REMOTE MONITORING OF SOLAR PANEL PARAMETER FOR EFFICIENT POWER GENERATION

SUMMER PROJECT REPORT

Submitted by

PAVITHRA M	**2022504537**
PARKAVI M	**2022504548**

in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

DEPARTMENT OF ELECTRONICS ENGINEERING

MADRAS INSTITUTE OF TECHNOLOGY

ANNA UNIVERSITY: CHENNAI - 600 044

NOVEMBER 2024

BONAFIDE CERTIFICATE

This is to certify that the project report titled **"REMOTE MONITORING OF SOLAR PANEL PARAMETER FOR EFFICIENT POWER GENERATION"** is the bonafide work of

PAVITHRA M	**2022504537**
PARKAVI M	**2022504548**

who carried out the project under my supervision.

DR. M. GANESH MADHAN

SUPERVISOR

Professor

Department of Electronics Engineering, Madras Institute of Technology,
Anna University, Chennai-44.

ACKNOWLEDGEMENT

We would like to extend our heartfelt gratitude to Prof RAVICHANDRAN KANDASWAMY, Dean of the Madras Institute of Technology, Anna University, for his invaluable support and for providing us with exceptional facilities and opportunities. His leadership and vision fostered an environment that was instrumental in the successful completion of our project.

Our deepest thanks also go to Dr.D.Meganathan, Professor and Head of the Department of Electronics Engineering, Madras Institute of Technology, Anna University, for his unwavering encouragement and guidance throughout our research.

We are particularly grateful to Dr.M.Ganeshmadhan, Assistant Professor, Department of Electronics Engineering, who guided us as our project mentor. His insightful advice and constructive feedback greatly influenced the direction and quality of our work.

Our sincere thanks also go to Dr.S.Piramasubramaniam, Teaching Fellow, Department of Electronics Engineering, for her constant support and motivation. Her encouragement and assistance were key to overcoming various challenges during this project.

Finally, we wish to acknowledge the Teaching and Non-Teaching Staff of the Department of Electronics Engineering, Madras Institute of Technology, for their consistent support and assistance throughout our journey. Their help and cooperation were invaluable in achieving our project goals.

PAVITHRA M **2022504537**

Place: Chennai **PARKAVI M** **2022504548**

Date: 15 - 11 - 2024

ABSTRACT

This project, titled "Remote Monitoring of Solar Panel Parameters for Efficient Power Generation," introduces an innovative solution for optimizing solar panel performance through real-time remote monitoring, automated maintenance, and data analysis. The system utilizes a combination of environmental sensors to assess key parameters impacting solar panel efficiency, including dust accumulation, light intensity, temperature, humidity, and voltage output. Four Light Dependent Resistors (LDRs) are multiplexed into a single output to measure light levels, detecting dust accumulation, while a DHT11 sensor records temperature and humidity. The voltage output of the solar panel is tracked through a voltage divider circuit, enabling precise efficiency calculations. Additionally, a servo motor is incorporated to automate dust cleaning, minimizing performance losses due to surface buildup. The ESP32 microcontroller processes these inputs, controls the cleaning mechanism, and transmits data wirelessly to the Blynk application, allowing for seamless remote monitoring and maintenance. This system provides real-time insights and automated upkeep to enhance power generation efficiency, supporting sustainable energy practices.

Keywords: Solar Panel Monitoring, Real-Time Data Acquisition, Multiplexed LDR Array, DHT11 Sensor, ESP32, Voltage Divider Circuit, Remote Efficiency Monitoring, Servo Motor Dust Cleaning, Sustainable Energy Practices.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Solar Panels

Solar panels, a key component of photovoltaic (PV) systems, convert sunlight into electrical energy through the photovoltaic effect. These panels are widely utilized in both commercial and residential applications due to their renewable energy potential and contribution to sustainable power solutions. However, environmental factors such as dust accumulation, temperature fluctuations, and humidity can affect the efficiency and output of solar panels, necessitating continuous monitoring for optimized performance.

1.2 Key Factors Affecting Solar Panel Efficiency

Solar panel efficiency is influenced by several environmental parameters:

- **Light Intensity and Dust Accumulation**: Light intensity directly impacts the electrical output, while dust accumulation reduces efficiency by blocking sunlight. Regular monitoring of light levels enables timely cleaning and maintenance.
- **Temperature and Humidity**: High temperatures can decrease panel efficiency, while high humidity may accelerate corrosion. Monitoring these factors helps in managing and preserving panel longevity.

1.3 Remote Monitoring System Design

This project incorporates a real-time monitoring system that gathers and transmits critical environmental data for remote analysis, enabling proactive maintenance and enhanced solar panel performance. The setup includes:

- **Light-Dependent Resistors (LDRs)**: Four LDRs are positioned at the corners of the panel to gauge light intensity, with multiplexing used to provide a combined output to measure dust accumulation in terms of resistance. If dust is present, light absorption decreases, and resistance changes are logged for actionable insights.
- **Temperature and Humidity Sensors (DHT11)**: These sensors provide ambient temperature and humidity data to the ESP32, which transmits the information for remote display on Blynk.
- **Voltage Divider Circuit**: This circuit captures the voltage output, facilitating efficiency calculations based on current solar conditions.
- **Sero Motor**: Using a servo motor for dust cleaning on solar panels leverages the vibration it generates to dislodge dust and debris effectively. This low-energy, vibration-based cleaning method helps maintain panel efficiency without requiring extensive mechanical components.

1.4 ESP32 Microcontroller and Blynk Application

The ESP32 microcontroller is responsible for collecting data from the sensors and transmitting it wirelessly to the Blynk app. This allows real-time monitoring and remote access to panel conditions, supporting informed maintenance decisions.

1.5 Chapter Organization

This report comprehensively examines the development, functionality, and benefits of the solar panel monitoring system.

- **Chapter 2** reviews relevant literature, highlighting the impact of environmental factors on solar panel efficiency and existing monitoring solutions.
- **Chapter 3** provides an overview of the foundational concepts in sensor technology, multiplexing, and data transmission, forming the technical basis of the project.
- **Chapter 4** block diagram representing the data flow.
- **Chapter 5** focuses on the design methodology , calibration of sensors and data validation, enhancing the system's accuracy and reliability.
- **Chapter 6** presents and interprets experimental results, discussing how the monitoring system aids in maintaining solar panel efficiency.
- **Chapter 7** concludes with insights on the project's impact on sustainable energy practices and potential areas for future improvements.

This structured report provides a clear trajectory through the project's objectives, methodology, analysis, and conclusions. A references section at the end ensures proper acknowledgment of related studies and sources.

CHAPTER 2

LITERATURE SURVEY

Automatic Dust Detection Mechanism for Solar Panel Cleaning System

Ingle et al. (2023) presented an automated dust detection and cleaning approach for solar panels using sensors to monitor dust accumulation. This system autonomously initiates cleaning, enhancing solar panel efficiency and reducing labor costs in high-dust areas. This research highlights the significance of automated maintenance, especially for larger solar installations, where periodic cleaning improves energy output.

Design and Development of Solar Panel Cleaning Bot

Kumar (2012) designed a solar panel cleaning robot with a combination of mechanical brushes and water spray. The bot autonomously cleans the panel surfaces, significantly reducing dust-related efficiency loss, especially in environments where manual cleaning is impractical. The inclusion of robotic technology in this system ensures effective cleaning, with potential for remote control through IoT-based data monitoring.

Automatic Water and Dust Detector Based Solar Panel Cleaning System

Khan(2016) developed a system that integrates water and dust detection mechanisms, where sensors identify dust buildup and trigger an automatic cleaning process involving water spray. This approach not only detects the need for cleaning based on dust levels but also optimizes water usage, making it environmentally and economically efficient. The study's focus on automated water control is particularly valuable for regions with water scarcity, adding an environmentally conscious element to solar maintenance systems.

IoT and Sensor Integration for Enhanced Efficiency

Each of these studies underlines the role of IoT and sensors in automating solar maintenance. Ingle et al. use sensors to detect dust, which could be paired with cloud-based platforms like Blynk for real-time data tracking. Kumar et al.'s bot could benefit from remote monitoring for functionality checks and maintenance scheduling. Khan et al. introduce an additional dimension by integrating water detection, ensuring efficient use of cleaning resources. Together, these studies highlight how sensor data and IoT platforms enhance maintenance automation, offering real-time alerts and predictive insights into environmental conditions affecting panel efficiency.

Predictive Maintenance and Environmental Adaptation

Predictive maintenance, enabled by cloud-based data logging and IoT, is crucial in these systems. Real-time monitoring of dust levels, water availability, temperature, and humidity helps predict when cleaning is necessary, optimizing both labor and resource use. Using sensors like LDRs, DHT11, and water level detectors, these systems achieve high adaptability to environmental changes. This approach is evident in Khan et al.'s work, where water conservation techniques are integrated into dust cleaning routines, ensuring eco-friendly operations.

Cost-Effectiveness and Real-World Application

The combined approaches of dust and water detection, robotic cleaning, and IoT-based monitoring deliver a comprehensive solution for solar panel maintenance, reducing the need for frequent manual intervention and supporting consistent energy production. The self-sufficiency of these systems, as described in all three studies, demonstrates how automation makes solar installations in remote or arid locations more viable, boosting efficiency and cost-effectiveness in the renewable energy sector.

CHAPTER 3

DESIGN OVERVIEW

The solar panel monitoring system is designed to optimize the panel's efficiency by tracking environmental and electrical parameters, such as temperature, humidity, light intensity, and output voltage. It also includes an automatic dust cleaning feature using a servo motor, which is triggered when the panel's voltage drops below a specific threshold.

Components

1. ESP32 Microcontroller: Manages data collection, processing, and transmission to the Blynk app for remote monitoring.

2. LDR Sensors: Four Light Dependent Resistors (LDRs) placed at various points measure ambient light and detect dust accumulation, helping to monitor panel efficiency.

3. DHT11 Sensors: Temperature and humidity sensors to measure environmental conditions that can affect panel performance.

4. Voltage Divider Circuit: Measures the solar panel’s output voltage, allowing efficiency calculations.

5. Servo Motor: Mounted to activate a dust-cleaning mechanism when the voltage drops below a set threshold, indicating potential dust buildup.

6. WiFi Module: ESP32's built-in WiFi allows connection to the Blynk app for real-time data monitoring and control.

Design Flow

1. Data Collection:

LDRs measure light intensity across the panel.

DHT11 sensors record temperature and humidity levels.

The voltage divider circuit monitors the panel's output voltage.

2. Processing:

The ESP32 microcontroller reads values from all sensors and averages the

LDR readings.

It compares the voltage reading to a pre-set threshold to determine if the panel might be dusty.

3. Servo Motor Activation:

If the voltage falls below a threshold, the ESP32 signals the servo motor to rotate, activating a cleaning mechanism over the panel to remove dust.

4. Data Transmission:

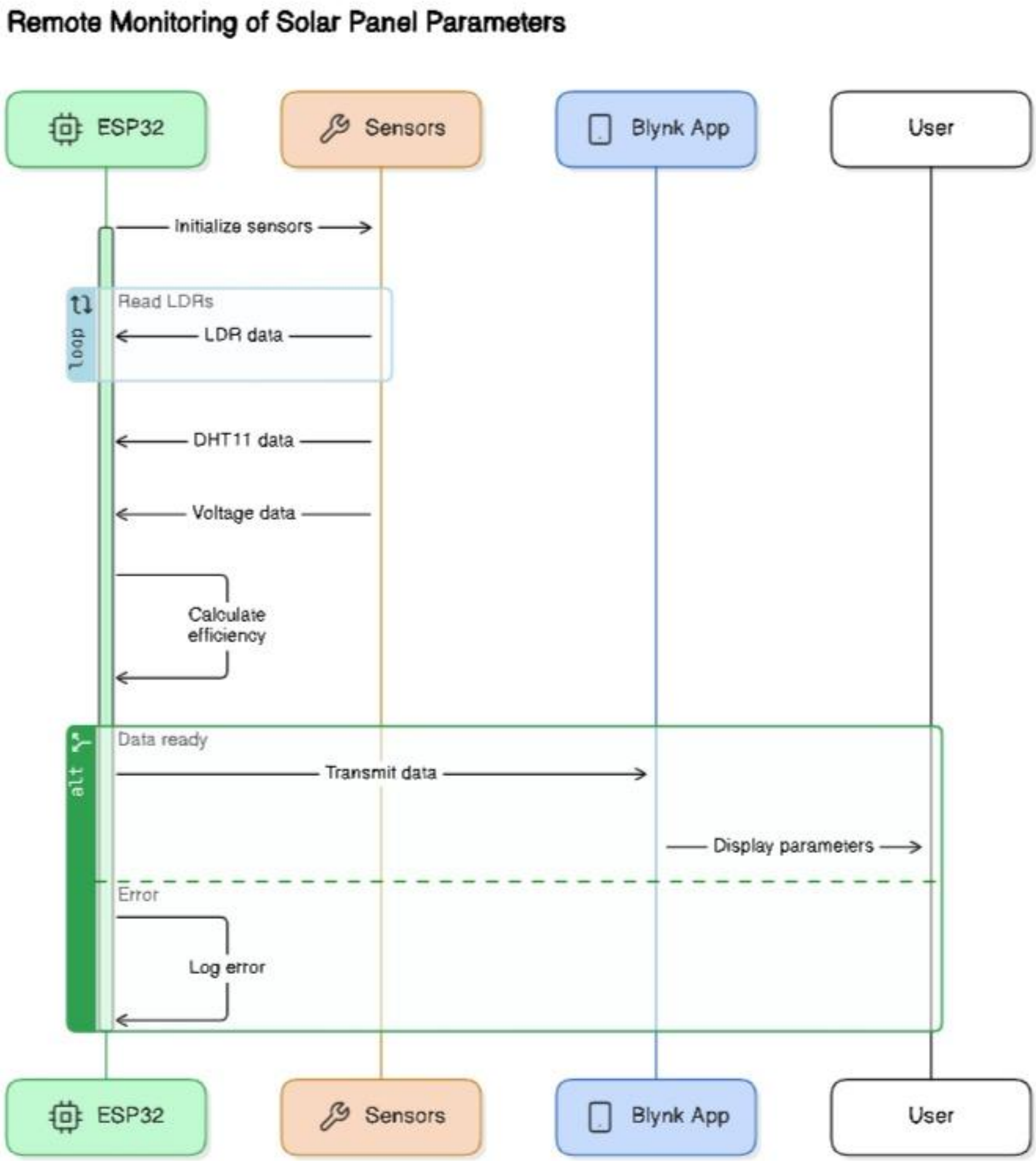
The ESP32 transmits all sensor data (LDR, DHT11, voltage) to the Blynk app using WiFi, where users can monitor the panel’s efficiency and environmental factors in real time.

5. User Monitoring and Control:

In the Blynk app, users can view real-time data, monitor efficiency, and remotely observe the system's status.

CHAPTER 4

BLOCK DIAGRAM



CHAPTER-5

METHODOLOGY

1. System Architecture and Component Integration

The project begins by establishing the system’s architecture, integrating core components including ESP32, DHT11 temperature and humidity sensors, light-dependent resistors (LDRs), and a voltage divider circuit. Each component is selected based on its role in tracking specific environmental parameters like dust accumulation, temperature, humidity, and voltage output. The ESP32 microcontroller is configured to act as the primary control unit, interfacing with all other components and collecting real-time data from the sensors. This data collection process is crucial to ensuring that environmental factors affecting the solar panel are effectively monitored.

2. Data Collection and Processing

Once the hardware setup is complete, the next step involves configuring data collection protocols. The ESP32 is programmed to read data from the DHT11 sensors and LDRs at regular intervals, ensuring a continuous stream of information. The DHT11 sensors provide temperature and humidity data, while the LDRs detect dust accumulation by measuring light intensity changes. The data is processed within the ESP32, where threshold values for dust, temperature, and humidity are set. The voltage divider circuit measures the solar panel’s output voltage, providing insights into the power generation efficiency under varying environmental conditions.

3. Multiplexing System for Dust Measurement

To optimize dust detection, a multiplexing system is employed. Multiple LDRs are strategically positioned at the corners of the solar panel, with their outputs combined to reflect dust accumulation levels. By multiplexing these LDR signals, a single output is generated that conveys a clear indication of dust levels, represented as resistance on the monitoring interface. This multiplexed output provides a more accurate and consolidated measure of dust coverage, which is then displayed on Blynk, facilitating real-time monitoring and timely maintenance interventions if the dust threshold is exceeded.

4. Voltage and Current Measurement Setup

The voltage output from the solar panel is assessed using the voltage divider circuit, which reduces the panel’s voltage to a level suitable for the ESP32’s analog input. To measure current efficiency, the voltage output is routed through this circuit, allowing the ESP32 to process and display the corresponding voltage level in the Blynk interface. This setup enables a clear view of how environmental conditions impact power output, providing actionable insights for enhancing the panel’s efficiency.

5. Data Transmission and Display on Blynk

Data from the ESP32 is transmitted to the Blynk platform, where a custom dashboard displays the real-time values of dust accumulation, temperature, humidity, and voltage output. The Blynk mobile interface is configured to update continuously, offering a user-friendly visualization of the solar panel's environmental and performance metrics. Alerts and notifications can be set within Blynk to inform users when any parameter, such as dust level or temperature, exceeds the defined threshold, allowing for timely corrective actions.

6. Analysis of Data for Power Generation Optimization

The collected data is analyzed to assess the impact of environmental conditions on solar panel efficiency. By comparing voltage outputs under varying levels of dust, temperature, and humidity, insights can be derived regarding optimal maintenance intervals and necessary cleaning routines to maximize power generation. This stage involves assessing trends over time, providing a foundation for predictive maintenance that can be applied to similar setups in larger-scale solar installations.

7. Conclusion and Recommendations for Future Work

In conclusion, the environmental monitoring system offers a comprehensive method to track factors influencing solar panel efficiency, with real-time monitoring enabled by Blynk. Future work may include expanding the system to support multiple panels, refining the accuracy of the dust measurement system, and exploring additional environmental factors such as wind speed or precipitation. Such enhancements would further optimize power generation and promote sustainable energy management practices.

CHAPTER 6

ARDUINO IDE

6.1 CODE

```
#define BLYNK_TEMPLATE_ID "TMPL3nBifyRgo"
#define BLYNK_DEVICE_NAME "SOLAR PANEL FINAL"
#define BLYNK_AUTH_TOKEN "_Y6PToyfgCYAoV1iQwL-
_b5VyqWlsJMQ"
#define BLYNK_TEMPLATE_NAME "SOLAR PANEL FINAL"

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include "DHT.h"
#include <ESP32Servo.h>  // Replaced Servo.h with ESP32Servo.h

// WiFi credentials
char ssid[] = "IQOO Z7s 5G";
char pass[] = "arunpavi";

// DHT11 Sensor Configuration
#define DHTPIN 4       // Digital pin connected to the DHT sensor
#define DHTTYPE DHT11  // DHT 11 sensor type
DHT dht(DHTPIN, DHTTYPE);
```

```
// Voltage Divider Pin and Resistor Values
#define VOLTAGE_DIVIDER_PIN 36 // Pin for voltage divider
(ADC1_CHANNEL0)
#define R1 1000.0            // Resistance of R1 in Ohms (10kΩ)
#define R2 1000.0            // Resistance of R2 in Ohms (10kΩ)
const float calibrationFactor = 1.05; // Optional calibration factor

// LDR Pins
const int ldrPin1 = 32;
const int ldrPin2 = 33;
const int ldrPin3 = 34;
const int ldrPin4 = 35;
const int numLDRs = 4; // Number of LDRs

// Servo Motor Pin
const int servoPin = 13; // Pin where the servo is connected
Servo myServo; // Create Servo object using ESP32Servo

// Blynk Virtual Pins
#define VIRTUAL_PIN_AVG_LDR V1
#define VIRTUAL_PIN_TEMPERATURE V2
#define VIRTUAL_PIN_HUMIDITY V3
#define VIRTUAL_PIN_VOLTAGE V4

BlynkTimer timer;
```

```
void setup() {
  // Start Serial Monitor
  Serial.begin(115200);

  // Connect to WiFi
  WiFi.begin(ssid, pass);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");

  // Connect to Blynk
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);

  // Initialize the DHT sensor
  dht.begin();

  // Initialize the Servo motor
  myServo.attach(servoPin);

  // Set up a timer to call sendSensorData every second
  timer.setInterval(1000L, sendSensorData);
}

void loop() {
```

```
  Blynk.run();
  timer.run();
}

// Function to read the voltage from the voltage divider circuit
float readVoltage() {
  int analogValue = analogRead(VOLTAGE_DIVIDER_PIN);
  float voltage = (analogValue / 4095.0) * 3.3; // Convert to voltage
  voltage = voltage * ((R1 + R2) / R2);        // Adjust based on resistor
values
  voltage *= calibrationFactor;               // Apply calibration factor if
needed
  return voltage;
}

// Function to control the servo motor when voltage drops below 1V
void controlServo(float voltage) {
  if (voltage < 1.0) { // If the voltage drops below 1V
    Serial.println("Voltage is below 1V, rotating servo...");
    myServo.write(90);  // Rotate servo to 90 degrees (you can change the
angle)
    delay(5000);       // Wait for 5 seconds
    myServo.write(0);   // Rotate back to 0 degrees
  }
}
```

```
// Function to read LDR values, DHT11 sensor data, and voltage, and send them to Blynk
void sendSensorData() {
  // Array to store LDR readings
  int ldrValues[numLDRs] = {0};

  // Read from each LDR and store the values
  ldrValues[0] = analogRead(ldrPin1);
  ldrValues[1] = analogRead(ldrPin2);
  ldrValues[2] = analogRead(ldrPin3);
  ldrValues[3] = analogRead(ldrPin4);

  // Calculate the average LDR reading
  int averageLDR = 0;
  for (int i = 0; i < numLDRs; i++) {
    averageLDR += ldrValues[i];
  }
  averageLDR /= numLDRs;

  // Read temperature and humidity from DHT11 sensor
  float temperature = dht.readTemperature();
  float humidity = dht.readHumidity();

  // Check if any DHT11 reads failed and exit early if so
  if (isnan(humidity) || isnan(temperature)) {
    Serial.println("Failed to read from DHT sensor!");
```

```
    return;
  }

  // Read voltage from the voltage divider
  float panelVoltage = readVoltage();

  // Control servo based on the voltage
  controlServo(panelVoltage);

  // Send data to Blynk
  Blynk.virtualWrite(VIRTUAL_PIN_AVG_LDR, averageLDR);
  Blynk.virtualWrite(VIRTUAL_PIN_TEMPERATURE, temperature);
  Blynk.virtualWrite(VIRTUAL_PIN_HUMIDITY, humidity);
  Blynk.virtualWrite(VIRTUAL_PIN_VOLTAGE, panelVoltage);

  // Print values to Serial Monitor
  Serial.print("Average LDR: ");
  Serial.print(averageLDR);
  Serial.print(", Temperature: ");
  Serial.print(temperature);
  Serial.print(" °C, Humidity: ");
  Serial.print(humidity);
  Serial.print(" %, Voltage: ");
  Serial.print(panelVoltage);
  Serial.println(" V");
}
```

6.2 CODE EXPLANATION;

1. Blynk and WiFi Configuration

The code sets up Blynk with the necessary template ID, device name, and authentication token for remote monitoring. WiFi credentials allow the ESP32 to connect to the internet and communicate data to the Blynk app.

2. Sensor and Pin Configurations

Several sensors are configured:

DHT11 measures temperature and humidity.

Voltage Divider circuit measures solar panel voltage.

LDRs (Light-Dependent Resistors) detect light levels to assess dust accumulation.

Servo Motor controls a servo attached to a pin and is programmed to move when solar panel voltage drops below 1V (suggesting possible dust accumulation).

3. Initialization

The setup function connects the ESP32 to WiFi and Blynk, initializes the DHT sensor, and attaches the servo motor to the specified pin. A timer is also set up to call sendSensorData every second.

4. Voltage Reading and Calibration

readVoltage() reads the voltage from the solar panel using the ADC pin and converts it to actual voltage by considering resistor values. A calibration factor is applied to ensure accuracy.

5. Servo Control Function

controlServo() checks if the panel voltage drops below 1V (indicating potential dust) and rotates the servo to initiate a cleaning action by setting it to 90 degrees, holding it for 5 seconds, then returning it to 0 degrees.

6. Data Collection and Transmission

sendSensorData() performs the following:

LDR Readings: Reads light levels from each LDR to determine an average value, indicating dust accumulation.

DHT11 Readings: Collects temperature and humidity data.

Voltage Reading: Retrieves the current voltage from the solar panel.

Servo Activation: Calls controlServo() if voltage is below the threshold.

After collecting data, it sends the average LDR reading, temperature, humidity, and panel voltage to Blynk for remote monitoring and logs the readings in the Serial Monitor.

7. Main Loop

The loop() function runs Blynk and the timer to ensure data is continuously collected, sent, and the servo control function is executed based on voltage level feedback.

CHAPTER 7

KICAD SOFTWARE

7.1 INTRODUCTION:

KiCad is an open-source software suite primarily used for electronic design automation (EDA). Developed originally in 1992 by Jean-Pierre Charras, KiCad has evolved into a powerful tool that enables designers to create complex printed circuit board (PCB) layouts and schematics. Available on multiple platforms, including Windows, macOS, and Linux, it is popular among hobbyists, academic institutions, and professional engineers for its accessibility and feature-rich environment. Unlike proprietary software, KiCad allows users to freely modify and distribute their designs, making it ideal for collaborative and open-source projects.

The software offers a comprehensive set of tools for circuit design, layout, and visualization. KiCad includes a schematic capture module, where users can draw circuit diagrams, define components, and link them to a netlist, which is then used to generate the PCB layout. The PCB layout editor provides users with precise control over component placement, trace routing, and layer configuration. KiCad also includes a 3D viewer, which enables users to see a realistic rendering of the completed PCB with components in place, making it easier to visualize the final product and check for errors before manufacturing.

One of the standout features of KiCad is its library management and customization capabilities. KiCad offers extensive component libraries, with symbols and footprints for various components, and allows users to create custom components when needed. With plugins and additional scripts, users can further enhance KiCad’s functionality, such as adding design rule checks or importing/exporting data from other EDA tools. KiCad's ongoing development, supported by a dedicated community and organizations like CERN, continues to expand its capabilities, solidifying its position as a versatile tool for electronic design.

7.2 KICAD INTEGRATION WITH OUR PROJECT:

This project introduces a solar panel monitoring system, designed for real-time analysis and optimization of photovoltaic efficiency. Using KiCad software for schematic capture and PCB layout, the project focuses on developing an efficient circuit board that integrates ESP32 for wireless data transmission, sensors like DHT11 for environmental monitoring, LDRs for detecting dust accumulation, and a voltage divider circuit to assess the panel's voltage output. By designing the PCB in KiCad, the layout achieves optimal component placement and trace routing to ensure reliable data flow and sensor accuracy. Additionally, a DC motor with a vibrating stud at the bottom of the solar panel is employed to facilitate dust removal, further enhancing the system’s self-maintenance capabilities.

The KiCad-designed PCB includes modules for temperature, humidity, and voltage monitoring, allowing the ESP32 microcontroller to process and send data wirelessly to the Blynk platform. KiCad’s 3D viewer assists in

visualizing the final board design, verifying component placement, and identifying potential layout issues before fabrication. The use of KiCad for circuit design and layout not only simplifies the development process but also reduces the risk of signal interference between the sensors and microcontroller by allowing fine-tuned adjustments to the PCB layout.
This solar panel monitoring system, with its data accessible through a mobile application, provides users with critical insights into panel conditions and efficiency. The integration of KiCad in this project enables precise circuit board design, contributing to the accuracy and reliability of the monitoring system. Through real-time feedback and proactive dust removal, the system aims to improve solar panel performance and ensure consistent energy output.

CHAPTER 8

ANALYSIS

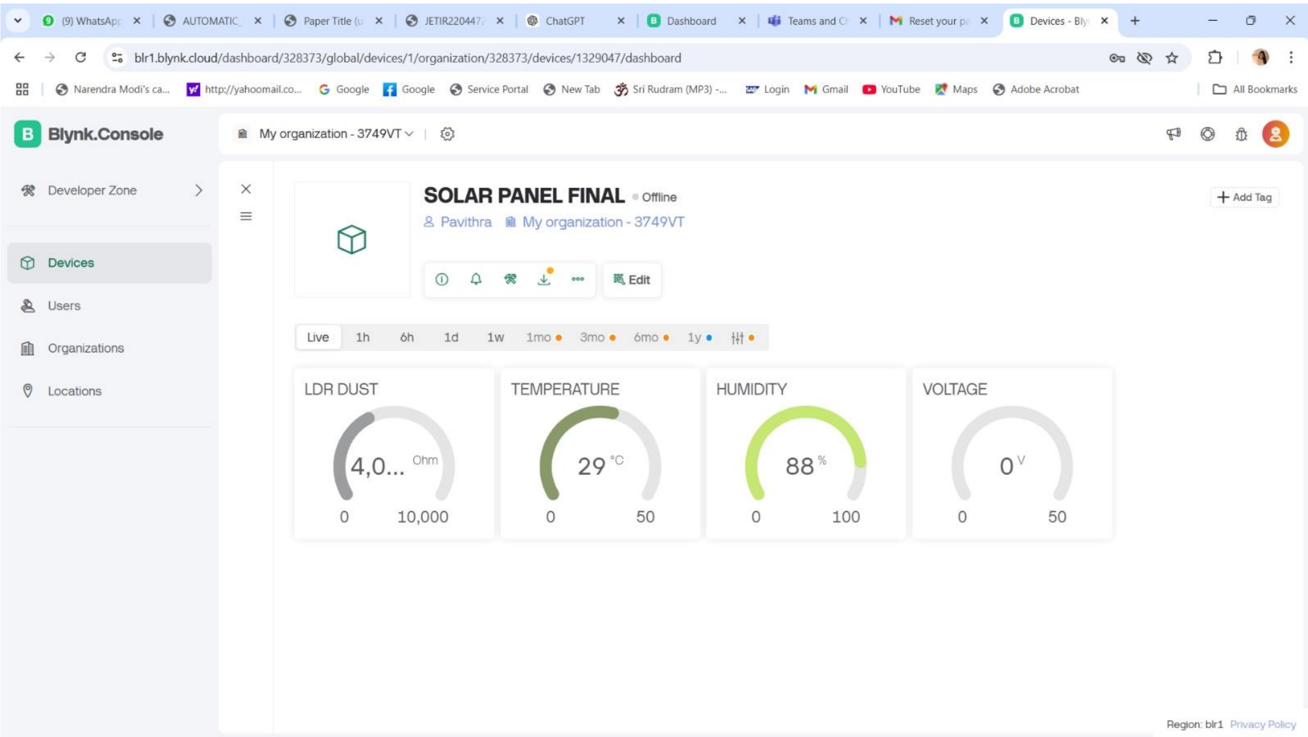
8.1 RESULT AND DISCUSSION

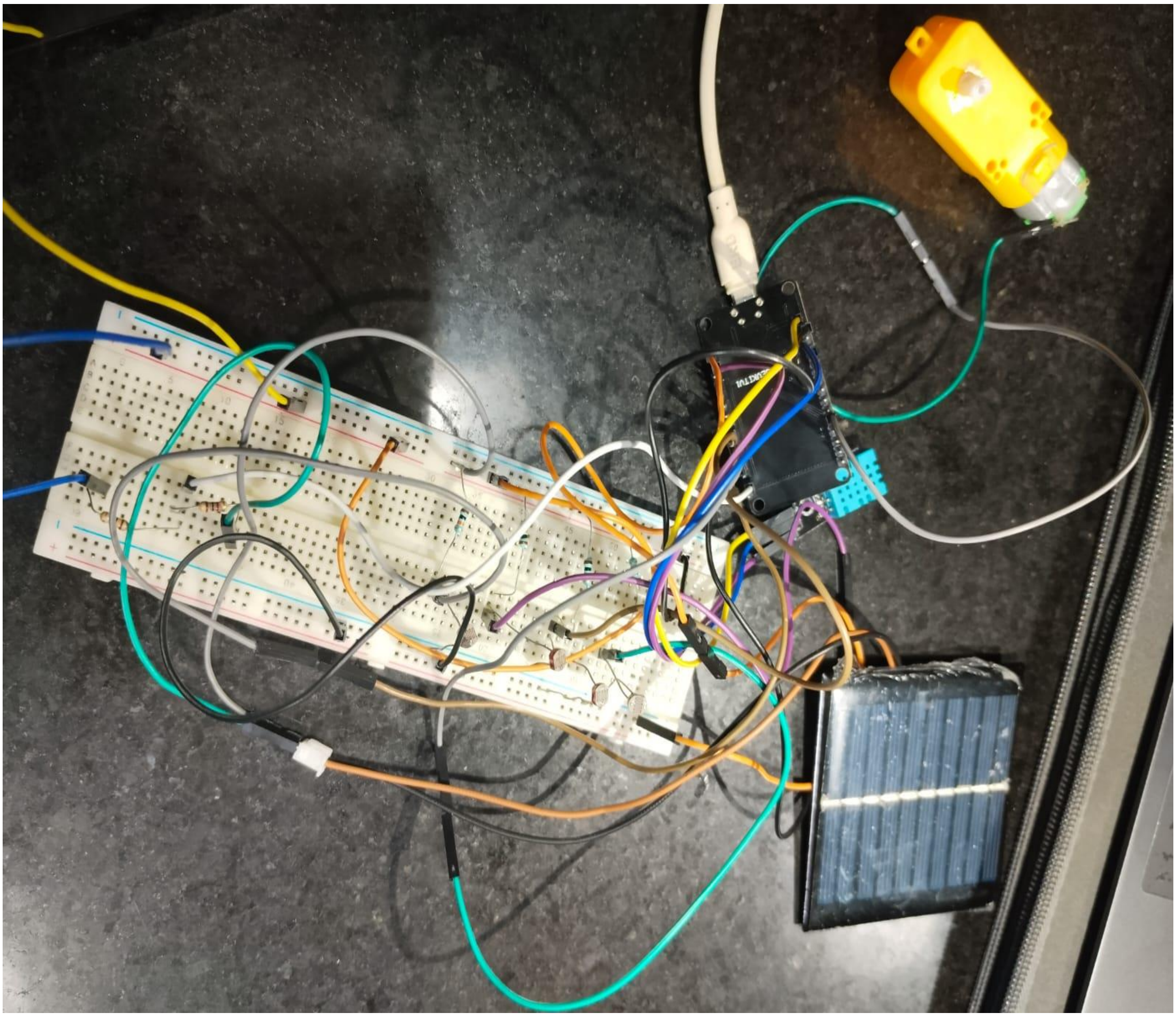
The Solar Panel Monitoring System developed in this project focuses on real-time monitoring of the solar panel's operational parameters such as temperature, humidity, dust accumulation, and voltage output. By using an ESP32 microcontroller, the system integrates various sensors, including the DHT11 sensor for temperature and humidity, light-dependent resistors (LDRs) to monitor dust accumulation, and a voltage divider circuit to measure the solar panel's output voltage. Data from these sensors is wirelessly transmitted and visualized on the Blynk mobile app, enabling remote monitoring and analysis of the panel's efficiency.

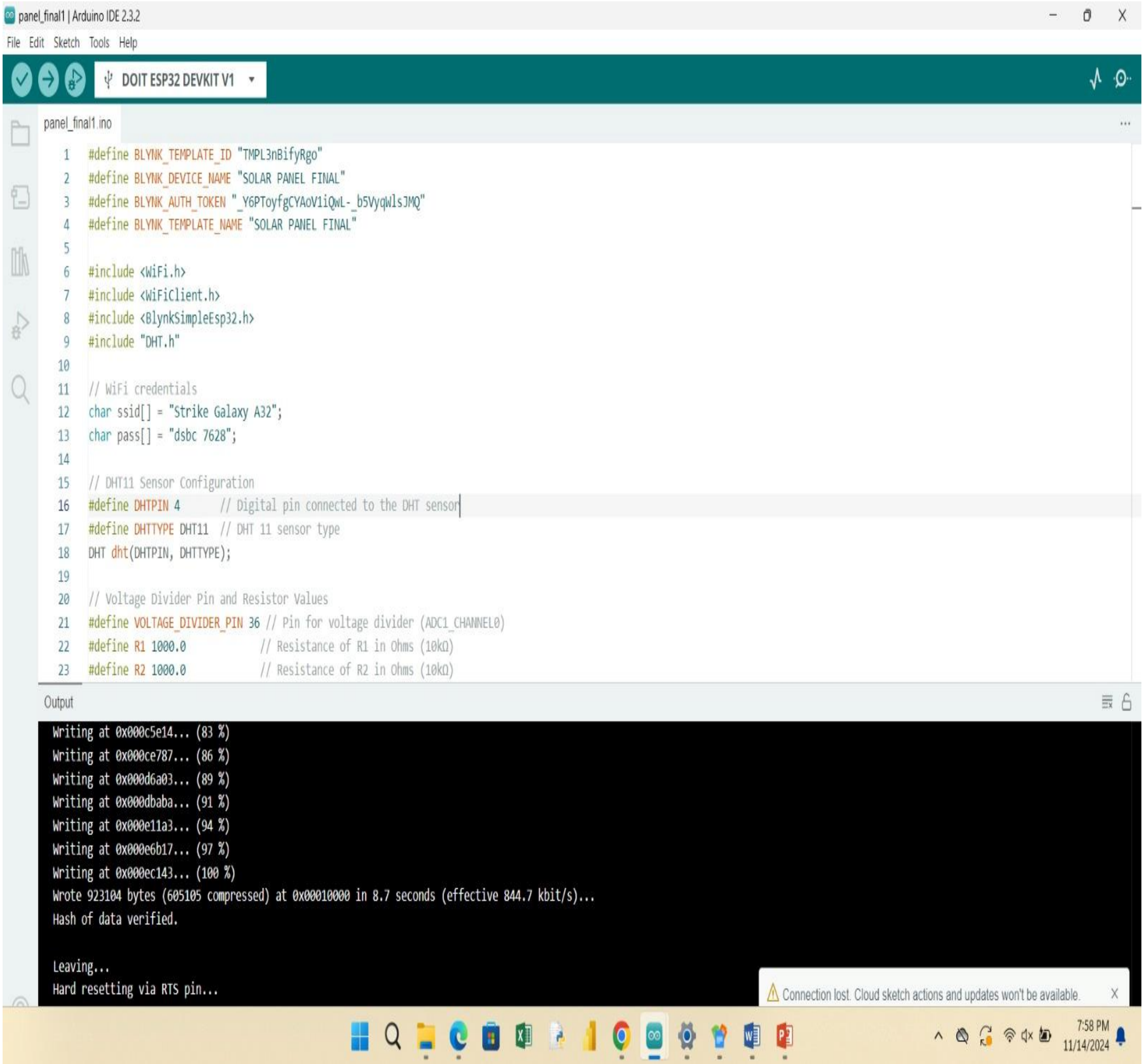
The system incorporates an automatic dust removal mechanism using a DC motor attached to the solar panel. The motor vibrates the panel to help dislodge dust that accumulates over time, thus maintaining its efficiency. LDRs are used at four corners of the panel, and their combined output indicates the dust accumulation levels. The environmental data collected is processed by the ESP32 and displayed in real-time on the Blynk app, making it accessible from any location. This continuous monitoring allows users to take timely action to clean the panel and ensure optimal energy generation.

Results from the implementation indicate a significant improvement in monitoring and maintaining solar panel efficiency. The integration of temperature and humidity data with LDR readings allows for a more accurate assessment of the panel's environmental performance. Voltage readings from the panel provide insights into its operational state, making it easier to detect any issues that may affect energy output. The system has proven effective in enhancing the performance and lifespan of solar panels through real-time maintenance feedback.

8.2 OUTPUT AND HARDWARE IMAGES






panel_final1 | Arduino IDE 2.3.2
File Edit Sketch Tools Help
DOIT ESP32 DEVKIT V1
panel_final1.ino
#define BLYNK_TEMPLATE_ID "TMPL3nBifyRgo"
#define BLYNK_DEVICE_NAME "SOLAR PANEL FINAL"
#define BLYNK_AUTH_TOKEN "_Y6PToyfgCYAoV1iQwL-_b5VyqWlsJMQ"
#define BLYNK_TEMPLATE_NAME "SOLAR PANEL FINAL"
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include "DHT.h"
// WiFi credentials
char ssid[] = "Strike Galaxy A32";
char pass[] = "dsbc 7628";
// DHT11 Sensor Configuration
#define DHTPIN 4 // Digital pin connected to the DHT sensor
#define DHTTYPE DHT11 // DHT 11 sensor type
DHT dht(DHTPIN, DHTTYPE);
// Voltage Divider Pin and Resistor Values
#define VOLTAGE_DIVIDER_PIN 36 // Pin for voltage divider (ADC1_CHANNEL0)
#define R1 1000.0 // Resistance of R1 in Ohms (10kΩ)
#define R2 1000.0 // Resistance of R2 in Ohms (10kΩ)
Output
Writing at 0x000c5e14... (83 %)
Writing at 0x000ce787... (86 %)
Writing at 0x000d6a03... (89 %)
Writing at 0x000dbaba... (91 %)
Writing at 0x000e11a3... (94 %)
Writing at 0x000e6b17... (97 %)
Writing at 0x000ec143... (100 %)
Wrote 923104 bytes (605105 compressed) at 0x00010000 in 8.7 seconds (effective 844.7 kbit/s)...
Hash of data verified.
Leaving...
Hard resetting via RTS pin...
Connection lost. Cloud sketch actions and updates won't be available.
7:58 PM
11/14/2024

CHAPTER 9

CONCLUSION AND FUTURE WORKS

9.1 CONCLUSION

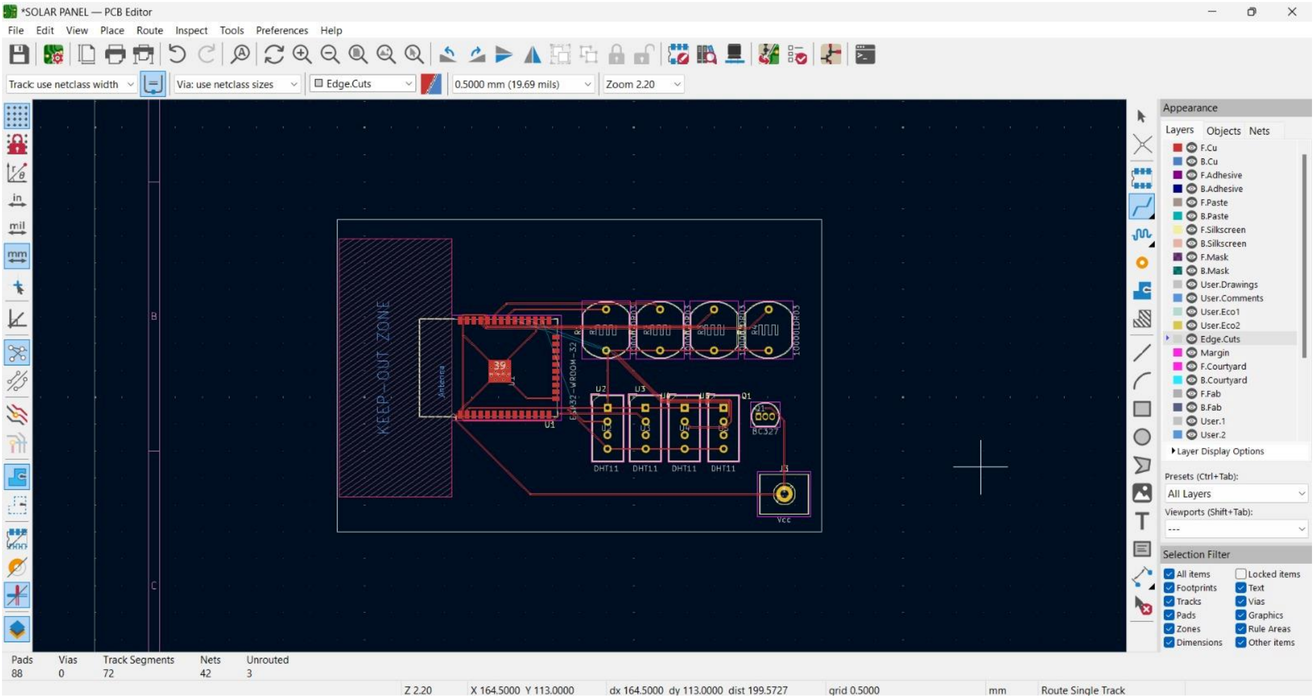
This project, titled "Remote Monitoring of Solar Panel Parameters for Efficient Power Generation," successfully demonstrates a practical solution for optimizing solar panel performance through real-time monitoring and proactive maintenance. By integrating the ESP32 microcontroller, Blynk platform, LDRs, a DHT11 sensor, and a servo motor, this system continuously monitors key parameters such as voltage, temperature, humidity, and light intensity. This data-driven approach allows for better understanding of panel efficiency, especially in varying environmental conditions.

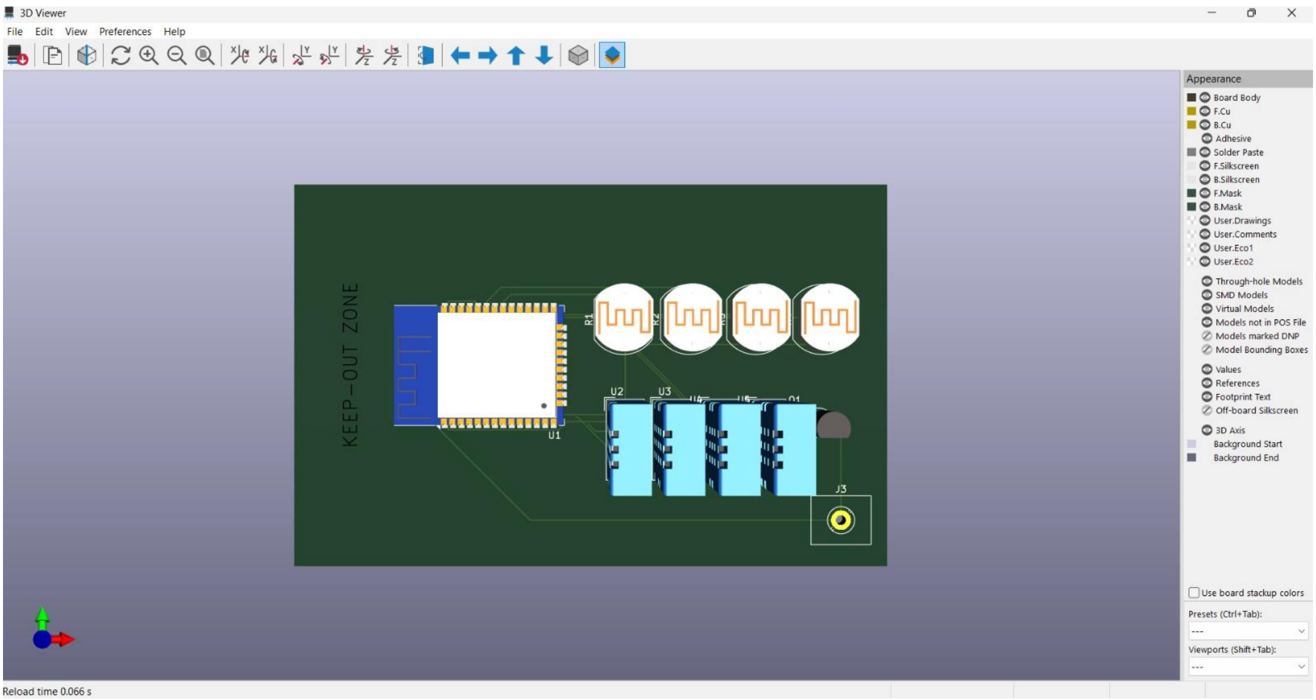
The servo motor is an innovative addition, activated to perform a cleaning function when light or voltage readings indicate potential dust accumulation. This feature ensures the panel remains clear of obstructions that might degrade its performance. With remote monitoring through Blynk, users can track these parameters in real-time, enhancing decision-making for maintenance schedules.

In conclusion, this project offers a cost-effective, scalable, and reliable solution to enhance the efficiency and lifespan of solar panels, promoting sustainable energy generation. It is a valuable step forward in remote solar panel monitoring and could be further developed for large-scale applications in solar farms.

9.2 FUTURE WORKS

For future development, KiCad could be incorporated into this project to design a custom PCB (Printed Circuit Board) layout for the solar panel monitoring system. KiCad is an open-source software that allows detailed schematic capture and PCB layout, making it easier to design, simulate, and create complex electronic circuits. By utilizing KiCad, the system can be made more compact, efficient, and reliable, allowing all the sensor inputs, ESP32 microcontroller, servo motor control, and other components to be integrated onto a single board. This would help reduce wiring complexity, improve durability, and ensure a professional finish to the finalproduct.





9.3 SUMMARY

This project presents a practical solution for real-time solar panel monitoring, using ESP32, DHT11, LDRs, and Blynk for remote data tracking. With features like light intensity and temperature monitoring, efficiency calculations, and automatic dust-cleaning via a servo motor, the system is designed to enhance solar panel performance through regular maintenance alerts. Adding KiCad for future PCB development could further optimize the system, streamlining the design and improving reliability in diverse environmental conditions.

CHAPTER 10

REFERENCES

[1] Design and Development of Solar Panel Cleaning Bot Nagesh Kumar Assistant Professor Department of E & CE Jyothy Institute of Technology Bengaluru ,India.

[2] Rahul B. Ingle1, Ravindra S. Chavan2, Rameshwar R. Kondke3, Nishant V. Mahadane4, Vishnu D. Phuke5, Prof. K. V. Nemade6 1 UG. Rahul B. Ingle, Mechanical, S.Y.C.E.T. A’Bad, Maharashtra,India 2 UG.Ravindra S. Chavan, Mechanical, S.Y.C.E.T. A’Bad, Maharashtra, India 3 UG.Rameshwar R. Kondke, Mechanical, S.Y.C.E.T. A’Bad, Maharashtra, India 4 UG.Nishant V. Mahadane, Mechanical, S.Y.C.E.T. A’Bad, Maharashtra, India 5 UG.Vishnu D. Phuke, Mechanical, S.Y.C.E.T. A’Bad, Maharashtra, India 6 Assistant Prof. K. V. Nemade Mechanical, S.Y.C.E.T. A’Bad, Maharashtra, India

[3] Km Saba Khan1 , Thanuku Hemanth Kumar2 , Sanapala Sri Naveen3 , Kottiyada Sai Yochan4 , Thripuram Balarama Krishna Murthi5 , and Mandeep Singh6 1 2 3 4 & 5 Undergraduate Student; Department of Mechatronics Engineering; Lovely Professional University, 6 Assitant Professor; Department of Robotics and Automation