solar Based Dc Grid using Arduino Uno | Arduino Uno | *No* | *No* | *No* | *No* | *No* | *No* |
| Solar Power Monitoring System Using on IOT | NodeMCU | *No* | *No* | *No* | *No* | *No* | *No* |
| Improving the Energy efficiency of using Solar Panel | Raspberry Pi | *No* | *No* | *No* | *No* | *No* | *No* |
| IOT Based Solar Power Monitoring System | Arduino Uno | *No* | *Yes* | *No* | *No* | *No* | *No* |
| Our Proposed System | Wemos DI R2 | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* | *Yes* |

## III. SYSTEM ARCHITECTURE AND DESIGN

Our proposed technique involves continuously monitoring all the solar energy panels produced. This is achieved using sensors attached to the system, which sense the conditions and transmit data to the Wemos device [16]. The Wemos device then analyzes the data from these sensors to determine various parameters such as voltage, current, and power output. The system has a Wi-Fi module that enables it to connect to a mobile application, and a web-based interface [19]. The collected parameters are uploaded to the cloud in real time, and the user can access this data at any time [23]. Additionally, the system is designed to notify the user of any flaws or provide recommendations to optimize the performance of the solar panels.

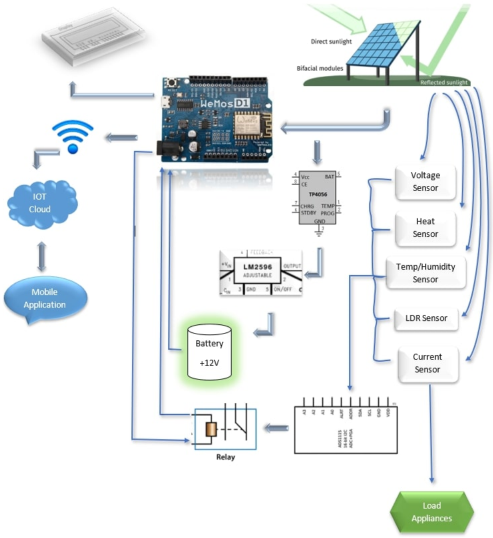


Figure 2: Data Flow Diagram (DFD)

Figure 2 depicts a data flow diagram of our proposed approach, which involves the integration of the Wemos D1 R2 micro-controller chip with essential sensors, components, and statistical analysis. The Wemos chip is connected to five sensors that sense various factors that affect the entire system. These sensors are attached directly to both the battery and solar panel, and the battery is connected to the solar panel using a dc charging module. The Wemos device further relates to the ADS1115 for analog data and to a Step-Down transformer for voltage and using a relay module for power tripping. An LCD is also connected to the Wemos device to display the collected data.

The process of the entire system is illustrated in Figure 3 through a flow diagram. The procedure starts with the initialization of the Wemos device, followed by establishing an internet connection. If the relationship is successful, the system proceeds, but an error message is sent if it fails. After a successful internet connection, an IP address is generated. The input is then taken from the solar panel, and the sensors attached to it access this input and pass it to the Wemos microcontroller [24]. The Wemos device processes the initial data and transfers it to the cloud. These parameters are displayed on the LCD and uploaded to the cloud, where the user can access the data via a mobile application. The system also monitors power consumption and any catastrophic situation, alerting users through the mobile application and email notifications.

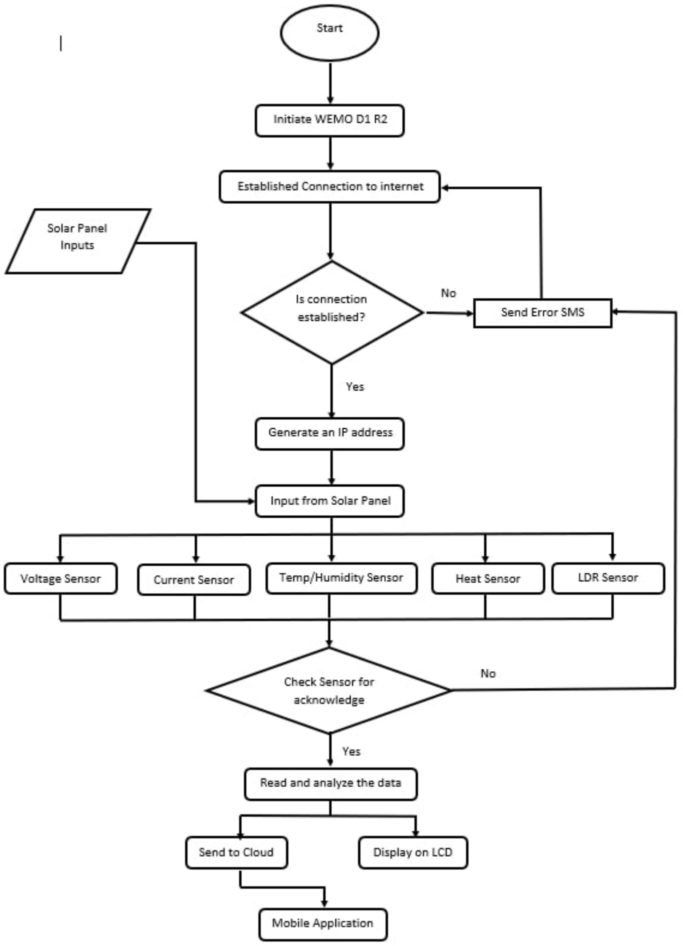


Figure 3: Process Flow Chart of Proposed System

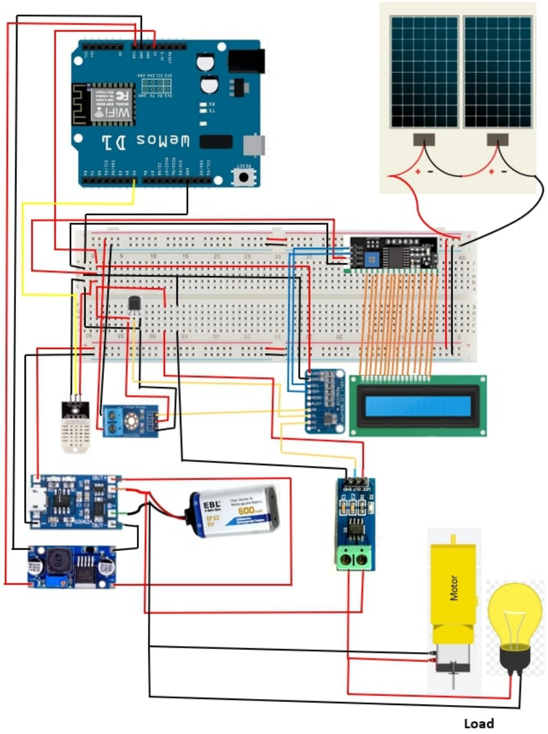


Figure 4: Circuit Diagram

The proposed approach circuit diagram is illustrated in Figure 4, showcasing the integration of the system. The circuit includes five sensors: voltage, current, LDR, heat, temperature, and humidity, which are connected to Wemos and the breadboard. The battery is connected to the breadboard and charges from the solar panel via a charging module, which is also attached to the Wemos. The LCD display, ADS1115, and step-down transformer are also connected to the board and the Wemos. Finally, the load is connected to the current sensor, utilizing power from either the panel or the battery.

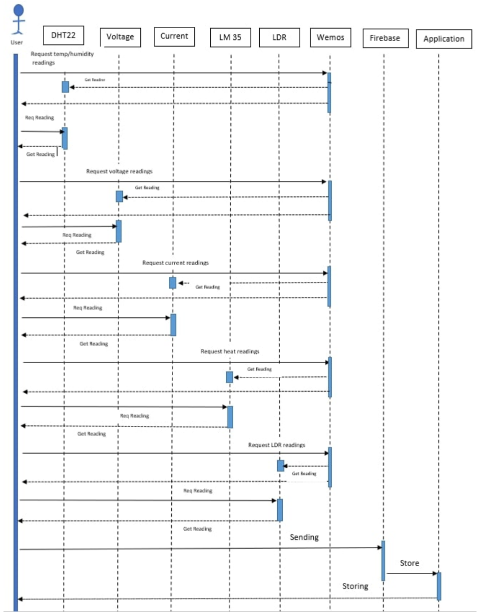


Figure 5: Sequence Diagram of reading the data

Figure 5, A sequence diagram is used to illustrate how different components of the system interact with each other. The sequence diagram shows how the sensors collect data on things like voltage, current, and temperature and how that data is transmitted to the Wemos for processing. It might also show how the Wemos communicates with the LCD, displaying information about the system's performance and how the Wemos interacts with the charging module and battery to ensure that the battery stays charged.

## IV. HARDWARE COMPONENTS

The following components are used to build the prototype of the solar panel monitoring system.

### A. *Wemos D1 R2*

The WeMos D1 R2 WiFi UNO ESP8266 is a versatile development board that combines the power of the ESP8266 chip with the convenience of the Arduino Uno form factor. The ESP8266 is a powerful WiFi-enabled microcontroller that can be used for many projects, from IoT devices to home automation systems [28]. The WeMos D1 R2 board provides a convenient way to access the full capabilities of the ESP8266, with a layout similar to the Arduino Uno and several additional features that make it even more powerful. These features include an integrated USB-to-serial converter, a micro-USB connector for power and data, and a set of GPIO pins that can be used for various purposes. With its combination of strength and flexibility, the WeMos D1 R2 WiFi UNO ESP8266 is an excellent choice for anyone looking to build projects that require wireless connectivity and advanced microcontroller capabilities.

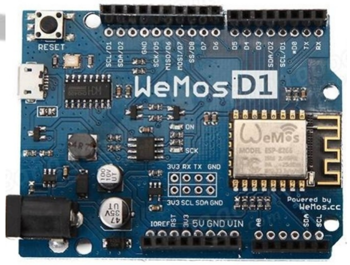


Figure 6: Wemos D1 R2

### B. *Solar Panel Monocrystalline silicon*

A solar panel made of monocrystalline silicon and capable of producing 12V of voltage and 2.1W of power is a device that converts sunlight into electricity [29]. Monocrystalline silicon, a single crystal of silicon, is known for its high efficiency in transforming sunlight into electricity. This type of solar panel can be used for various purposes, such as charging batteries, operating small electronic devices, and providing electricity for off-grid systems. It is suitable for charging 12V batteries and can power devices that require 12V power. However, its 2.1W power output may be insufficient for powering larger devices or systems, but it could be suitable for small, low-power applications.

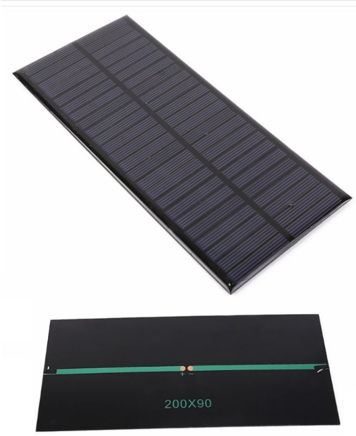


Figure 7: Solar Panels

### C. Voltage Sensor

A simple but handy module which uses a potential divider to reduce any input voltage by a factor of 5. This allows you to use the analog input of a microcontroller to monitor voltages much higher than it is capable of sensing [30]. For example, with a 0–5V analog input range, you can measure a voltage up to 25V. This module is based on the resistive voltage divider design principle and can make the red terminal connector input voltage five times smaller.

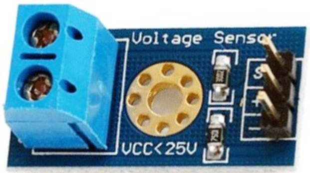


Figure 8: Voltage Sensor

### D. Current Sensor ACS712

It is a device that detects the electrical current passing through any material and then generates signals that are the same as the electrical current [31]. This signal can be an analog signal or a digital signal. The current signs are passed through an ammeter for measuring current. This sensor is ACS712, which measures the current up to 20 amps. It operates on a 5V power supply on-board power indicator. The module can measure the positive and negative 20 amps, corresponding to the analog output of 100mV / A.

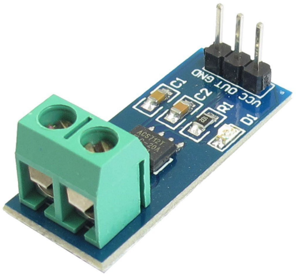


Figure 9: Current Sensor

### E. DHT22 AM2302

The DHT22 (also known as the AM2302) is a digital temperature, and humidity sensor that can measure the temperature and humidity of the air [32]. It communicates with a microcontroller or other device through a digital signal. It has a temperature measurement range of -40 to +125 degrees Celsius (-40 to +257 degrees Fahrenheit) and a humidity measurement range of 0-100 percent, with an accuracy of +/- 2 percent for humidity and +/- 0.5 degrees Celsius for temperature.

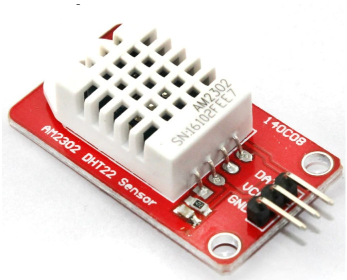


Figure 10: Temperature and Humidity Sensor

### F. LM35 Precision Heat Sensor

The LM35 is a high-precision temperature sensor that comes in a TO-92 package [33]. It is a linear temperature sensor that produces an output voltage that is proportional to the temperature in degrees Celsius. The LM35 has a sensitivity of 10 mV/degree Celsius, meaning that the output voltage will change by ten mV for every 1 degree Celsius change in temperature. It has a temperature range of -55 to +150 degrees Celsius and is accurate within +/- 0.5 degrees Celsius across its entire range.

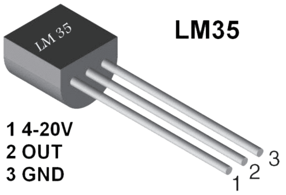


Figure 11: LM35 Sensor Module

### G. TP18650 Battery Charging Module

A lithium charging module 18650 is a device that is used to charge lithium-ion batteries, particularly those that use the 18650 form factor [34]. Lithium-ion batteries are widely used in various devices, including laptops, smartphones, and power banks, due to their high energy density and long cycle life. The lithium charging module 18650 is designed to provide a safe and efficient way to charge these batteries while protecting them from overcharging, over-discharging, and short-circuiting. The module typically includes a microcontroller that monitors the battery's voltage and current and adjusts the charging rate accordingly to ensure the battery is charged safely and efficiently. It has adjustable voltage from 3.7V to 9V, 2A.

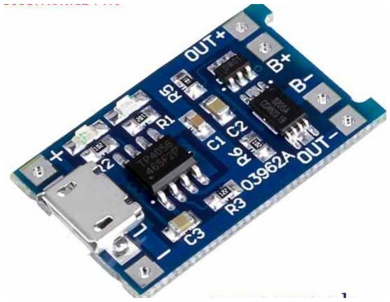


Figure 12: Battery Charging Module

### H. ADS1115 16-Bit ADC 4 Channel

For microcontrollers without an analog-to-digital converter or when you want a higher-precision ADC, the ADS1115 provides 16-bit precision at 860 samples/second over I2C [35]. The chip can be configured with power/logic as four single-ended input channels or two differential channels. As a nice bonus, it even includes a programmable gain amplifier, up to x16, to help boost smaller single/differential signals to the full range. We like this ADC because it can run from 2V to 5V , measure a large range of movements, and is super easy to use. It is an excellent general-purpose 16-bit converter.

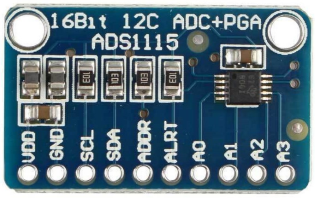


Figure 13: Digital to Analog converter ads

LM2596 ADJUSTABLE STEP-DOWN POWER

### I. LM2596 ADJUSTABLE STEP-DOWN POWER

This LM2596 chip of the power module is made in China. A module to adjust the power supply [36] is used primarily in this project because the Wemos operating voltage is 3.3V, so we can step down the voltage for the Wemos. The module is protected with current limiting and recovery lookup, operating on 4.5V up to 40V. Its output current is 2A maximum, a 3A additional heatsink is required, and its dynamic response speed is 5 percent (200 uS). Its conversion efficiency is up to 92 percent, and its switching frequency is 150KHz.

Figure 14: Adjustable step-down power

### J. 16x2 LCD I2C 1602 Display Screen

This display uses a 2-wire communications method called "IIC," "I2C," "I squared C," and "TWI." All these terms mean the same thing [37]. This serial protocol supports multiple devices on the same 2-wire bus, voltage, and ground. Its power supply voltage is +5V, and it keeps the I2C protocol and I2C address. It's either 0x27 or 0x3F. The pin definitions are GND, VCC, SDA, and SCL. It comes backlit green with black characters. Its size is 82x35x18 mm.

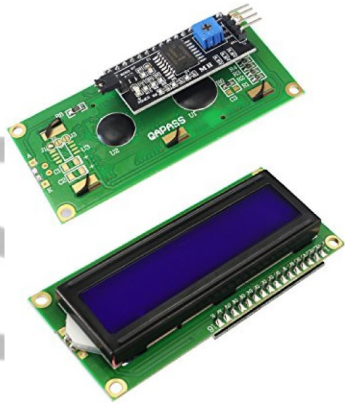


Figure 15: LCD I2C 1602 Display Screen

### K. Lithium Rechargeable Battery

It is a device that contains one or more electrochemical cells [38]. It has two terminals, cathode and anode, which connect the battery to any device. The electrical energy produced by the solar panels is stored in these batteries, which help provide energy to appliances.

Figure 16: Rechargeable Battery

### *L. Breadboard*

An essential component when learning to create circuits is a breadboard [39]. You will learn a little about breadboards in this tutorial, including what they are, why they are called breadboards, and how to use them. After finishing, you need to be able to construct a simple circuit on a breadboard and have a fundamental understanding of how breadboards operate.

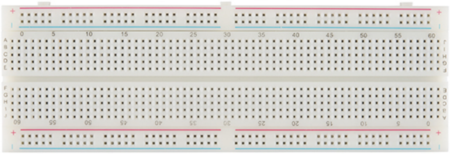


Figure 17: Use of Breadboard

### *M. Bynk-Cloud*

Blynk is an Internet-of-Things platform for iOS or Android smartphones that allows users to operate devices remotely [40] like Arduino, Raspberry Pi, and NodeMCU. Using this application, you can compile and provide the correct address on the various widgets to construct a graphical interface or human-machine interface (HMI).

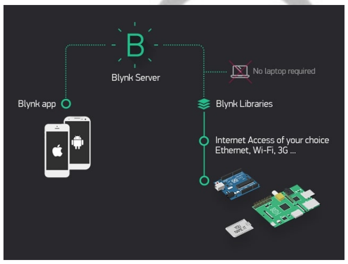


Figure 18: Arduino Integrated Development Environment

## V. SYSTEM IMPLEMENTATION

Successful solar panel monitoring system implementation, requires careful consideration of several vital factors. These include collecting data from sensors at regular intervals, filtering and pre-processing collected data, storing data in a suitable database, and analyzing stored data to gain valuable insights. Furthermore, the system can be enhanced with real-time alerts that notify stakeholders of potential issues or failures. By addressing these critical aspects of a solar panel monitoring system, stakeholders can ensure that their solar-based systems operate optimally and make informed decisions to improve system efficiency and performance. The findings of our system can be viewed directly on the LCD monitor attached to the entire system, as well as via mobile device. A mobile application is created that retrieves data from the cloud and displays real-time results to the user.

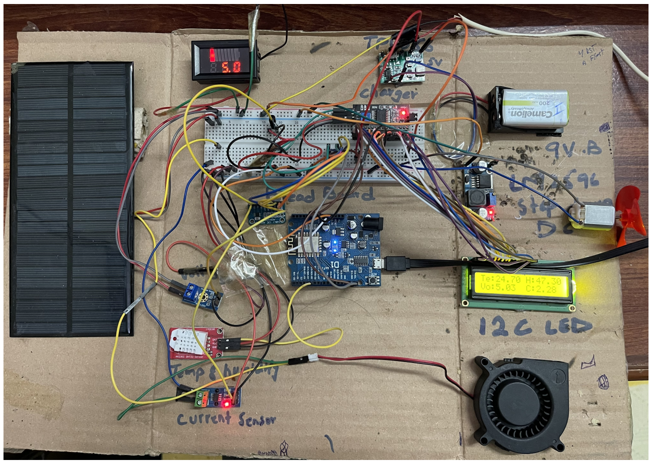
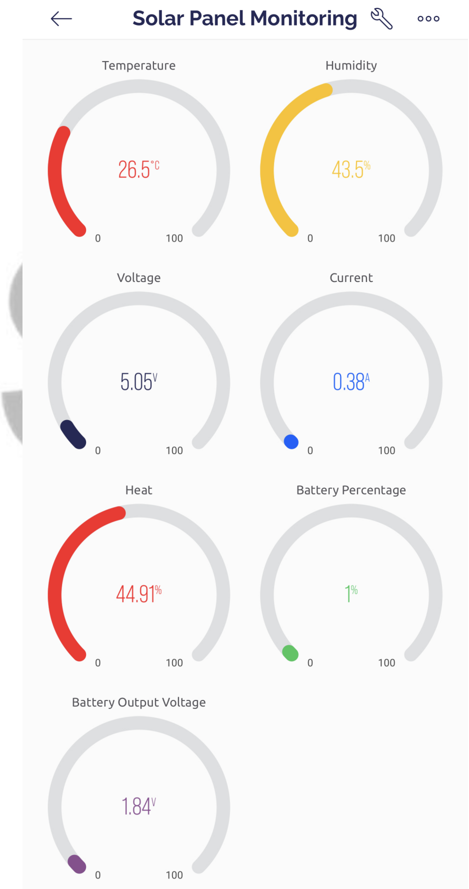


Figure 19: Proposed System with Results

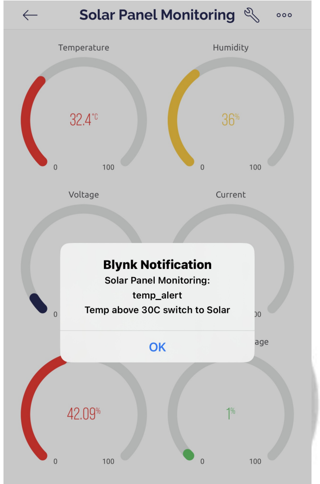


Solar Panel Monitoring

Temperature 26.5°C
Humidity 43.5%
Voltage 5.05V
Current 0.38A
Heat 44.91%
Battery Percentage 1%
Battery Output Voltage 1.84V

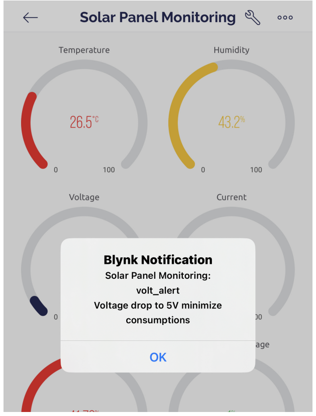
Figure 20: Real-Time Results over mobile interface

Figure 21: Results on LCD



**Blynk Notification**
Solar Panel Monitoring:
temp_alert
Temp above 30C switch to Solar
OK

Figure 22: Alert for Temperature



**Blynk Notification**
Solar Panel Monitoring:
volt_alert
Voltage drop to 5V minimize
consumptions
OK

Figure 23: Alert for Voltage

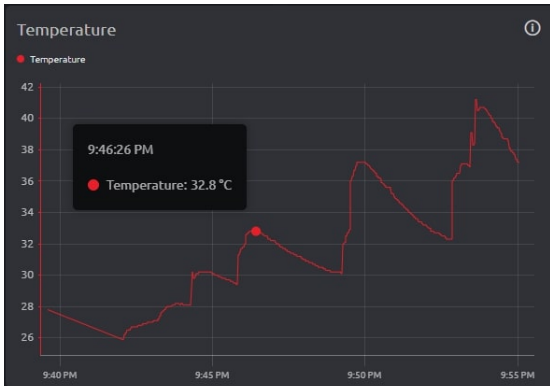


Figure 24: Temperature Profile

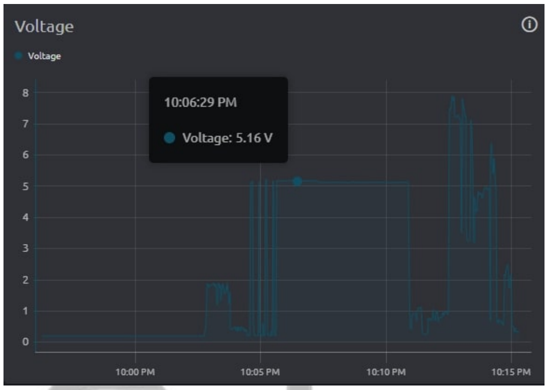


Figure 25: Voltage Profile

Figure 26: Current Profile

## VI. CONCLUSION

Implementing a solar panel monitoring and recommender system can be a highly effective tool for maximizing the performance of solar panel systems. Through continuous monitoring of energy output and environmental conditions, this system can promptly identify any issues and offer recommendations for improvement, leading to higher efficiency and reduced costs. The monitoring aspect of the plan involves gathering information on energy production, system performance, and environmental factors such as temperature and sunlight intensity, current, and humidity. After collecting this data, it is thoroughly analyzed to recognize patterns and trends and any abnormalities that may signify issues with the system. The recommender feature of the system employs the collected data to suggest improvements such as the percentage of charge coming and remaining in the battery, replacing defective components, or upgrading the system to a more efficient model. In general, a solar panel monitoring and recommender system can offer various advantages to solar panel owners, including enhanced energy efficiency, reduced expenses, and better system performance. By utilizing the power of data analysis and machine learning, these systems can ensure that solar panel systems operate at their peak performance, both currently and in the future.

## VII. FUTURE SCOPE

Solar panel monitoring and recommender systems are gaining significance as solar power continues to expand. These systems offer valuable insights into the performance of solar panels, identify faults and potential issues, and provide recommendations for optimizing their efficiency. This response outlines possible areas for future development in this field.

The field of solar panel monitoring is ripe for continued innovation and development. Future research efforts should focus on several key areas, including the development of more sophisticated algorithms for predictive maintenance and fault detection, the optimization of energy output and performance prediction through machine learning, and the creation of recommender systems that provide tailored suggestions to users for enhancing the performance of their solar panel systems. Furthermore, efficient data visualization tools and user interfaces are critical for facilitating easy access and comprehension of the significant amount of data generated by solar panel monitoring systems. By addressing these research areas, stakeholders can enhance the efficiency and performance of solar-based systems and make informed decisions to optimize their energy output.

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