A Project Report on

"UTILIZING IOT FOR SOLAR PANEL MONITORING"

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Submitted by

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CERTIFICATE

This is to certify that the project work entitled **"UTILIZING IOT FOR SOLAR PANEL MONITORING"** is a bonafied work carried out by students **JAZIB HASSAN (1GC20CS018), MOHAMMAD FARMAN (1GC20CS031), SAMEER (1GC20CS049), SYED NABIL UR RAHMAN (1GC20CS056)** of Ghousia College of Engineering in partial fulfilment for the award of Bachelor of Engineering in Computer Science and Engineering of the Visvesvaraya Technological University, Belagavi during the year 2023-2024. It is certified that all the corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the department library. The project report has been approved as it satisfies the academic requirements in respect to the technical part prescribed for the above said degree.

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ABSTRACT

The rapid integration of renewable energy sources, such as solar panels, into our power generation system has led to an increased need for efficiently monitoring and maintenance strategies. This work presents an innovative approach to monitoring and fault detection of solar panels using Internet of Things [IoT] technology. By deploying a network of sensors and communication devices, real-time data on various parameters, including temperature, voltage, current, light intensity, and panel orientation, can be collected, and transmitted to a centralized data repository. The proposed IoT-based system offers several advantages over traditional monitoring methods. It enables remote and continuous monitoring of solar panel performance, eliminating the need for manual inspections and reducing maintenance costs. The data collected from the sensors can be processed and analysed using advanced algorithms to detect anomalies, faults, and suboptimal conditions. Such timely detection allows for swift corrective actions, thereby optimizing energy generation and increasing the overall lifespan of the solar panel system**.**

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Chapter 1

EMBARKING ON SMART ENERGY

1.1 INTRODUCTION

Solar energy is gaining prominence as an increasingly advantageous alternative, propelled by the escalating costs of fossil fuels, their diminishing supply, and the growing imperative for sustainable energy sources like wind, solar, and geothermal options. At the heart of this transition is solar power, derived from the sun, which stands out as a reliable and environmentally friendly solution to our energy needs. The pivotal role of solar technology is exemplified by the Internet of Things (IoT)-based solar monitoring systems. These systems not only enhance the efficiency of solar panels but also offer the convenience of real-time monitoring through the internet from any location. This technological marvel enables solar panels to dynamically rotate from East to West, optimizing their exposure to sunlight throughout the day. The integration of IoT in solar energy infrastructure underscores the adaptability and sophistication of renewable energy systems, marking a significant step towards a sustainable future. The shift towards solar energy is not merely a technological trend but a necessity driven by multiple factors. The burgeoning demand for energy, coupled with the finite nature of fossil fuel resources and their escalating costs, underscores the urgency of transitioning to more sustainable alternatives. Solar power emerges as a front-runner in this pursuit, offering a virtually limitless and clean source of energy. As we witness the adverse impacts of climate change and the perils associated with greenhouse gas emissions, the adoption of solar technology becomes not only feasible but imperative for mitigating environmental risks. The potential of solar power to meet our energy needs in an eco-friendly manner positions it as a cornerstone of a responsible energy strategy. Embracing solar technology allows us to significantly reduce our reliance on fossil fuels, mitigating the adverse environmental effects associated with their extraction, production, and consumption. The call to harness as much solar energy as possible is a rallying cry for a sustainable future. Governments, businesses, and individuals alike must actively contribute to the widespread adoption of solar technology. This involves not only investing in solar infrastructure but also fostering research and development to further enhance the efficiency and affordability of solar solutions. Through concerted efforts, we can usher in an era where solar energy plays a pivotal role in powering our world, offering a cleaner, greener, and more sustainable alternative to conventional energy sources.

1.2 Objectives of the project

- A solar monitoring system utilizing IoT collects real-time data on solar production, enabling remote monitoring from any location through the internet.
- Examine data for power generation, evaluating its efficiency, output, and trends to optimize and enhance overall energy production processes.
- Display data both offline and online by utilizing a cloud server, ensuring accessibility and synchronization for efficient information management.
- Aiding in pinpointing faults, it facilitates the identification of issues within solar panels, contributing to efficient troubleshooting and maintenance.
- It offers a user-friendly interface, ensuring ease of interaction for users to navigate and engage with the system seamlessly.

1.3 Existing System

While conventional non-renewable energy sources are diminishing, the utilization of renewable resources for energy generation is on the rise. Solar energy technology stands out as an excellent choice for harnessing natural assets. It involves the collection of solar energy through solar panels, its conversion into electrical power, and subsequent storage in batteries for on-demand usage. This monitoring system furnishes straightforward information regarding diverse solar parameters, facilitates fault detection, and addresses associated energy losses. Enhancing the efficiency of this work can be achieved through the incorporation of solar trackers which utilize maximum power point tracking mechanisms (MPPT). This system evaluates the sun's position and directs the movement of solar panels to optimize sun exposure on their surface. MPPT solar charge controllers, equipped with algorithms for maximum power point tracking, have been devised to substantially amplify the current supplied to batteries from photovoltaic modules. This work presents an innovative IoT-based solution designed for the detection and diagnosis of issues in solar PV panels. The primary objective of this approach is to enhance the performance and dependability of solar PV panels, which are susceptible to a range of problems like shading, soiling, degradation, and electrical malfunctions. The system incorporates wireless sensor nodes strategically placed on the panels to gather data concerning their electrical characteristics and environmental factors, including temperature, irradiance, and humidity.

1.4 Proposed System

The cutting-edge Solar Panel Monitoring System, employing Internet of Things (IoT) technology, is designed to optimize the efficiency, reliability, and sustainability of solar energy generation. This innovative system utilizes IoT to collect and analyse data from solar panels in real-time, offering remote-control capabilities and providing valuable insights. The system facilitates the continuous monitoring and collection of energy generation data, which is then transmitted to a cloud server, enabling monitoring from anywhere in the world.

Key Features:

1. **Real-time Data Collection:** The system employs IoT sensors and devices installed on each solar panel to collect real-time data on various parameters, including energy production, temperature, humidity, and voltage.
2. **Data Transmission:** Data collected from the solar panels is transmitted securely to a centralized cloud-based platform. This ensures that the information is accessible from anywhere and can be monitored by relevant stakeholders.
3. **Analytics and Monitoring:** Advanced analytics and machine learning algorithms are used to process the data, enabling the system to detect issues such as panel malfunctions, shading, or dirt build-up. System operators can monitor the performance of individual panels and the entire array in real-time.
4. **Energy Efficiency:** By continuously monitoring panel performance and making real-time adjustments, the system maximizes energy output, contributing to increased efficiency and return on investment for solar installations.
5. **User-Friendly Interface:** The user interface is designed to be intuitive, allowing users to access comprehensive data and control functionalities easily. It can be accessed via web or mobile applications.

1.5 Extra Features

- Cloud-based monitoring is essential for managing and optimizing resources and workloads in cloud environments.
- Implemented through automated software tools, providing comprehensive insights for cloud administrators.

- Offers a centralized platform for real-time tracking, enabling proactive issue identification and timely response.
- Primary goal is to measure workloads against specific metrics, ensuring optimal cloud tenancy operations.

1.6 Problem Definition

The widespread adoption of solar energy as a clean and sustainable power source has led to the deployment of solar panel arrays across diverse geographical locations. However, the efficient operation and maintenance of these solar panel's present challenges, including the need for real-time monitoring, fault detection, and performance optimization. Traditional monitoring methods often lack the granularity and immediacy required to address issues promptly, leading to decreased energy output, increased maintenance costs, and potential environmental impact. To address these challenges, there is a need for a comprehensive and intelligent solar panel monitoring system that leverages the capabilities of the Internet of Things (IoT). The current lack of a standardized and scalable IoT solution tailored for solar panel monitoring poses a significant obstacle to maximizing the potential of solar energy. This project aims to develop an integrated IoT-based monitoring system to enable real-time data collection, analysis, and management of solar panel performance, addressing key issues such as:

1. **Fault Detection and Diagnostics:** Existing solar panel monitoring systems often struggle to promptly detect faults or anomalies, leading to reduced energy output and increased downtime.
2. **Performance Optimization:** The IoT monitoring system should facilitate continuous performance optimization by collecting and analysing data related to solar irradiance, temperature, and other relevant parameters.
3. **Remote Monitoring and Management:** Solar panel installations are often distributed over large areas, making manual monitoring and management challenging.
4. **Energy Yield Prediction:** Predicting energy yields accurately is crucial for optimizing the overall efficiency of solar panel installations. The IoT-based monitoring system should incorporate predictive analytics to estimate future energy yields based on historical data and environmental conditions.

Chapter 2

LITERATURE SURVEY

Vishal Singh et.al., “IoT based solar power monitoring system”

This work presents a solution and methodology for effectively monitoring dust accumulation on solar panels, aimed at optimizing power output for practical utilization. The performance of solar panel is inherently tied to the energy received by its solar cells. The anticipated system not only ensures the display of malfunctioning solar panels but also indicate s whether electrical appliances are being directly powered by the solar panel or if the load is being supplied by the battery. This work involves the creation of IoT-based systems aimed at achieving optimal power output from the solar panels even in presence of dust accumulation. Additionally, a monitoring system has been developed to promptly identify any malfunctions in the solar panels. This system also provides information about whether the loads are being powered by solar panels.

Balakrishnan D et.al., “IoT-based system for fault detection and diagnosis in solar pv panels”

This work presents an innovative IoT-based solution designed for the detection and diagnosis of issues in solar PV panels. The primary objective of this approach is to enhance the performance and dependability of solar PV panels, which are susceptible to a range of problems like shading, soiling, degradation, and electrical malfunctions. The system incorporates wireless sensor nodes strategically placed on the panels to gather data concerning their electrical characteristics and environmental factors, including temperature, irradiance, and humidity. This data is subsequently transmitted to a central server for in-depth analysis and processing using machine learning algorithms. Importantly, this system has the ability to swiftly identify and diagnose faults in real-time, issuing alerts and offering recommendations to maintenance personnel for timely interventions to avert further damage or downtime. Compared to traditional manual inspection and maintenance practices, this system offers multiple advantages, such as reduced downtime, lower maintenance expenditures, and enhanced energy efficiency. The viability of this system has been substantiated through rigorous experimental tests, conclusively demonstrating its remarkable accuracy and efficiency in fault detection and diagnosis for solar PV panels.

T. Asha Rakshana et.al., "IoT based solar panel fault monitoring and control by using wi-fi modem"

To ensure optimal power generation from solar the power plants, a comprehensive monitoring strategy is imperative. This work facilitates the attainment of efficient power production by identifying and rectifying issues such as faulty solar panels, connectivity problems, dust accumulation on panels, and other factor that can undermine solar performance. This work introduces a hardware design for an intelligent grid home gateway, seamlessly integrating a smart home network with photovoltaic (PV) integration within the solar system. Detection of faults occurs through the comparison of the Light Dependent Resistor (LDR) sensor intensity with the voltage measured from the panel. Our system maintains a continuous monitoring process of solar panel and subsequently transmits the power output data to IoT system via internet connectivity.

Preethi Sekar et.al., "IoT-based Solar Energy Monitoring"

While conventional non-renewable energy sources are diminishing, the utilization of renewable resources for energy generation is on the rise. Solar energy technology stands out as an excellent choice for harnessing natural assets. It involves the collection of solar energy through solar panels, its conversion into electrical power, and subsequent storage in batteries for on-demand usage. This monitoring system furnishes straightforward information regarding diverse solar parameters, facilitates fault detection, and addresses associated energy losses. Enhancing the efficiency of this work can be achieved through the incorporation of solar trackers which utilize maximum power point tracking mechanisms (MPPT). This system evaluates the sun's position and directs the movement of solar panels to optimize sun exposure on their surface. MPPT solar charge controllers, equipped with algorithms for maximum power point tracking, have been devised to substantially amplify the current supplied to batteries from photovoltaic modules.

P. Sampurna Lakshmi et.al., "Solar Panel Fault Detection System using IoT"

Solar parks are rapidly emerging as a pivotal form of renewable energy systems, underscoring the urgency for optimized utilization of their resources while tackling errors and performance challenges. To address these concerns, the Internet of Things (IoT) technology presents an accessible, cost-effective, and sustainable solution for enhancing solar park efficiency. In this work, we outline a monitoring and alert system designed to proactively detect Potential Induced Degradation (PID) and Hotspot failures issues that can significantly impair solar panel performance. This entails continuous monitoring of essential metrics such as temperature, voltage, and humidity at the panel level. Thorough functional testing of the complete circuit has been conducted, confirming its seamless compatibility with the application software. The design implemented in this study offers a combination of portability and adaptability, facilitating efficient data transfer with minimal power consumption.

Darshan Nandurkar et.al., “Solar Energy Monitoring System Using IoT”

Renewable energy is a type of energy, that is derived from ongoing natural processes and energy of natural processes converted into available forms. Solar energy is any type of energy that is generated by the sun. To make use of this energy and convert it into electricity we use solar panels. The IoT allows objects to be sensed or controlled remotely over existing network infrastructure, creating opportunities for pure integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention. This technology has many applications like Solar cities, Smart villages, Micro grids, and Solar Street lights and so on. As Renewable energy grew at a rate faster than any other time in history during this period. The proposed system refers to the online display of the power usage of solar energy as a renewable energy. This monitoring is done through atmega328p using ATMEGA328P IDE. Smart Monitoring displays voltages of renewable energy. This helps the user to analysis of energy generation. Analysis impacts on the renewable energy usage and electricity issues.

Mirsad Hyder Shah et.al., “IoT based efficient solar panel monitoring”

The invention of smart grid has already outdated the conventional method of one-way power production supply concept. While developed countries have already started to adopt smart meters, appliances, and renewable energy sources: underdeveloped and developing countries are still facing power shortages every day. In the second Industrial Revolution, electricity was the main advancement, and the recent Industrial Revolution 4.0 has pushed giant Production companies into the adoption and promotion of Renewable Energy sources. The integration of IoT and power systems has revolutionized the world in terms of power efficiency and real time monitoring. This paper discusses an experimental work done on how IoT can monitor the power/voltage and current production of a standalone renewable energy source i.e. a solar panel. This paper also discusses how to improve the solar panel efficiency by correcting the tilt angle of the solar panel. The monitoring of the solar panel is done via an inter-connected system using

NodeMCU, Node-RED, Arduino and an MQTT channel. The monitoring of solar panels can be made easier by implementing the proposed work in a photovoltaic (PV) power plant. Moreover, the monitoring of energy production will greatly enhance the health of the PV system. A 24% increase in the power output has been noticed after the correction of the tilt angle which was corrected using a solar tracker.

Vishal S. Patil et.al., "A Review Paper on Solar Power Monitoring System using an IoT"

The solar power monitoring system is used the Internet of Things for the purpose, to overcome the drawbacks of previous solar systems. An IoT is a joint network of the connected devices together and shares the data about how they are used in the environment in which they are operated. The solar power monitoring system is used for generating the electricity by using the energy of sunlight. This system is uses the Arduino Uno for enhancement of the solar systems. This solar power monitoring system uses the Arduino Uno. The Arduino Uno is microcontroller board, this microcontroller used the ATmega328p. ATmega328p is also a microcontroller chip which is developed by Atmel. By using Arduino Uno the solar panel is capable of moving in the direction where sunlight is moves, this is the additional feature of this solar system. This paper shows the working, architecture and connections of the solar power monitoring system using an IoT.

M. Keerthana et.al., "IoT based solar power monitoring system"

Solar power plants need to be monitored for optimum power supply. This helps retrieve efficient power output from power plants while monitoring for faulty solar panels, connections, dust accumulated on panels lowering output and other such issues affecting solar performance. So here we propose an automated IoT based solar power monitoring system that allows for automated solar power monitoring from anywhere over the internet. We use Arduino based system to monitor a 10W solar panel parameters. Therefore, internet of things technology using sensors to monitor the parameters of the solar photovoltaic systems remotely from anywhere using smartphones and computers using web server. In order to achieve it here we propose a sun tracking technology to control the solar panel and rotate it, so it absorbs maximum sunlight every instant. The system is based on a using a IoT monitors and controls the solar photovoltaic system remotely from anywhere around the world. The purpose of the project is to implement a system to continuously track the sun rays with the help of the solar panel and grasping the maximum power from the sun by checking the solar panel according to the sun rays direction with respect voltage sensor and current sensor.

Rajesh Malvi et.al., *"A Paper on Solar Power Monitoring System Using IoT"*

Renewable energy sources are proven to be reliable and accepted as a good alternative for fulfilling our increasing energy requirement. The user can get the information about the current and previous average parameter like voltage, temperature, current and power saving. Solar photovoltaic energy is the new emerging and enticing clean technologies with zero carbon emission in today's world. This also provide the real time information to the user which will help to monitor the system the main purpose of this paper is that the solar panel can collect, or we can say capture maximum solar radiation and maintain the system more reliably and good. To harness the solar power generation, it is indeed necessary to pay some serious attention to its maintenance as well as application. These IOT based technology is best suitable for remote like areas where solar Power plant are set up due to the large availability of solar energy but regular access to the areas is very much difficult and is not cost efficient.

J. Samuel et.al., "IoT Based Solar Panel Monitoring and Control"

IoT technologies are used to track solar power in this study. On the Internet of Things (IoT), data can be collected and sent wirelessly without human involvement. In remote areas where there is abundant solar energy, this IoT-based technology is best suited. As it stands, regular access to the areas is still a challenge and expensive. Solar panels, NODE-MCU (ESP8266), Voltage Sensor, Current Sensor, Temperature Sensor, Servo motor, LDR, etc. comprise these IoT-based technologies.

Vedanti Hardas et.al., "Solar Panel Monitoring System Using IoT"

The invention of the smart grid goes beyond the traditional notion of a one-way power supply. Developed countries have already begun to adopt smart meters, devices, and renewable energy sources. Developing and countries still face power shortages daily. The integration of IoT and energy systems has revolutionized the world in terms of energy efficiency and real-time monitoring. This paper describes an experimental study of how IoT can power the current/ voltage and power generation of self-contained renewable energy sources. Solar modules can be monitored. This document also describes how to modify the tilt angle of the solar panel to improve the efficiency of the solar panel. Solar modules are monitored via a network system with NodeMCU, Atmega328 IC, Arduino. By carrying out the proposed work at a photovoltaic (PV) power plant, you can simplify the monitoring of solar panels. In addition, monitoring power generation can significantly improve the health of PV systems.

Srilakshmi Madadi et.al., “A Study of Solar Power Monitoring System Using Internet of Things (IoT)”

Renewable energy sources are a practical solution for addressing the ongoing supply gap in the power industry. Because of the availability of solar energy throughout the world, unlike other geographically restricted resources, solar energy is most beneficial of all renewable energy resources. Sophisticated frameworks for remote monitoring of the plant using web-based interface is required for this massive scale of solar system deployment. Since the greater part of them are set in areas that are inaccessible and therefore monitoring them is not possible from a specific location. Internet of Things (IoT) enables the objects to be detected and remotely controlled by an established infrastructure of a network, creating possibilities for the pure physical-environment integration into frameworks that are based on computers. Application of IoT is proving beneficial for monitoring renewable energy generation. This application of IoT uses system based on Arduino to monitor parameters of the solar panel. The solar panel is monitored by the system continuously and the power output is transmitted over the internet to the IoT Network. It now uses an effective Interface to display these solar panel parameters to the user and it also alerts user when the outcome falls underneath the cut-off points specified. This makes, distantly monitoring of solar power plants more convenient and the best output of power is guaranteed.

Neelanshi S Palkar et.al., “Solar power monitoring system using IoT”

This paper describes the monitoring of solar power by using internet of thing. The Internet of Things (IoT) refers to a system of interrelated, internet-connected objects that are able to collect and transfer data over a wireless network without human intervention. These IoT based technology is best suited for remote areas where solar Power plant is set up due to the ample availability of solar energy but regular access to the areas is very difficult and is not cost efficient. These IoT based technology are comprises of Solar Panel, NODE-MCU ESP8266, Voltage Sensor, Current Sensor, Temperature Senor etc.

Marulasiddappa H et.al., “IoT- Based Solar Power Monitoring”

Rooftop solar panels are becoming more popular these days, but in order to know how effectively the solar photovoltaic system is working and for performance evaluation, there should be some monitoring system. As the world is moving towards renewable energy and nations like ICELAND have achieved 100% renewable energy status and India has also started to lean towards renewable energy, a growing number of people are using renewable energy sources.

Some solar photovoltaic systems are inaccessible, making it impossible to monitor them, and the solar panels are not use to their full effectiveness towards the day. To achieve this, the solar panel was to observe the most sunlight possible at all times. Microcontroller and internet of things technologies are used in the system to monitor the solar photovoltaic system. The world now is turning towards renewable energy sources and countries like ICELAND have obtained 100% renewable energy status of india has also started to lean towards renewable energy.

Sheikh Hasib Cheragee et.al., “A Study of IoT based Real-Time Solar Power Remote Monitoring System”

We have Developed an IoT-based real-time solar power monitoring system in this paper. It seeks an open-source IoT solution that can collect real-time data and continuously monitor the power output and environmental conditions of a photovoltaic panel. The Objective of this work is to continuously monitor the status of various parameters associated with solar systems through sensors without visiting manually, saving time and ensures efficient power output from PV panels while monitoring for faulty solar panels, weather conditions and other such issues that affect solar effectiveness. Manually, the user must use a mustimeter to determine what value of measurement of the system is appropriate for appliance consumers, which is difficult for the larger System. But the Solar Energy Monitoring system is designed to make it easier for users to use the solar system. This system is comprised of a microcontroller (Node MCU), a PV panel, sensors (INA219 Current Module, Digital Temperature Sensor, LDR), a Battery Charger Module, and a battery. The data from the PV panels and other appliances are sent to the cloud (Thingspeak) via the internet using IoT technology and a Wi-Fi module (NodeMCU). It also allows users in remote areas to monitor the parameters of the solar power plant using connected devices. The user can view the current, previous, and average parameters of the solar PV system, such as voltage, current, temperature, and light intensity using a Graphical User Interface. This will facilitate fault detection and maintenance of the solar power plant easier and saves time.

K.G.Srinivasan et.al., “Solar Energy Monitoring System by IoT”

The Internet of Things has a vision in which the internet extends into the real world, which incorporates everyday objects. The IoT allows objects to be sensed or controlled remotely over existing network infrastructure, creating opportunities for pure integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention. This technology has many applications like

Solar cities, Smart villages, Micro grids and Solar Street lights and so on. As Renewable energy grew at a rate faster than any other time in history during this period. The proposed system refers to the online display of the power usage of solar energy as a renewable energy. This monitoring is done through raspberry pi using flask framework. Smart Monitoring displays daily usage of renewable energy. This helps the user to analysis of energy usage. Analysis impacts on the renewable energy usage and electricity issues.

P. Sampurna Lakshmi et.al., "Solar Panel Fault Detection System using IoT"

The solar parks are now quickly becoming one of the most significant renewable forms of energy systems, hence there is a pressing need for more streamlined use of the aid they provide, as well as error discernment and performance difficulties. The Internet Of Things (IoT) technology attempts to bridge the gap by providing low-priced, modest and long-term results for solar park efficiency. We describe a monitoring and alerting system in this project that is employed in the early identification of Potential Induced Degradation (PID) and Hotspots failures, which can result in a considerable reduction in solar panel performance. Certain practical characteristics like as temperature, voltage, and humidity are continually monitored at the panel level in order to do this. It is mainly focused on the installation of Internet of Things for remote monitoring and performance evaluation of a solar facility. This will make preventative maintenance, solar panel defect detection, and real-time monitoring much easier. Solar towns, smart villages, micro grids, and solar street lighting are just a few of the possibilities for this technology.

Chapter 3

DESIGN AND ARCHITECTURE

In this part, we will present the design by arguing why we use or do not use different features. First, we will present an overview of the entire architecture and after that continues with specific decisions regarding the design. In the end, we finish with the presentation of the final design.

3.1 Project Planning

Project management begins with planning, which is perhaps the single largest responsibility of the project management. Proper planning is recognized as a critical ingredient for a successful project. The project plan provides the fundamental basis for project management. A software plan is usually produced before the development activity begins and is updated as development proceeds and data about the progress of the project becomes available.

The major activities of project planning are:

- Cost estimation
- Schedule and Milestone determination
- Project-Staffing
- Quality control plans
- Controlling and monitoring plan

3.2 Modules

- **#include <WiFi.h>**

  - The #include <WiFi.h> directive in Arduino code tells the compiler to include the WiFi library in the program.
  - Syntax:
    - #include is the pre-processor directive used to include header files.
    - <WiFi.h> specifies the name of the header file to include.
    - The angle brackets < > denote that the header file is a system header file.
  - **Usage**

```
#include <WiFi.h>
```

```
void setup() {
  WiFi.begin("SSID", "password");
  while  (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("WiFi connected!");
}
  void loop() {
  // do something
  }
```

- **#include <LiquidCrystal_I2C.h>**
  - It is an Arduino sketch tells the compiler to include the LiquidCrystal_I2C library in the sketch.
  - Including this header file allows you to use the LiquidCrystal library with I2C (Inter-Integrated Circuit) interface in your Arduino project.
  - Syntax
    - #include: Pre-processor directive used to include header files.
    - <LiquidCrystal_I2C.h>: Specifies the name of the header file to include.
    - The angle brackets < > denote that the header file is a system header file.
  - **Usage**

```
#include <Arduino.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);
  void setup() {
  lcd.init();
  lcd.backlight();
}
  void loop(){
  lcd.clear();
  lcd.setCursor(0, 0);
```

```
    lcd.print("Hello, world!");
    delay(1000);
}
```

3.3 Device Lifecycle

Implementing effective device lifecycle and change management is crucial for an IoT-based Solar Panel Monitoring System. Key considerations include:

- **Device On-boarding:** Streamlined processes for adding new devices to the monitoring system ensure efficient integration and deployment, enhancing the overall lifecycle.
- **Configuration Management:** Managing device configurations is vital for optimizing performance. Ensuring proper alignment with solar panels and continuous monitoring helps maintain efficiency.
- **Monitoring and Analytics:** Continuous monitoring and data analytics allow for proactive identification of device issues, enabling timely maintenance and preventing disruptions in the solar panel monitoring system.
- **Integration:** Integrate the solar panel monitoring system with the actual solar panel setup. Ensure proper connectivity between sensors, microcontrollers, and the cloud. Validate the system's performance under real-world conditions.
- **Operation:** Monitor the solar panel system in real-time through the user interface. Collect and analyse data to ensure optimal performance and energy production.

3.4 Architecture Overview

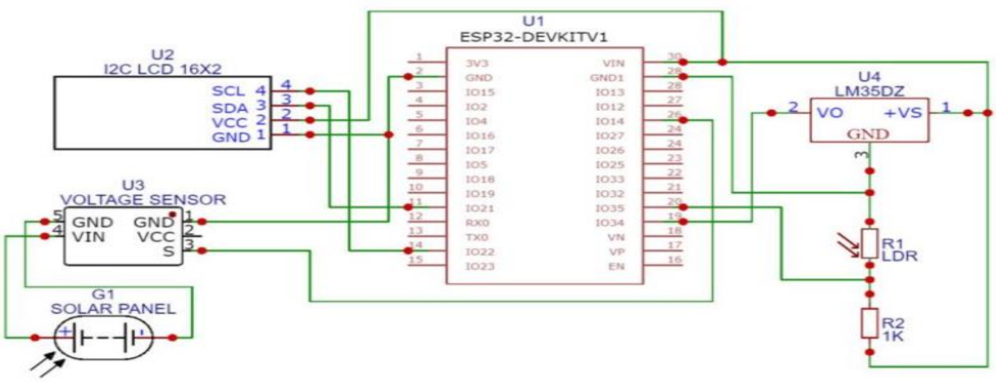

Fig. 3.1 Circuit Diagram of the Device

This architecture seamlessly melds together a sophisticated amalgamation of hardware and software components, serving as the foundation for an advanced smart system. At its core lie a multitude of hardware elements, including the versatile ESP32 microcontroller, an array of sensors catering to diverse sensing needs, a Liquid Crystal Display (LCD) for visual feedback, and a solar panel for sustainable power provision. These hardware components collectively form the physical framework of the system, facilitating its sensory perception capabilities, user interaction, and energy autonomy. Complementing this hardware infrastructure is a robust suite of software components meticulously crafted to orchestrate the system's operations. At the heart of the software stack lies the firmware tailored for the ESP32 microcontroller, providing the essential logic and functionality to govern its behavior, manage peripheral devices, and interface with the external environment. This firmware acts as the system's neural network, orchestrating the intricate dance of data acquisition, processing, and transmission.

Chapter 4

IMPLEMENTATION & MAINTENANCE

4.1 Cloud Integration

- **Introduction to IoT in Solar Panel Monitoring:**

In recent years, the adoption of IoT (Internet of Things) technology has significantly transformed various industries, including renewable energy. One such application is monitoring solar panels using IoT devices. Solar panel monitoring involves tracking parameters such as voltage, current, temperature, and energy production to ensure optimal performance and efficiency. By leveraging IoT devices and cloud platforms, real-time monitoring, data analysis, and remote management of solar panels become feasible

- **Understanding ThingSpeak:**

ThingSpeak is an IoT platform developed by MathWorks that enables users to collect, analyze, and visualize data from IoT devices in real-time. It provides a cloud-based infrastructure for storing and processing sensor data, along with tools for data analysis, visualization, and integration with other applications. ThingSpeak supports various IoT protocols such as MQTT, HTTP, and REST API, making it versatile and compatible with a wide range of devices and sensors.

4.2 Working of ThingSpeak in Solar Panel Monitoring

1. Data Acquisition: The first step in monitoring solar panels using ThingSpeak involves acquiring data from IoT sensors deployed on or near the solar panels. These sensors may include voltage and current sensors to measure electrical parameters, temperature sensors to monitor panel temperature, and irradiance sensors to measure solar radiation intensity.

2. Data Transmission: Once the sensor data is collected, it needs to be transmitted to the ThingSpeak platform for further processing and analysis. This transmission typically occurs over the internet using wireless communication protocols such as Wi-Fi, cellular, or LoRaWAN. IoT devices equipped with communication modules send the data to ThingSpeak using APIs or protocols supported by the platform.

3. Data Storage: Upon receiving the sensor data, ThingSpeak stores it in its cloud-based storage infrastructure. Each data entry is timestamped, allowing for chronological organization and retrieval of historical data. ThingSpeak provides built-in support for time-series data storage, making it suitable for IoT applications where data is generated continuously over time.

4. Data Analysis: ThingSpeak offers built-in analytics tools that enable users to perform real-time analysis on the collected data. Users can define custom MATLAB scripts or use pre-built algorithms to analyze sensor data, detect patterns, and derive insights. Common analysis techniques include anomaly detection, trend analysis, and predictive modeling to identify potential issues or optimize system performance.

5. Visualization: Visualizing data is crucial for gaining insights and making informed decisions. ThingSpeak provides customizable visualization tools such as charts, graphs, and gauges to display sensor data in a user-friendly format. Users can create dashboards with real-time updates to monitor solar panel performance and track key metrics over time.

6. Alerts and Notifications: ThingSpeak allows users to set up alerts and notifications based on predefined conditions or thresholds. For example, users can receive notifications via email or SMS when a solar panel exceeds a certain temperature or when energy production drops below a specified level. This proactive approach helps in early detection of issues and timely intervention.

7. Integration and Collaboration: ThingSpeak offers integration capabilities with other IoT platforms, cloud services, and third-party applications. Users can integrate ThingSpeak with platforms such as MATLAB, Simulink, and MATLAB Analysis and visualization tools for advanced data analysis and modeling. Moreover, ThingSpeak supports RESTful APIs for seamless integration with custom applications and services, facilitating collaboration and data sharing across different stakeholders.

4.3 Platform as a Service (PaaS) in Cloud Computing

Platform as a Service (PaaS) is a cloud computing model that provides a platform for developing, deploying, and managing applications without the complexity of infrastructure management. In a

PaaS environment, the cloud provider manages the underlying infrastructure, including servers, storage, and networking, allowing developers to focus on building and running applications.

4.4 Role of PaaS in ThingSpeak

ThingSpeak can be considered a PaaS offering in the realm of IoT and cloud computing. As a PaaS solution, ThingSpeak abstracts the complexities of managing infrastructure and provides a ready-to-use platform for IoT application development and deployment. Here's how PaaS benefits the utilization of ThingSpeak in solar panel monitoring

1. Scalability: PaaS platforms like ThingSpeak offer scalability features that allow applications to handle varying workloads and data volumes. As the number of IoT devices and sensors increases, ThingSpeak automatically scales its resources to accommodate growing data influx without requiring manual intervention from users.

2. Flexibility: PaaS platforms provide flexibility in terms of application development and customization. ThingSpeak offers a range of APIs, tools, and integrations that enable developers to tailor the platform according to their specific requirements.

3. Cost-Effectiveness: By leveraging a PaaS solution like ThingSpeak, organizations can reduce infrastructure costs and operational overhead associated with managing on-premises servers and software. PaaS platforms typically follow a pay-as-you-go pricing model, allowing users to pay only for the resources they consume, thereby optimizing costs and maximizing ROI.

4. Rapid Deployment: PaaS platforms accelerate the development and deployment of IoT applications by providing pre-built components, templates, and deployment pipelines. With ThingSpeak, users can quickly set up IoT data collection, visualization, and analysis workflows without the need for extensive configuration or software installation.

5. Reliability and Security: PaaS providers like ThingSpeak ensure high levels of reliability, availability, and security for IoT data and applications. With redundant infrastructure, data encryption, and access control mechanisms, ThingSpeak safeguards sensitive sensor data and ensures uninterrupted operation even in the event of hardware failures or security threats.

4.5 Benefits of using ThingSpeak

- **Ease of Use:** ThingSpeak offers a user-friendly interface for creating channels, managing data, and building visualizations.
- **Cost-Effective:** ThingSpeak has a free tier suitable for hobbyist projects and personal use. Paid plans offer extended storage and additional features.
- **Scalability:** ThingSpeak can accommodate a wide range of data streams, making it suitable for small-scale deployments and larger monitoring systems.
- **Open Standards:** ThingSpeak utilizes open communication protocols like REST API and MQTT, ensuring compatibility with various sensors and MCUs.

4.6 Project Management and Challenges

This chapter serves as an essential foundation for understanding the principles and practices of project management in the context of deploying IoT for solar panel monitoring. Effective project management is vital for ensuring the successful delivery of projects on time, within budget, and according to specifications. It involves various processes, methodologies, and tools to plan, execute, monitor, and control project activities. By adopting sound project management principles, organizations can minimize risks, optimize resources, and achieve their strategic objectives. This section provides a comprehensive overview of project management fundamentals, emphasizing the importance of clear goals, effective communication, and stakeholder engagement in project success.

4.6.1 Project Scope Definition

Defining the scope of the project is a critical initial step in project management. It involves clearly outlining the objectives, deliverables, boundaries, and constraints of the project. A well-defined project scope provides a common understanding among stakeholders and serves as a roadmap for project planning and execution. It helps prevent scope creep, scope ambiguity, and misunderstandings that can lead to project delays and cost overruns. Additionally, it enables project managers to prioritize tasks, allocate resources effectively, and manage stakeholder expectations throughout the project lifecycle. This section delves into the intricacies of project scope definition, offering practical tips and examples for effectively defining and managing project scope to ensure project success.

4.6.2 Stakeholder Identification and Engagement

Identifying and engaging stakeholders is essential for project success. Stakeholders are individuals, groups, or organizations that have an interest in or are affected by the project. They may include project sponsors, customers, end-users, suppliers, regulators, and other relevant parties. Effective stakeholder engagement involves identifying key stakeholders, understanding their interests, concerns, and expectations, and involving them in project planning and decision-making processes. It requires clear communication, active listening, and building positive relationships to ensure alignment and commitment to project goals. This section provides practical strategies for identifying stakeholders, assessing their needs, and developing tailored engagement plans to foster collaboration and support throughout the project lifecycle.

4.6.3 Resource Planning and Allocation

Resource planning and allocation involve identifying, acquiring, and allocating resources needed to execute the project successfully. Resources may include human resources, financial resources, equipment, materials, and technology. Effective resource management requires assessing resource requirements, estimating resource availability, and optimizing resource utilization to meet project objectives within budget and schedule constraints. It also involves developing contingency plans to address resource shortages or unexpected changes in project requirements. This section explores best practices for resource planning and allocation, including techniques for resource estimation, allocation, and monitoring to ensure optimal resource utilization and project success.

4.6.4 Risk Identification and Management

Risk management is the process of identifying, analyzing, and responding to project risks to minimize their impact on project objectives. Risks are uncertainties that may arise during the project lifecycle and have the potential to affect project outcomes negatively. Effective risk management involves identifying potential risks, assessing their likelihood and impact, and developing strategies to mitigate, transfer, or accept risks based on their significance. It requires proactive planning, regular risk monitoring, and timely implementation of risk responses to ensure project success. This section delves into risk identification techniques, risk analysis methods, and risk response strategies to help project managers effectively manage project risks and uncertainties.

4.6.5 Project Schedule Development

Developing a project schedule involves creating a detailed plan that outlines project activities, milestones, and timelines for completion. A well-developed project schedule provides a roadmap for project execution, resource allocation, and progress tracking. It helps identify critical path activities, dependencies, and constraints that may impact project duration and identifies opportunities for schedule optimization. Effective project scheduling requires accurate task estimation, realistic deadlines, and regular schedule updates to adapt to changing project conditions. This section explores project scheduling techniques, tools, and best practices to help project managers develop and maintain effective project schedules that ensure project success.

4.6.6 Communication Planning and Management

Communication is essential for project success as it facilitates information exchange, decision-making, and collaboration among project stakeholders. Communication planning involves identifying communication needs, defining communication objectives, and establishing communication channels, protocols, and frequency. It ensures that relevant information is shared effectively, timely, and accurately to keep stakeholders informed and engaged throughout the project lifecycle. Effective communication management requires active listening, clear messaging, and regular feedback to foster trust, transparency, and alignment among project stakeholders. This section provides practical guidance on communication planning and management, including tips for effective communication, stakeholder engagement, and conflict resolution to enhance project communication and collaboration.

4.6.7 Quality Assurance and Control

Quality assurance and control are essential processes to ensure that project deliverables meet specified requirements and standards. Quality assurance focuses on preventing defects and ensuring that project processes adhere to quality standards and best practices. It involves establishing quality criteria, conducting reviews and audits, and implementing quality assurance measures to prevent errors and defects. Quality control, on the other hand, involves monitoring project performance, inspecting deliverables, and verifying that they meet.

4.7 Environmental impact and sustainability

Environmental impact and sustainability are crucial considerations in the deployment of IoT for solar panel monitoring. This section introduces the concept of environmental impact and sustainability in the context of solar energy generation. It highlights the importance of assessing and mitigating environmental impacts while promoting sustainable practices to ensure the long-term viability of solar panel monitoring projects. Furthermore, it emphasizes the need for holistic approaches that consider environmental, social, and economic factors to achieve truly sustainable outcomes in the deployment of IoT technologies for solar panel monitoring.

4.7.1 Assessment of Environmental Footprint

Conducting a comprehensive assessment of the environmental footprint associated with IoT-enabled solar panel monitoring systems is essential. Beyond analyzing energy consumption, material usage, waste generation, and greenhouse gas emissions, stakeholders should also consider indirect impacts such as habitat disruption and water usage. By quantifying environmental impacts, stakeholders can identify areas for improvement and implement strategies to minimize negative environmental effects effectively. Moreover, conducting a thorough environmental footprint assessment helps organizations fulfill their corporate social responsibility commitments and demonstrates their commitment to environmental stewardship**.**

4.7.2 Energy Efficiency and Resource Conservation

Leveraging IoT technology presents significant opportunities to enhance energy efficiency and resource conservation in solar panel monitoring. Beyond optimizing panel performance and reducing energy consumption, stakeholders can explore innovative solutions such as predictive maintenance algorithms and real-time performance optimization to further enhance energy efficiency and resource utilization. Additionally, integrating renewable energy sources such as wind or hydroelectric power into IoT-enabled monitoring systems can further reduce environmental impacts and promote sustainability. By prioritizing energy efficiency and resource conservation, stakeholders can maximize the environmental benefits of deploying IoT for solar panel monitoring while minimizing ecological footprints.

4.7.3 Lifecycle Analysis

Conducting a thorough lifecycle analysis of IoT-enabled solar panel monitoring systems is essential for understanding their overall environmental impact. This analysis should encompass every stage of the product lifecycle, from raw material extraction and manufacturing to end-of-life disposal or recycling. By considering the environmental implications of each stage, stakeholders can identify opportunities to reduce environmental impacts and improve sustainability. Furthermore, lifecycle analysis helps organizations identify potential hotspots of environmental impact and prioritize efforts to address them effectively. By adopting a lifecycle approach to environmental management, stakeholders can minimize their ecological footprint and promote sustainability across the entire value chain.

4.7.4 Sustainability Considerations

Integrating sustainability considerations into the design, implementation, and maintenance of IoT-enabled monitoring systems is essential for promoting environmental stewardship. This includes selecting eco-friendly materials, minimizing energy consumption, and optimizing resource utilization throughout the product lifecycle. Additionally, stakeholders should prioritize renewable energy sources and explore circular economy principles to minimize waste and maximize resource efficiency. By embedding sustainability into every aspect of the project lifecycle, stakeholders can reduce environmental impacts, enhance resilience, and create lasting value for society and the planet. Moreover, adopting sustainable practices can also lead to cost savings, regulatory compliance, and enhanced brand reputation.

4.7.5 Environmental Benefits and Challenges

Deploying IoT-enabled solar panel monitoring systems offers significant environmental benefits, including reducing greenhouse gas emissions, conserving resources, and mitigating climate change. However, stakeholders must also address challenges such as electronic waste generation, energy consumption, and supply chain impacts to maximize environmental sustainability. By adopting a lifecycle approach and integrating sustainability considerations into project planning and execution, stakeholders can overcome these challenges and maximize the environmental benefits of deploying IoT for solar panel monitoring. Furthermore, addressing environmental challenges can also lead to innovation, cost savings, and competitive advantage in the market-place.

4.7.6 Regulatory Compliance and Environmental Standards

Regulatory Compliance and Environmental Standards: Ensuring compliance with environmental regulations and standards is critical for the successful deployment of IoT-enabled solar panel monitoring systems. This includes adhering to environmental laws, industry standards, and sustainability certifications to mitigate environmental risks and liabilities. Additionally, stakeholders should stay informed about emerging regulations and proactively address environmental concerns to maintain regulatory compliance. By integrating environmental considerations into project planning and execution, stakeholders can minimize regulatory risks, build public trust, and demonstrate their commitment to environmental responsibility. Moreover, compliance with environmental standards can also lead to operational efficiencies, improved stakeholder relations, and enhanced brand reputation.

4.7.7 Case Studies and Best Practices

Highlighting case studies and best practices provides valuable insights into successful implementations of IoT for solar panel monitoring with positive environmental outcomes. By showcasing real-world examples of environmental sustainability, stakeholders can learn from best practices, identify opportunities for improvement, and replicate successful strategies in their own projects. Additionally, case studies help demonstrate the business value of sustainability initiatives, including cost savings, risk reduction, and brand enhancement. By sharing lessons learned and best practices, stakeholders can accelerate the adoption of sustainable practices and drive positive environmental change in the solar energy sector.

4.8 Implementation Guidelines and Best Practices

❖ **Pre-Deployment Planning:**

- ✓ Conduct environmental impact assessments to evaluate the ecological effects of solar panel installations and mitigate potential risks to local ecosystems.
- ✓ Collaborate with local authorities and community stakeholders to obtain necessary permits and approvals for solar panel deployment.
- ✓ Consider factors such as local regulations, zoning restrictions, and building codes when selecting installation sites for solar panels.
- ✓ Develop contingency plans for unforeseen challenges such as inclement weather, supply chain disruptions, or regulatory changes that may affect project timelines.
- ✓ Evaluate the economic feasibility of solar panel installations through cost-benefit analyses, return on investment calculations, and financial modeling.
- ✓ Establish clear communication channels and escalation procedures to address project delays, budget overruns, or other unforeseen obstacles.

- ✓ Conduct pilot studies or feasibility assessments to test the viability of solar panel installations in specific locations before full-scale deployment.
- ✓ Engage with local communities to assess their needs, preferences, and concerns regarding solar energy projects and incorporate their feedback into project planning.

❖ Technology Selection

- ✓ Evaluate emerging technologies such as thin-film solar panels, bifacial modules, and smart inverters to enhance the efficiency and performance of solar panel installations.
- ✓ Investigate alternative energy storage solutions such as battery storage systems or grid-connected storage to optimize energy management and resilience.
- ✓ Explore advanced sensor technologies such as hyperspectral imaging, LiDAR, or drones for accurate monitoring of solar panel performance and environmental conditions.
- ✓ Consider the scalability and interoperability of IoT platforms to support future expansion and integration with other smart grid technologies.
- ✓ Evaluate the environmental sustainability of technology options, including their carbon footprint, resource usage, and end-of-life disposal considerations.
- ✓ Collaborate with research institutions and industry partners to develop innovative solutions for solar panel monitoring, data analytics, and predictive maintenance.
- ✓ Investigate regulatory incentives, grants, or funding opportunities available for adopting advanced technologies and implementing sustainable energy projects.
- ✓ Engage with technology vendors and suppliers to stay informed about the latest advancements, product offerings, and industry trends in solar energy and IoT.

❖ Hardware Installation and Integration

- ✓ Train installation crews on proper safety procedures, equipment handling, and installation techniques to minimize risks of accidents or injuries during solar panel deployments.
- ✓ Utilize standardized installation practices and quality control measures to ensure consistency, reliability, and compliance with industry standards.
- ✓ Implement advanced mounting solutions such as tracking systems or tilting mechanisms to optimize solar panel orientation and maximize energy production.

- ✓ Leverage modular design principles to facilitate flexible and adaptable installations that can accommodate varying site conditions and customer requirements.
- ✓ Employ smart grid integration techniques to synchronize solar panel operations with utility grid infrastructure, demand response programs, and energy management systems.
- ✓ Implement remote monitoring capabilities during the installation process to verify system performance, troubleshoot issues, and ensure successful commissioning.
- ✓ Conduct comprehensive system testing and commissioning procedures to validate equipment functionality, verify compliance with specifications, and ensure customer satisfaction.

❖ **Data Collection and Analysis**

- ✓ Implement data encryption and authentication mechanisms to protect sensitive information and ensure data integrity during transmission and storage.
- ✓ Integrate data validation and error detection algorithms to identify and mitigate anomalies, outliers, or data inconsistencies that may affect analysis outcomes.
- ✓ Leverage cloud-based analytics platforms and edge computing technologies to process and analyse large volumes of sensor data in real-time.
- ✓ Employ machine learning algorithms such as regression analysis, neural networks, or decision trees to model complex relationships and patterns in solar panel performance data.
- ✓ Utilize anomaly detection techniques such as clustering, classification, or time series analysis to identify abnormal behaviour and potential system faults or failures.
- ✓ Implement data visualization tools and interactive dashboards to communicate insights, trends, and performance metrics to stakeholders effectively.
- ✓ Integrate historical data with real-time sensor readings to enable predictive analytics and forecasting of future system behaviour and performance.
- ✓ Conduct periodic data audits and quality assurance checks to ensure data accuracy, completeness, and compliance with regulatory requirements.
- ✓ Establish data governance policies and procedures to define roles, responsibilities, and access controls for managing and safeguarding data throughout its lifecycle.
- ✓ Collaborate with data scientists, domain experts, and research partners to develop customized algorithms, models, and analytics solutions tailored.

Chapter 5

METHODOLOGY

5.1 Block Diagram

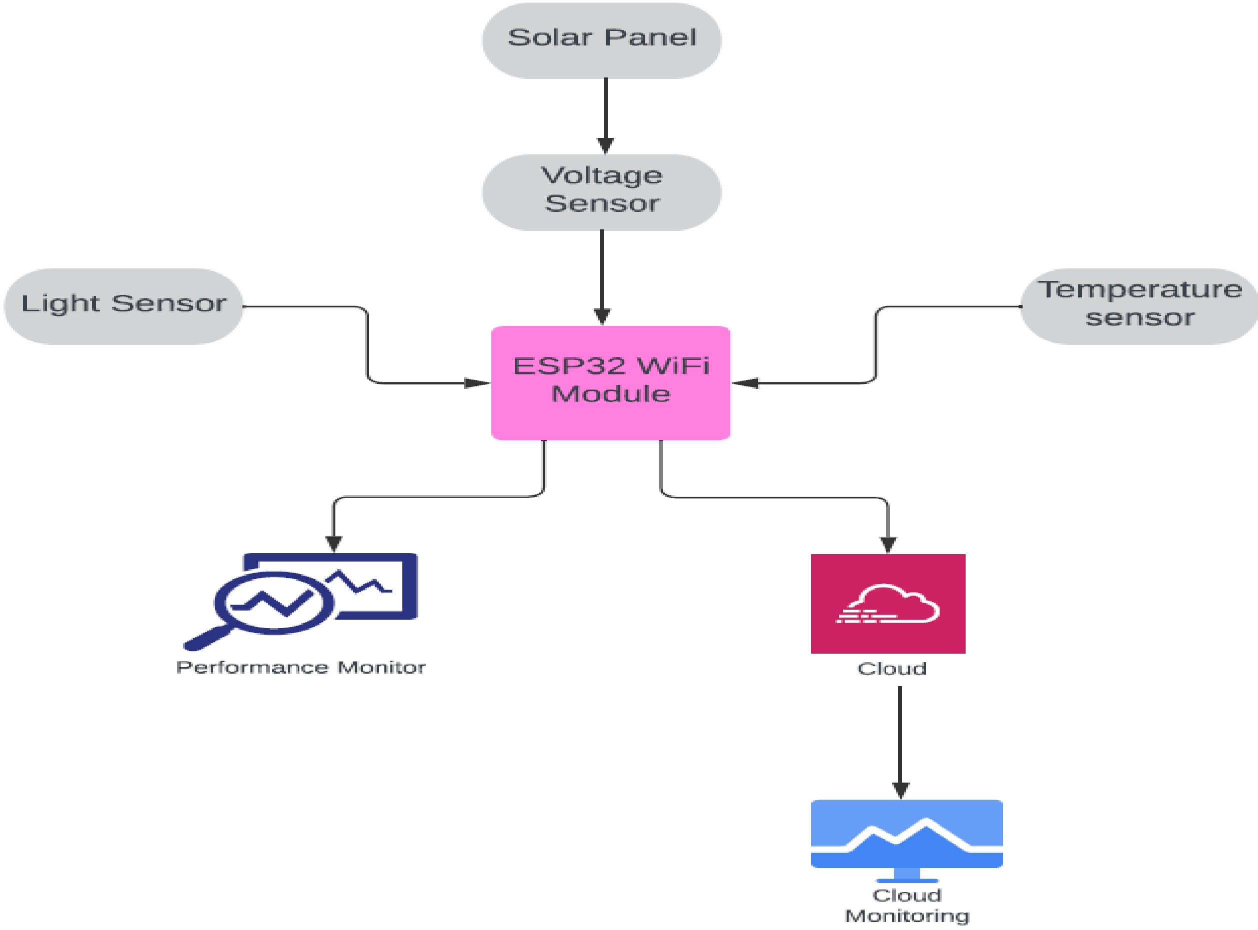

Fig 5.1 Block Diagram of System

The system revolves around an ESP32 Wi-Fi module serving as the central hub, intricately connected to an LCD display, a voltage sensor, a light sensor, a temperature sensor. This integrated setup aims to collect comprehensive data from the sensors, providing a real-time display on the connected LCD while simultaneously transmitting this information to the cloud.

5.2 Graphical Representation

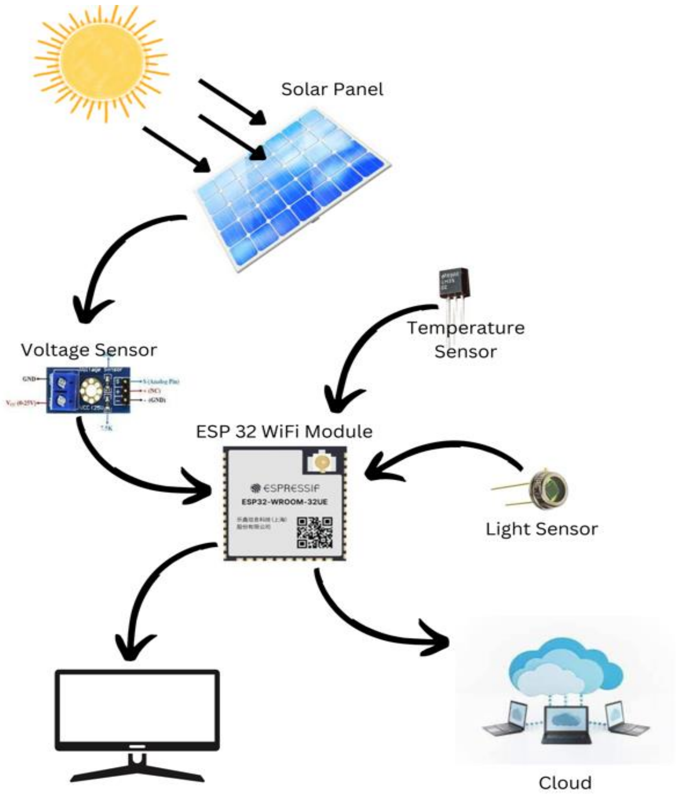

Fig. 5.2 Graphical Representation of the System

The system's core is the ESP32 Wi-Fi module, functioning as the central hub. It intricately connects to an LCD display, a voltage sensor, a light sensor, and a temperature sensor. The primary objective is to gather extensive data from these sensors. This data is then utilized to provide real-time updates on the LCD display, offering immediate insights into the environmental conditions being monitored. Simultaneously, the collected information is transmitted to the cloud, ensuring remote access and storage for further analysis or archival purposes.

5.3 System Specifications

The ESP32, acting as the main microcontroller, orchestrates the data acquisition process, reading inputs from the voltage, light, and temperature sensors, and monitoring the output of the solar panel. Through intricate data processing, the ESP32 optimizes and refines the collected information before presenting it on the local LCD display for immediate user insight. Simultaneously, the ESP32 establishes a secure connection to the internet via Wi-Fi, facilitating the seamless transfer of processed data to the cloud. This cloud platform, such as AWS IoT or

Google Cloud IoT, becomes the repository for historical data, allowing remote users to monitor, analyse, and visualize the solar panel system's performance through a user-friendly dashboard. The system, enriched by security measures and power management considerations, offers a holistic solution for efficient solar panel monitoring, combining local visibility with remote accessibility and analysis.

5.4 Component Required

5.4.1 Software Requirement

- **Arduino IDE**

  - The arduino software (IDE) is an open source software, which is used to programme the Arduino boards, and is an integrated development environment, devlopped by arduino.cc. Allow to write and upload code to arduino boards. And it consiste of many libraries and a set of examples of mini projects.
  - The arduino software (IDE) is compatible with different operating systems (Windows, Linux, Mac OS X), and supports the programming languages (C/C++)
  - The Arduino software is easy to use for beginners, or advanced users. It uses to get started with electronics programming and robotics, and build interactive prototypes.
  - So Arduino software is a tool to develope new things. and create new electronic projects, by Anyone (children, hobbyists, engineers, programmers).

- **Language**

  - Embedded C: Embedded C is a programming language that is used in the development of Embedded Systems. Embedded Systems are specialized systems designed to perform very specific functions or tasks. Embedded System is the combination of hardware and software and the software is generally known as firmware which is embedded into the system hardware. Embedded C is used to program a wide range of microcontrollers and microprocessors. Embedded C requires less number of resources to execute in comparison with high-level languages such as assembly programming language.

- **Blynk Arduino Module**

  - The Blynk Arduino Module is an extension that runs on hardware and allows users to build IoT products with a mobile app. Blynk is an Internet of Things (IoT) platform that can control hardware remotely, display sensor data, store data, and more. It can run on over 400 hardware modules, including Arduino.

5.4.2 Hardware Requirement

- **Solar Panel**

Fig 5.3 Solar Panel

A solar panel, also known as a photovoltaic (PV) device, converts sunlight into electricity and heat. Solar panels are made of silicon or other semiconductor materials, such as photovoltaic (PV) cells, that are installed in a metal frame with a glass casing. When exposed to sunlight, the material releases electrons and produces an electric charge, which creates an electric current (DC). The rate at which solar panels generate electricity depends on the amount of direct sunlight and the quality, size, number, and location of panels in use. The capacity of a solar panel is measured in watt peak (Wp), which is the maximum electrical capacity that a solar cell can produce under ideal conditions. The ideal orientation for solar panels is south-facing. The output of a solar panel depends on the type of panel. First-generation solar panels use monocrystalline or polycrystalline silicon and have an output of 12 to 19%. Second-generation solar panels use amorphous silicon or other materials.

❖ ESP32 WiFi Module

Fig 5.4 ESP32 Wifi Module

ESP32 comes with an on-chip 32-bit microcontroller with integrated Wi-Fi + Bluetooth + BLE features that targets a wide range of applications. It is a series of low-power and low-cost developed by Espressif Systems.

Features of ESP32:

- 4MB of Flash Memory
- 16 KB SRAM in RTC
- Wi-Fi 802.11b/g/n
- Bluetooth v4.2 BR/EDR and Bluetooth LE specifications
- 520 KB of on-chip SRAM for data and instructions.
- 448 KB of ROM for booting and core functions.

❖ ESP8622 WiFi Module

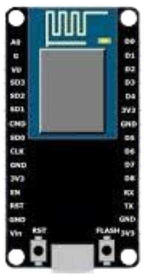

Fig 5.5 ESP8266 WiFi Module

An ESP8266 Wi-Fi module is a SOC microchip mainly used for the development of end-point IoT (Internet of things) applications. It is referred to as a standalone wireless transceiver, available at a very low price. It is used to enable the internet connection to various applications of embedded systems.

Feature:

- It is a powerful Wi-Fi module available in a compact size at a very low price.
- It is based on the L106 RISC 32-bit microprocessor core and runs at 80 MHz.
- It requires only 3.3 Volts power supply.
- The current consumption is 100 m Amps.
- The maximum Input/Output (I/O) voltage is 3.6 Volts.
- The size of flash memory is 513 kb.

❖ Ultrasonic Sensor

Fig 5.6 Ultrasonic Sensor

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target). Ultrasonic sensors are used primarily as proximity sensors. They can be found in automobile self-parking technology and anti-collision safety systems. Ultrasonic sensors are also used in robotic obstacle detection systems, as well as manufacturing technology. In comparison to infrared (IR) sensors in proximity sensing applications, ultrasonic sensors are not as susceptible to interference of smoke, gas, and other airborne particles (though the physical components are still affected by variables such as heat). Ultrasonic sensors are also used as level sensors to detect, monitor, and regulate liquid levels in closed containers (such as vats in chemical factories).

- **IR Sensor**

Fig 5.7 IR Sensor

An infrared (IR) sensor is an electronic device that measures and detects infrared radiation in its surrounding environment. Infrared radiation was accidentally discovered by an astronomer named William Herchel in 1800. While measuring the temperature of each color of light (separated by a prism), he noticed that the temperature just beyond the red light was highest. IR is invisible to the human eye, as its wavelength is longer than that of visible light (though it is still on the same electromagnetic spectrum). Anything that emits heat (everything that has a temperature above around five degrees Kelvin) gives off infrared radiation. There are two types of infrared sensors: active and passive. Active infrared sensors both emit and detect infrared radiation. Active IR sensors have two parts: a light emitting diode (LED) and a receiver. When an object comes close to the sensor, the infrared light from the LED reflects off of the object and is detected by the receiver. Active IR sensors act as proximity sensors, and they are commonly used in obstacle detection systems (such as in robots).

- **Buzzer**

Fig 5.8 Buzzer

A buzzer, also known as a beeper, is an audio signaling device that makes a buzzing sound. Buzzers can be mechanical, electromechanical, or piezoelectric. They are often used in alarm devices, timers, and to confirm user input, such as a mouse click or keystroke. Buzzers are a simple and inexpensive way to communicate between a product and the user.

❖ **16x2 LCD with i2c Converter**

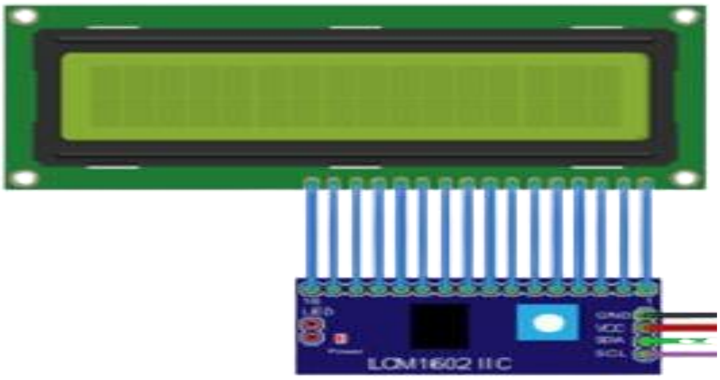

Fig 5.9 LCD with i2c Converter

A 16x2 LCD with an I2C interface is a character LCD display with two rows, each capable of displaying up to 16 characters on a blue background. The I2C LCD component is used in applications that require a visual or textual display, or when a character display is needed but seven consecutive GPIOs on a single GPIO port are not possible.

❖ **Voltage Sensor**

Fig 5.10 Voltage Sensor

A voltage sensor, also known as a voltage detector or voltmeter, is a device that measures and communicates electrical pressure or voltage in a circuit, equipment, devices, batteries, or other sensors. Voltage sensors can measure high voltages and detect low current levels. They can also detect magnetic fields, such as the direction and strength of a magnetic field between two components. Voltage sensors are used in many industrial, commercial, and household applications, including:

- Industrial controls
- Power systems
- Navigation equipment
- Scientific measurement
- Detecting of load

❖ LM35 Temperature Sensor

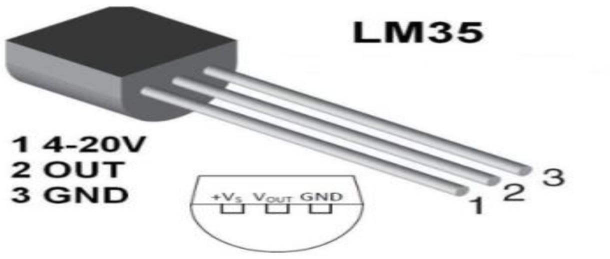

Fig 5.11 LM35 Temperature Sensor

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly proportional to the Centigrade temperature. It has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range.

❖ Light Dependent Resistor(LDR)

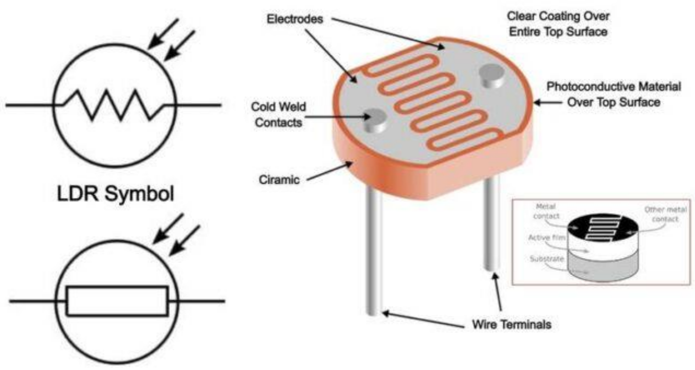

Fig 5.12 Light Dependent Resistor(LDR)

Light Dependent Resistor or LDR or Photoresists are electronic components that are often used in electronic circuit designs where it is necessary to detect the presence or the level of light. LDRs are very different from other forms of resistor like the carbon film resistor, metal oxide film resistor, metal film resistor, and the like that are widely used in other electronic designs. They are specifically designed for their light sensitivity and the change in resistance this causes.

Chapter 6

RESULTS

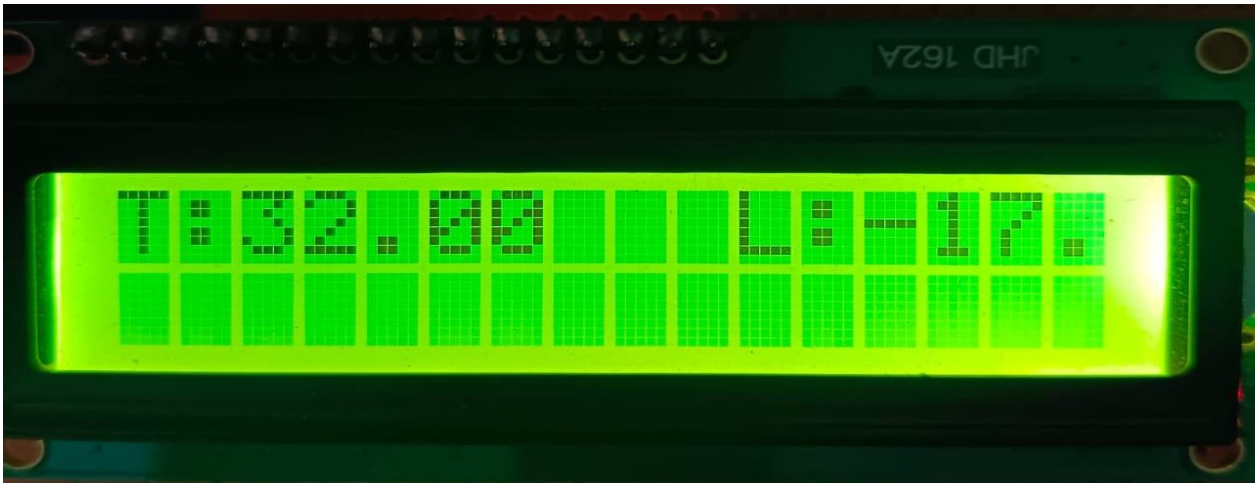

Fig 6.1 LCD Display

The figure displaying the Temperature and the Light Intensity of the environment around the solar panel which helps in increasing the efficiency of the solar panel.

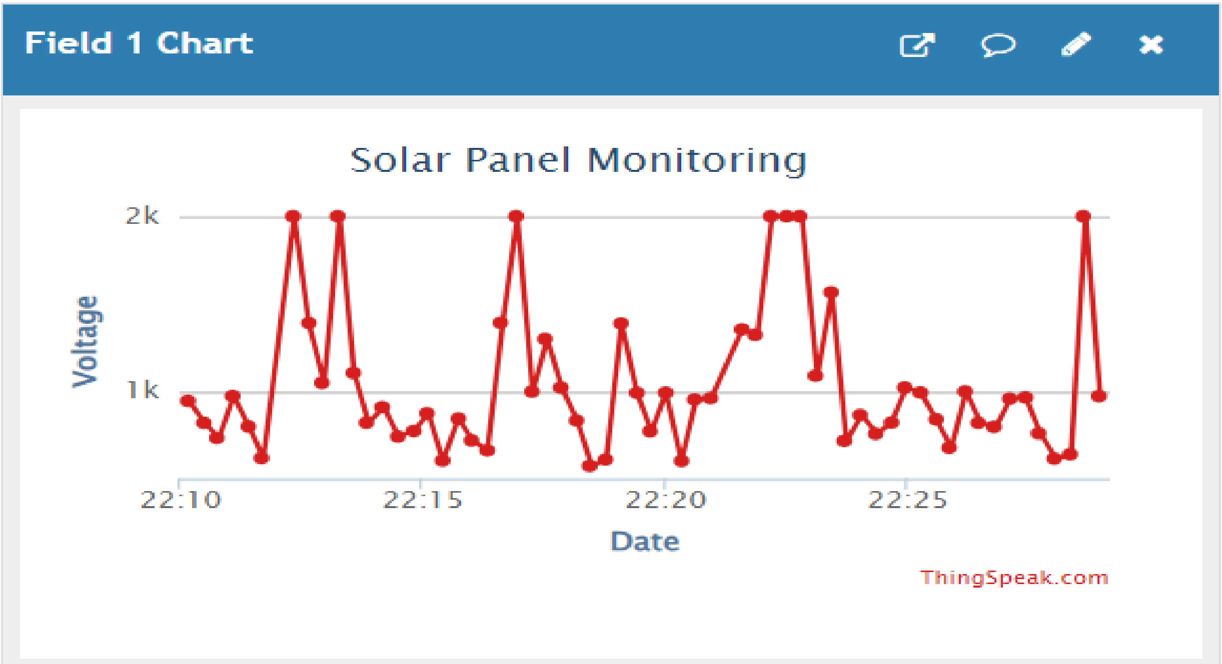

Fig 6.2 Voltage Graph

The Voltage Graph displayed on the ThingSpeak server where the data has been sent by the ESP32 WiFi Module. The data has been sent in the interval of 15 second.

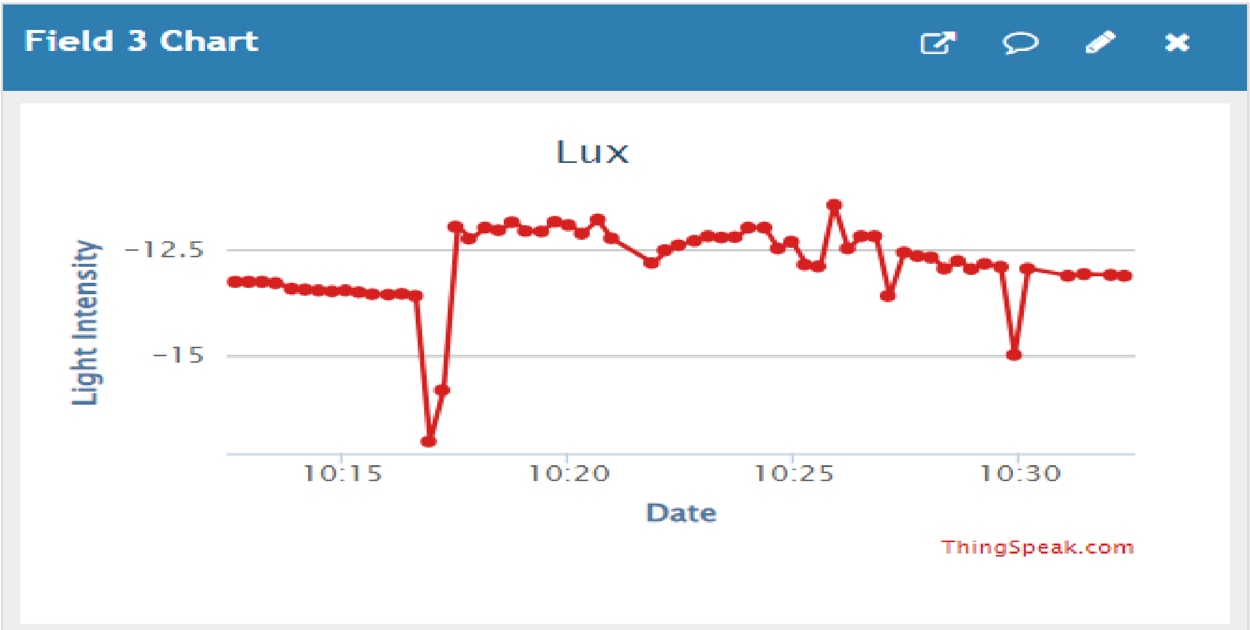

Fig 6.3 Light Graph

The Light Intensity Graph displayed on the ThingSpeak server where the data has been sent by the ESP32 WiFi Module. The data has been sent in the interval of 15 second.

Fig 6.4 Temperature Graph

The temperature Graph displayed on the ThingSpeak server where the data has been sent by the ESP32 WiFi Module. The data has been sent in the interval of 15 second.

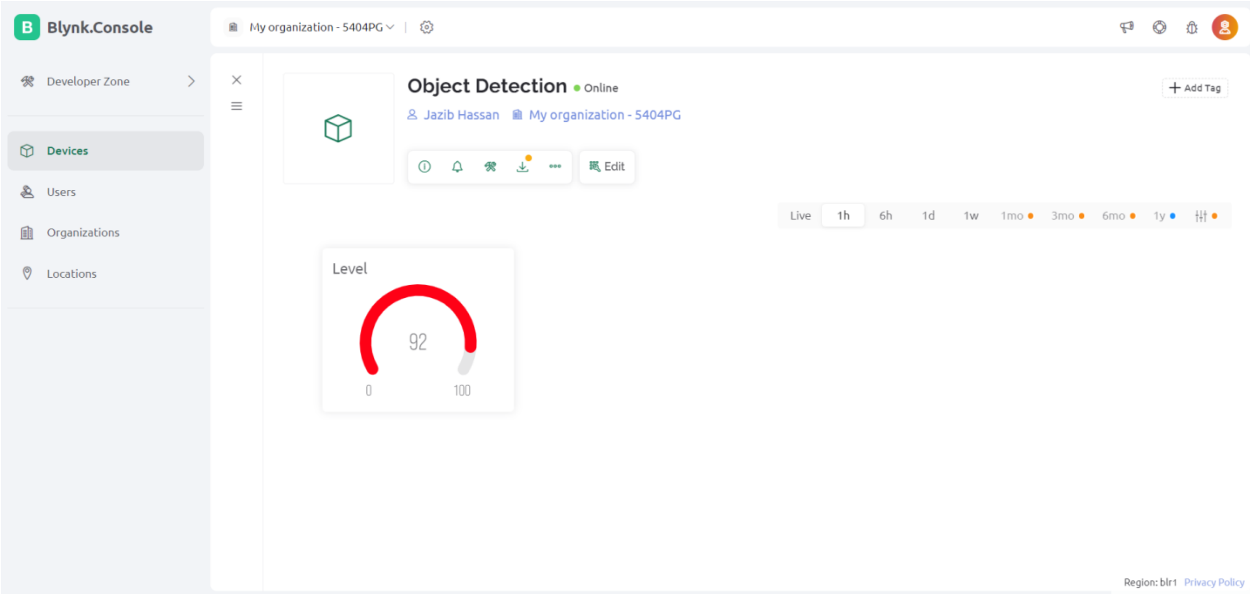

Fig 6.5 Blynk Desktop Console(Object Distance)

The Blynk Desktop console for the object detection, it will show that how much solar panel is covered by the obstacle.

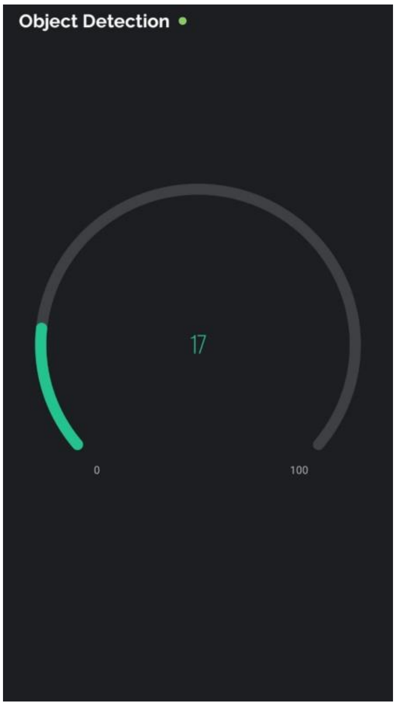

Fig 6.6 Blynk Mobile Console

The Blynk Mobile console for the object detection, it will show that how much solar panel is covered by the obstacle.

CONCLUSION

In this project IoT Based systems are designed to get an optimum power output from the solar panels during dust in accumulated on it. And, a monitoring system is designed for there is any malfunctioning of solar panels will be displayed on and we can also get information about whether the solar for the loads. It now displays these parameters like shown in figure's the user using an effective GUI and alerts user when the Object detected on the solar panel. Solar panels are used that keeps monitoring sunlight. Here different parameters like voltage, light intensity and temperature are displayed on LCD by using 10T technology. Now we are getting only information we can see it in cloud but in future we can control whole system through IoT which distant is a way.

REFERENCES

[1] Vishal Singh 1st, 2Dr. Devesh Katiyar 2nd, 3MR. GAURAV GOEL 3rd, 4rth Yogesh Dev Singh 4th 2021 "IOT BASED SOLAR POWER MONITORING SYSTEM" JETIR September 2021, Volume 8, Issue 9.

[2] Balakrishnan D 1, Raja J 2, Manikandan Rajagopal3, Sudhakar K4 and Janani K 5 "IOT-BASED SYSTEM FOR FAULT DETECTION AND DIAGNOSIS IN SOLAR PV PANELS" Kalasalingam Academy of Research and Education, Anand Nagar, Krishnankoil-626126, Tamilnadu, India.

[3] T.Asha Rakshana 1st, R.Palselvam 2nd, S.Priya 3rd, K Genda Devi 4rth "IOT Based Solar Panel Fault Monitoring and Control By Using Wi-Fi Modem" SSRG_IJEEE)Volume 7 Issue 1 - January 2020.

[4] Preethi Sekar 1st, Priya Sabde 2nd, Ganesh Patil 3rd "IoT-based Solar Energy Monitoring " (IRJET) Volume: 09 Issue: 06 | June 2022.

[5] P.Sampurna Lakshmi 1st, Dr.S. Sivagama Sundari 2nd, Dr. R. Manjula sri 3rd " Solar Panel Fault Detection System using IoT" Eur. Chem. Bull. 2023, 12(Special Issue 7), 3199-3206.

[6] Kabalci, Ersan, Alper Gorgun, and Yasin Kabalci. "Layout and implementation of a renewable energy tracking device." power Engineering, energy and electric Drives (POWERING), 2013 Fourth worldwide conference on. IEEE, 2013.

[7] Jiju, k., et al. "development of Android-based totally on line monitoring and manipulate gadget for Renewable power resources." laptop, Communications, and control era (I4CT), 2014 international conference on. IEEE, 2014.

[8] Stankovic, John A. "studies guidelines for the internet of things." IEEE net of factors magazine 1.1 (2014): three-nine.

[9] Bartolomeo. M. (2014), Internet of things; Science fiction or business fact. A Harvard Business Review of Analytic and also Services Report From the Haward, Tech. Rep.

[10] Adhya, S., Saha, D., Das, A., Jana, J., &Saha, H. (2016, January). An IOT based smart Solar panel Photovoltaic remote monitoring and control unit, In 2016 2nd international conference on control, instrumentation, energy & communication (CIEC) (pp. 432-436), IEEE.

[11] K Karthik Kumar, F Antony Jeffrey Vaz "An Automatic Solar Panel Performance Monitoring System and Load Control using IoT Technique", Proceedings of the 5th International Conference on Smart Systems and Inventive Technology (ICSSIT 2023) IEEE Xplore Part Number: CFP23P17-ART; ISBN: 978-1-6654-7467-2.

[12] Ashim Mondal, Md Jishan Ali, Pallav Dutta "IoT Enabled Smart Solar Panel Monitoring System Based on Boltuino Platform", 2022 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS) | 978-1-6654-8684-2/22/$31.00 ©2022 IEEE | DOI: 10.1109/IEMTRONICS55184.2022.9795836

[13] Shakil Hossain Sajjad, Md. Erfanul Haque Sajib, Md. Nasim Hasan, Md. Abdur Razzak, "Design and Implementation of an IoT Based Solar Power Monitoring System", 2023 IEEE World AI IoT Congress (AIIoT) | 979-8-3503-3761-7/23/$31.00 ©2023 IEEE | DOI: 10.1109/AIIoT58121.2023.10174311

[14] H.Vidhya, U.Akshaya, M.G.Keerthana, T.Dhivyanandhini, "IoT based Solar Technology Monitoring and Cleaning System, 2022 International Conference on Automation", Computing and Renewable Systems (ICACRS) | 978-1 6654-6084-2/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICACRS55517.2022.10029254

[15] Nirmal David Parappully, Sharon Joseph, Rajeswari P S, Immanuel Sabu P, Vishnu P Madhanmohan, "IoT Based Solar Performance Monitoring System", 2023 9th International Conference on Smart Computing and Communications (ICSCC) | 979-8-3503-1409-0/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICSCC59169.2023.10334989

[16] Sayed Tanimun Hasan, Musrin Sultana Shompa, Md. Abdur Rahman, Md Abu Rasel, Md Rahim Hossain Apu, Md Arifur Rahman, "IoT Based Solar Power Monitoring & Data Logger System" 2022 IEEE International Women in Engineering (WIE) Conference on Electrical and Computer Engineering (WIECON-ECE) | 979-8-3503-1156-3/22/$31.00 ©2022 IEEE | DOI: 10.1109/WIECON-ECE57977.2022.10150511

[17] Dr.T.Muthamizhan, Janarthanan M, "IOT BASED SOLAR ENERGY MONITORING SYSTEM" 2022 International Conference on Computer, Power and Communications (ICCPC) | 979-8-3503-9784-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICCPC55978.2022.10072032

[18] Nirmal M, Rajarajan R "studies guidelines for the internet of things." IEEE net of factors magazine 1.1 (2014): three-nine.

[19] A. Gupta, R. Jain, R. Joshi and R. Saxena, "Real time remote solarmonitoring system," 2017 3rd International Conference on Advances in Computing,Communication & Automation (ICACCA) (Fall), 2017, pp. 1-5, doi: 10.1109/ICACCAF.2017.8344723.

[20] D. Saravanan and T. Lingeshwaran, "Monitoring Of Solar Panel Based On IOT," 2019 IEEE International Conference on System, Computation, Automation and Networking (ICSCAN), 2019, pp. 1-5, doi: 10.1109/ICSCAN.2019.8878814.