



Solar Power Monitoring System Using IOT System

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Abstract: The increasing demand for renewable energy has led to the development of solar power systems as an alternative source of electricity. However, the efficiency of these systems is greatly influenced by the environment in which they are installed. To address this challenge, an IoT-based solar power monitoring system was designed and implemented to monitor the performance of a solar power system in real-time.

The system measures five critical parameters, namely, current, voltage, power, solar panel temperature, and light intensity, continuously. The system's hardware consists of a microcontroller unit (ESP32), current and voltage sensors, a temperature sensor, a light intensity sensor, and an LCD display. Additionally, the system is designed to communicate with both a mobile Blynk application and a computer screen, providing real-time monitoring and data visualization.

The data collected by the system is analyzed and used to optimize the performance of the solar power system. The system's software is programmed to generate alerts when any of the measured parameters falls below or exceeds the set threshold values. This ensures that the system is continuously monitored, and any issues are detected and addressed promptly, enhancing the efficiency of the solar power system.

Overall, the IoT-based solar power monitoring system has proved to be an effective solution for real-time monitoring and optimization of solar power systems. The system's ability to measure critical parameters and provide alerts has improved the efficiency and reliability of the solar power system, making it a valuable addition to the renewable energy sector.

I. INTRODUCTION

The increasing demand for renewable energy sources has prompted the development of solar power systems as an alternative source of electricity. Solar power systems harness the energy from the sun's radiation and convert it into electricity that can be used to power homes, businesses, and industries. Despite their benefits, solar power systems are subject to various factors that can affect their efficiency and reliability. For instance, the efficiency of solar panels decreases when their temperature increases, while the power output is also affected by the intensity of sunlight and weather conditions.

To address these challenges, monitoring systems have been developed to measure and optimize the performance of solar power systems. IoT-based solar power monitoring systems have emerged as a popular solution to monitor solar power systems in real-time. These systems measure critical parameters such as current, voltage, power, solar panel temperature, and light intensity, and continuously analyse the data to detect and address any issues that may affect the performance of the solar power system.

II. 1.2 Problem Statement

Solar power systems are becoming an increasingly popular and viable alternative source of electricity due to their ability to harness the sun's energy and convert it into electricity. However, solar power systems face a variety of challenges that can affect their efficiency and reliability, ultimately hindering their adoption and widespread use. One of the key challenges facing solar power systems is the effect of various factors, such as temperature, light intensity, and weather conditions, on their performance. For instance, high temperatures can

decrease the efficiency of solar panels, while fluctuations in light intensity and weather conditions can also impact the system's output. These factors can lead to suboptimal performance, reduced power output, and increased maintenance costs, ultimately making it challenging for solar power systems to be a viable and cost-effective alternative to traditional energy sources.

To address these challenges, monitoring systems have been developed to measure and optimize the performance of solar power systems. However, most of these monitoring systems have limited functionality, do not provide real-time monitoring, and do not offer data visualization. This makes it challenging for users to monitor the critical parameters of the solar power system effectively and detect issues promptly. Therefore, there is a need for a comprehensive monitoring system that can measure the critical parameters of a solar power system in real-time, provide data visualization, and generate alerts when any of the measured parameters fall below or exceed the set threshold values. This would enable users to optimize the performance of the solar power system, reduce maintenance costs, and increase its efficiency and reliability. The IoT-based solar power monitoring system aims to address these challenges by providing real-time monitoring and data visualization, improving the efficiency and reliability of solar power systems.

1.3 The Importance of Iot Based Solar Monitoring System

This system has a significant importance in all ways as follows:

- 1. Improves the efficiency and reliability of solar power systems:** The IoT-based solar power monitoring system continuously measures critical parameters such as current, voltage, power, solar panel temperature, and light intensity, allowing users to detect and address issues promptly, ultimately improving the efficiency and reliability of the solar power system.
- 2. Real-time monitoring and data visualization:** The system provides real-time monitoring of critical parameters and offers data visualization through an LCD display, mobile Blynk application, and computer screen. This makes it easy for users to monitor the performance of the solar power system effectively and detect any issues promptly.
- 3. Cost-effective solution:** By providing real-time monitoring and alerts, the IoT-based solar power monitoring system can help reduce maintenance costs associated with solar power systems. This makes it a cost-effective solution for users who want to optimize the performance of their solar power systems.
- 4. Promotes renewable energy adoption:** The IoT-based solar power monitoring system promotes the adoption of renewable energy sources such as solar power by improving their efficiency and reliability. This can ultimately lead to reduced reliance on traditional energy sources and a shift towards a more sustainable energy future.
- 5. Potential for scalability:** The IoT-based solar power monitoring system is scalable and can be adapted to monitor multiple solar power systems. This makes it suitable for a variety of applications, from small residential solar power systems to large-scale industrial installations.
- 6. Educational value:** The IoT-based solar power monitoring system can be used as an educational tool to teach students about the principles of solar power systems and the importance of monitoring their performance. This can help promote awareness and understanding of renewable energy sources and their potential benefits.

1.4 Objectives

The objectives of the system are as follows:

- Develop an IoT-based solar power monitoring system capable of measuring critical parameters such as current, voltage, power, solar panel temperature, and light intensity in real-time.
- Integrate the monitoring system with an LCD display, mobile Blynk application, and computer screen to provide users with data visualization and monitoring options.
- Develop a system capable of generating alerts when measured parameters fall below or exceed set threshold values, enabling users to detect and address issues promptly.
- Optimize the performance of solar power systems by providing real-time monitoring and data visualization, ultimately improving their efficiency and reliability.
- Reduce maintenance costs associated with solar power systems by providing real-time monitoring and alerts.
- Promote the adoption of renewable energy sources such as solar power by improving their efficiency and reliability.
- Enable scalability of the monitoring system, allowing it to be adapted to monitor multiple solar power systems of varying sizes and applications.
- Provide an educational tool to promote awareness and understanding of renewable energy sources and their potential benefits.

2.1 Literature Review

[1] Solar Energy Monitoring System by IOT, January 2019, K.G.Srinivasan, Dr.K.Vimaladevi, Dr.S.Chakravarthi

The Internet of Things is a vision where the Internet extends into the real world, involving everyday objects. IoT enables the detection or remote control of objects through existing network infrastructure, creating opportunities for a clean integration of the physical world with computer systems, resulting in improved efficiency, accuracy and economic benefits, and reduced human effort. This technology has many applications such as solar cities, smart villages, micro-grids and solar street lights, etc. Renewable energy grew faster than at any other time in history during this period. The proposed system refers to the online display of solar energy use as renewable energy. This tracking is done with a Raspberry pi using a bottle frame. Smart Monitoring shows the daily use of renewable energy. It helps the user to analyze the energy usage. Analysis of the effects on the use of renewable energy and electricity.

[2] A STUDY OF SOLAR POWER MONITORING SYSTEM USING INTERNET OF THINGS (IOT), MAY 2021, SRILAKSHMIMADADI

Renewable energy sources are practical solution to address the current supply shortage energy industry. Due to the availability of solar energy anywhere in the world, unlike anywhere else geographically limited resources, solar energy is the most useful sources of renewable energies. A complex framework for remote facility monitoring online interface is needed for this vast solar system commissioning Because most of them are placed inside in areas that do not have access and are therefore monitored it is not possible from a specific location. The Internet of Things (IoT) enables the detection and remote detection of objects managed by the infrastructure created by the network, creating opportunities for a clean physical environment integration with computer frameworks. The implementation of IoT has proven to be useful in monitoring production of renewable energy. This IoT application uses Arduino based system for parameter monitoring solar panel. The solar panel is monitored by the system continuously and the output power is transmitted from the Internet to the IoT network. Now it is used effectively User interface to display these solar panel parameters user and it also alerts the user when the score drops the limit values defined below. It does more remote monitoring of solar power plants comfortable and the best performance is guaranteed.

[3] SOLAR POWER MONITORING SYSTEM USING IOT, 2021, NEHALIDATAR, SAKSHIBHOYAR, ASHAR KHAN, SAURABHDEKAPURWAR

The power produced by solar panels must be effectively monitored and reduced production losses from solar power generation. We usually use solar power plants in construction in places where people don't go every day, so this approach helps them virtually manage your systems from remote locations. It controls the load using the panel IoT technologies and data from the panels are sent to the cloud for future use via the Internet. It also helps remote users observe the sun power plant. The user receives information about the current and previous average parameters such as voltage, temperature and current. This way it is easier to notice the error and preventive sun care. In this article we will use Internet of Things (IOT) management and monitoring of solar energy (renewable energy). This system is designed to solve problems such as management problems, maintenance and others arise in the production of solar electricity shortens the repair time. The cost of solar energy (renewable energy) using this technology, the generation will be smaller. It also provides real-time information to the user to facilitate monitoring system. The main purpose of this article is that the solar panel can be collected or retained maximum solar radiation and keeps the system in order more reliably and efficiently.

[4] IOT ENABLED SOLAR POWER MONITORING SYSTEM, 2018, R.L.R. LOKESHBABU, D RAMBABU, A. RAJESH NAIDU

This article proposes a solution and method to monitor dust accumulated on solar panels to achieve maximum output economy. The output power of the solar panel always depends on the radiation directed to the solar cell. The system too shows lists of faulty solar panels and whether the electrical device is running directly on the solar panels or if the load is on top battery. All panels are connected and sensors are connected directly to a central controller that monitors panels and loads. Incorporating IoT technology, data from panels and devices is sent to the cloud via the Internet also in future use, the remote user can monitor the parameters of the connected devices. User can view current, previous and average parameters such as voltage, current, temperature and sunlight using a graphical user interface. The controller is programmed with predefined conditions and the user is notified when it falls below the predefined conditions. Node MCU is used as controller.

[5] A REVIEW PAPER ON SOLAR POWER MONITORING SYSTEM USING AN IOT, AUGUST 2019, VISHAL S. PATIL, APARNA P. MOREY, GAURI J. CHAUHAN

For the Internet of Things, a solar energy monitoring system is used to overcome the disadvantages earlier solar systems. IoT is a shared network of connected devices that share information about their situation used in the environment in which they are used. A solar energy monitoring system is used to generate electricity using sunlight energy. This system uses an Arduino Uno to improve solar systems. This solar

energy the monitoring system uses an Arduino Uno. Arduino Uno is a microcontroller board, this microcontroller is used. ATmega328p. The ATmega328p is also a microcontroller chip developed by Atmel. Using an Arduino Uno Solar Panel the panel is able to move in the direction of sunlight movement, that is an additional feature of this solar system. This the article introduces the operation, architecture and connections of a solar energy monitoring system using the Internet of Things.

[6] SOLAR PANEL MONITORING SYSTEM USING IOT, MAY 2022, SAGARINGOLE

The invention of the smart grid surpasses the traditional concept of one-way power supply. Developed countries have already started to introduce smart meters, appliances and renewable energy sources. Developing countries and countries continue to face electricity shortages every day. 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 on how IoT can use current/voltage and power generation using autonomous renewable energy sources. Solar modules can be monitored. This document also describes how to change the tilt angle of the solar panel to improve the efficiency of the solar panel. The solar modules are monitored by a network system with NodeMCU, Atmega328 IC, Arduino. You can simplify the monitoring of the solar panels by performing the recommended tasks in the solar energy (PV) plant. In addition, monitoring power generation can significantly improve the health of solar energy systems.

I. RESEARCH METHODOLOGY

The IoT-based solar power monitoring system is a complex system that requires careful planning and implementation to achieve its objectives. The methodology for developing and implementing this system involves selecting appropriate sensors, microcontrollers, and wireless communication modules, developing data visualization interfaces, generating alerts, and testing the system's functionality. This methodology requires a comprehensive understanding of the principles of solar power systems, sensor technology, microcontroller programming, wireless communication, and data visualization.

The success of the IoT-based solar power monitoring system depends on the accurate selection and integration of all these components. The sensors must be accurate, reliable, and capable of interfacing with the microcontroller. The microcontroller must be capable of processing the data, generating alerts, and interfacing with the data visualization interfaces. The wireless communication module must be reliable, energy-efficient, and capable of interfacing with the microcontroller. The data visualization interface must be easy to use, intuitive, and provide real-time data visualization.

The methodology for developing the IoT-based solar power monitoring system is a step-by-step process that requires careful planning and execution. It involves selecting appropriate components, developing and integrating these components, and testing the functionality of the system. By following this methodology, it is possible to develop a comprehensive monitoring system capable of improving the efficiency and reliability of solar power systems.

The IoT-based solar power monitoring system comprises several key components, including sensors, a microcontroller, a wireless communication module, and data visualization interfaces. The methodology for developing and implementing this system involves several key steps, as outlined below.

- 1. Sensor Selection:** The first step in developing the IoT-based solar power monitoring system is to select the appropriate sensors capable of measuring critical parameters such as current, voltage, power, solar panel temperature, and light intensity. These sensors should be accurate, reliable, and capable of interfacing with the microcontroller.
- 2. Microcontroller Selection:** Once the sensors have been selected, the next step is to choose an appropriate microcontroller capable of interfacing with the sensors and wirelessly transmitting the measured data. The microcontroller should also be capable of processing the data, generating alerts, and interfacing with the data visualization interfaces.
- 3. Wireless Communication Module Selection:** The selected microcontroller must be equipped with an appropriate wireless communication module to transmit the measured data wirelessly to the data visualization interfaces. The wireless communication module should be reliable, energy-efficient, and capable of interfacing with the microcontroller.
- 4. Data Visualization Interface Development:** Once the data has been transmitted wirelessly to the data visualization interfaces, the next step is to develop an appropriate interface for displaying the data. This may include an LCD display, a mobile Blynk application, and a computer screen. The interface should be easy to use, intuitive, and provide real-time data visualization.
- 5. Alert Generation:** The IoT-based solar power monitoring system should be capable of generating alerts when measured parameters fall below or exceed set threshold values. This requires setting appropriate threshold values and developing a mechanism for generating alerts.

- 6. Integration and Testing:** Once all the components have been selected and developed, the final step is to integrate the components into a cohesive system and test its functionality. This may involve testing the sensors, microcontroller, wireless communication module, data visualization interfaces, and alert generation mechanism.

In summary, the methodology for developing the IoT-based solar power monitoring system involves selecting appropriate sensors, microcontrollers, and wireless communication modules, developing data visualization interfaces, generating alerts, and testing the system's functionality. By following this methodology, it is possible to develop a comprehensive monitoring system capable of improving the efficiency and reliability of solar power systems.

3.1.1 Working of Solar Panel

In the IoT-based solar power monitoring system, the solar panel is a critical component that generates electrical power from sunlight. The working of the solar panel can be explained in the following steps:

- **Absorption of Sunlight:** The solar panel is made up of photovoltaic (PV) cells, which absorb sunlight and convert it into electrical energy. When sunlight hits the PV cells, it excites electrons, creating a flow of electrical current.
- **Conversion of DC to AC:** The electrical current generated by the PV cells is in the form of direct current (DC), which must be converted into alternating current (AC) to power household appliances. This conversion is achieved using an inverter, which is connected to the solar panel and the electrical grid.
- **Power Measurement:** In the IoT-based solar power monitoring system, the electrical power generated by the solar panel is continuously measured using a current sensor and a voltage sensor. These sensors provide real-time data on the power generated by the solar panel.
- **Temperature Monitoring:** The temperature of the solar panel is also monitored using a temperature sensor. This sensor provides data on the temperature of the solar panel, which can affect its performance and efficiency.
- **Light Intensity Measurement:** The light intensity falling on the solar panel is measured using a light intensity sensor. This sensor provides data on the amount of sunlight falling on the solar panel, which can affect its electrical output.
- **Data Visualization:** The data on the electrical power generated by the solar panel, its temperature, and light intensity are transmitted wirelessly to data visualization interfaces such as an LCD display, a mobile Blynk application, and a computer screen. This allows users to monitor the performance of the solar panel in real-time.

By continuously monitoring the performance of the solar panel using the IoT-based solar power monitoring system, it is possible to optimize its efficiency and reliability. The real-time data on the electrical power generated, temperature, and light intensity can be used to identify issues and address them promptly, ensuring that the solar panel operates at its maximum potential.

3.1.2 Assembling the hardware components

The assembly of hardware components is a crucial step in the development of the IoT-based solar power monitoring system. The hardware components used in this project include a solar panel, temperature sensor, light sensor, voltage sensor, current sensor, load, ESP32 microcontroller, LCD display, power supply, and voltage regulator.

- **Solar Panel:** The solar panel is the primary component that generates electrical power from sunlight. It consists of photovoltaic (PV) cells that absorb sunlight and convert it into electrical energy.
- **Temperature Sensor:** The temperature sensor is used to measure the temperature of the solar panel. It provides data on the temperature of the solar panel, which can affect its performance and efficiency.
- **Light Sensor:** The light sensor is used to measure the amount of light falling on the solar panel. It provides data on the light intensity, which can affect the electrical output of the solar panel.
- **Voltage Sensor:** The voltage sensor is used to measure the voltage of the solar panel. It provides data on the voltage of the solar panel, which can be used to calculate the electrical power generated.
- **Current Sensor:** The current sensor is used to measure the electrical current generated by the solar panel. It provides data on the current flowing through the solar panel, which can be used to calculate the electrical power generated.
- **Load:** The load is the device or appliance that is powered by the electrical energy generated by the solar panel.
- **ESP32 Microcontroller:** The ESP32 microcontroller is the central processing unit of the system. It receives data from the sensors, processes the data, generates alerts, and transmits the data wirelessly to the data visualization interfaces.
- **LCD Display:** The LCD display is used to display real-time data on the electrical power generated, temperature, and light intensity.
- **Power Supply:** The power supply is used to provide power to the system. It converts the AC power from the electrical grid into DC power, which is used to power the system.

- **Voltage Regulator:** The voltage regulator is used to regulate the voltage of the power supply. It ensures that the voltage supplied to the system is within the required range.

The assembly of the hardware components involves connecting the sensors, load, and ESP32 microcontroller to the power supply and voltage regulator. The sensors are connected to the microcontroller using appropriate interfaces such as I2C or SPI. The microcontroller is programmed to receive data from the sensors, process the data, and generate alerts based on predetermined thresholds. The data is transmitted wirelessly to the data visualization interfaces, which display the data in real-time. The LCD display is connected to the microcontroller using appropriate interfaces such as I2C or SPI. The power supply and voltage regulator are connected to the system to provide power to the components. The voltage regulator ensures that the voltage supplied to the components is within the required range.

In summary, the assembly of the hardware components involves connecting the sensors, load, and microcontroller to the power supply and voltage regulator, programming the microcontroller, and connecting the data visualization interfaces to the microcontroller.

3.1.3 Working of the model

The IoT-based solar power monitoring system is designed to continuously monitor and display the electrical power generated, temperature, and light intensity of a solar panel. The system works by measuring the current, voltage, and temperature of the solar panel using sensors and transmitting the data wirelessly to data visualization interfaces such as an LCD display, a mobile application, and a computer screen. The working of the system can be divided into three parts: sensing, processing, and visualization.

- **Sensing:**

The first step in the system is sensing, where the current, voltage, temperature, and light intensity of the solar panel are continuously measured using the corresponding sensors. The voltage and current sensors measure the electrical power generated by the solar panel, while the temperature and light sensors measure the temperature and light intensity respectively.

- **Processing:**

Once the data is sensed, the ESP32 microcontroller processes the data using the pre-installed software. The software on the microcontroller analyses the data to calculate the power generated by the solar panel, the temperature of the panel, and the light intensity. The microcontroller then compares the calculated values with the preset thresholds and generates alerts if any of the parameters exceed the set limits.

- **Visualization:**

The last step in the system is the visualization of data, which involves displaying the real-time data on the LCD display, mobile application, and computer screen. The LCD display shows the real-time data on the electrical power generated, temperature, and light intensity. The mobile application and computer screen also display the real-time data, allowing the user to monitor the system remotely. The data can be saved in a database for further analysis and comparison.

Overall, the system continuously measures the parameters of the solar panel, processes the data, and generates alerts and real-time data visualization. The user can monitor the system's performance and make necessary adjustments, resulting in better performance and longer lifespan of the solar panel.

3.1.4 Recover the information from the system and send to the LCD display

The system works appropriately to avoid any inconvenience. The system works smartly with the help of ESP32 microcontroller, Solar Panel, LCD Display, Power Supply, Voltage Regulator, Load, Temperature Sensor, Current Sensor, Voltage Sensor, Light Sensor etc. The signals are sent to the LCD display and the solar monitoring system works appropriately.

3.1.5 Advantages of the Proposed System

- Continuous monitoring of solar panel performance
- Real-time data visualization
- Efficient power management
- Early detection of potential issues
- Improved system reliability
- Remote monitoring capability

3.1.6 Features of Proposed System

The following assumptions were made in the development of the proposed method:

- Continuous monitoring of solar panel parameters
- Real-time data visualization of electrical power generated, temperature and light intensity
- Efficient power management through performance monitoring
- Early detection of potential issues through alerts
- Improved system reliability through continuous monitoring and adjustments
- Remote monitoring capability for increased convenience and flexibility
- Sensor-based data acquisition for accurate and reliable data
- ESP32 microcontroller for data processing and transmission
- Multiple display options for easy access to real-time data
- Wireless data transmission for convenience and flexibility.

3.1.7 Components Used

The components used in the system are as follows:

1. ESP32

Antenna switches, a power amplifier, a low-noise receive amplifier, filters, and power management modules are all included into the ESP32. With only a small amount of Printed Circuit Board (PCB) needed, ESP32 enhances your applications with incomparable capability and diversity. The ESP32 chip, designed for mobile, wearable, and Internet of Things applications, uses a variety of proprietary software to achieve extremely low power consumption. Modern features like fine-grained clock gating, several power modes, and dynamic power scaling are also included in ESP32. ESP32 can function as a full standalone system or as a slave device to a host MCU, which lessens the burden on the primary application CPU caused by communication stack overhead. Through its SPI and UART interfaces, the ESP32 may connect to other systems and provide Wi-Fi and Bluetooth capability.



Figure 1: ESP32

2. LCD Display

Liquid crystal display is spelled LCD. It is one kind of electronic display module that is used in a wide variety of circuits and devices like computers, mobile phones, televisions, and others. Seven segments and multi-segment light-emitting diodes are the primary uses for these displays. The principal advantages of using this module are its low cost; basically programmable, activities, and there are no limits for showing custom characters, exceptional and even movements, and so on.

Features:

- It has two rows, each of which can write 16 characters.
- It displays a few custom-generated characters
- Uses 1 mA current without a backlight.
- The alphanumeric LCDs display alphabets and numbers.
- These are available with blue and green backlights.



Figure 2: LCD Display

3. Voltage Regulator

Due to variations in the circuit, no voltage source can produce a constant output. Voltage regulators are used to obtain a constant and steady output. Voltage regulator integrated circuits (ICs) are electronic devices used to control voltage. Voltage sources in a circuit may have fluctuations resulting in not providing fixed voltage outputs. A voltage regulator IC maintains the output voltage at a constant value. 7805 Voltage Regulator, a member of the 78xx series of fixed linear voltage regulators used to maintain such fluctuations, is a popular voltage regulator integrated circuit (IC).

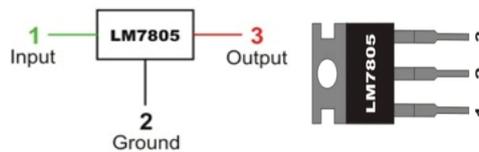


Figure 3: Voltage Regulator

4. Power Supply

A battery provides the wheelchair's DC motors with power. There are rechargeable batteries and non-rechargeable batteries. The one that can be recharged is also known as a secondary cell, storage battery, or accumulator. Electrical batteries of this kind can be charged, discharged during use, and recharged multiple times. The primary battery, also known as the non-rechargeable battery, is provided fully charged and then castaway after being discharged. One or more electrochemical cells make up the rechargeable battery. The term "accumulator" refers to the process of accumulating and storing energy through an electrochemical reaction that can be reversed. Batteries come in a variety of sizes and shapes. From button cells to megawatt systems, they are available. By connecting them together, they are used to stabilize an electrical distribution network. When compared to disposable batteries, rechargeable ones are initially more expensive, but their total cost of ownership and impact on the environment are significantly lower because they can be recharged inexpensively multiple times before needing to be replaced. Some types of rechargeable batteries are available in sizes and voltages that are comparable to those of disposable batteries; they and they can be used interchangeably.

5. Load

An electrical signal that can be measured and standardized is produced when a force, such as tension, compression, pressure, or torque, is converted into a load cell. A force transducer, that is. The electrical signal varies in response to the force acting on the load cell. Pneumatic, hydraulic, and strain gauge load cells are the most used varieties.

Features:

- A load cell is a transducer that is used to convert a force into an electrical signal.
- By means of a mechanical Device, the force to be measured deforms the sensor and displacement or deformation becomes electrical signals.
- These cells loads offer an IP66 degree of protection, with two holes M4, M5 for mounting



Figure 4: Load

6. Temperature Sensor

A temperature sensor is one of the critical components used to measure the temperature of the solar panel. A temperature sensor is an electronic device that measures temperature and converts it into an electrical signal that can be used for further processing. It is a crucial component in the IoT-based solar power monitoring system as it plays a critical role in ensuring the efficient functioning of the solar panel. The temperature sensor used in the project is based on the thermistor principle, where a thermistor is used as the sensing element. A thermistor is a type of resistor whose resistance changes with temperature. The thermistor used in the project is a Negative Temperature Coefficient (NTC) thermistor, where the resistance decreases with an increase in temperature. The resistance of the thermistor changes in a non-linear fashion, making it difficult to measure the temperature directly.



Figure 5: Temperature Sensor

7. Current Sensor

A current sensor is one of the key components used to measure the current flowing from the solar panel to the load. A current sensor is an electronic device that detects the current flowing through a wire and converts it into an electrical signal that can be used for further processing. It is a crucial component in the IoT-based solar power monitoring system as it plays a critical role in ensuring the efficient functioning of the solar panel and load. The current sensor used in the project is based on the Hall Effect principle, where a magnetic field is used to measure the current flow through the wire. The current sensor consists of a Hall Effect sensor and a signal conditioning circuit. The Hall Effect sensor detects the magnetic field generated by the current flowing through the wire, and the signal conditioning circuit amplifies and converts the signal into a voltage that can be read by the microcontroller.



Figure 6: Current Sensor

8. Voltage Sensor

In the IoT-based solar power monitoring system, a voltage sensor is used to measure the voltage output from the solar panel, load, and battery. The voltage sensor is a critical component that helps in monitoring the performance of the solar power system and detecting any potential issues. The voltage sensor used in the project is based on the voltage divider principle, where a high resistance resistor is connected in series with the circuit to divide the voltage across the resistor. The voltage across the resistor is then measured by the microcontroller using analog-to-digital conversion. The voltage sensor is connected to the ESP32 microcontroller, which is the central processing unit of the system.



Figure 7: Voltage Sensor

9. Light Sensor

In the IoT-based solar power monitoring system, a light sensor is used to measure the intensity of light falling on the solar panel. The light sensor is an essential component that helps in determining the efficiency of the solar panel and detecting any potential issues such as shading or obstruction. The light sensor used in the project is a photodiode, which is a semiconductor device that converts light energy into electrical energy. The photodiode is connected to the ESP32 microcontroller, which is the central processing unit of the system.

The microcontroller measures the voltage output from the light sensor and converts it into a digital signal using analog-to-digital conversion. The digital signal is then processed to calculate the intensity of light falling on the solar panel.

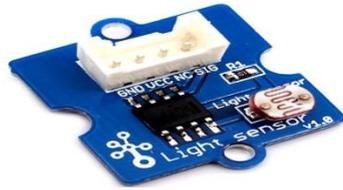


Figure 8: Light Sensor

10. Solar Panel

In the IoT-based solar power monitoring system, a solar panel is used to capture the energy from the sun and convert it into electrical energy. The solar panel is made up of photovoltaic (PV) cells that are made from semiconductor materials such as silicon. When sunlight falls on the PV cells, it excites the electrons in the semiconductor material, creating a flow of electrons that generates electrical energy. The electrical energy generated by the PV cells is in the form of direct current (DC) electricity.

In the above project, the solar panel is connected to a charge controller, which regulates the voltage and current from the solar panel to the battery. The charge controller ensures that the battery is charged safely and efficiently by maintaining the optimal voltage and current levels. The solar panel is also connected to a voltage sensor and a current sensor, which measure the voltage and current output from the solar panel. The voltage and current data are sent to the ESP32 microcontroller, which processes the data and calculates the power generated by the solar panel. The power generated by the solar panel is displayed on the LCD display, mobile application, and computer screen for real-time data visualization. The real-time data visualization of solar panel power generation enables the user to monitor the efficiency of the solar panel and detect any potential issues such as shading or obstruction.



Figure 9: Solar Panel

3.2 Flowchart

The flowchart of the system is as follows, through which all the process is done.

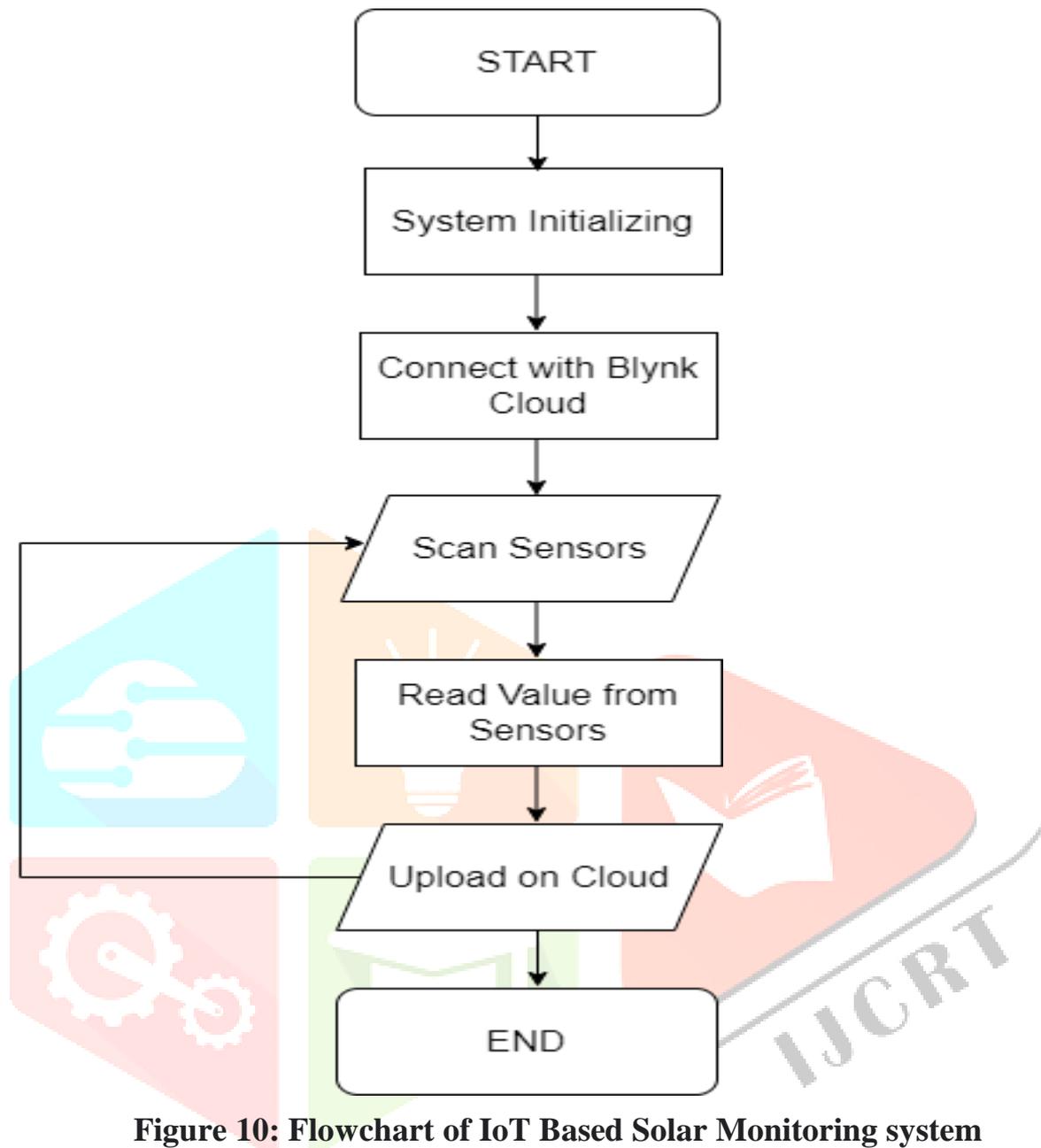


Figure 10: Flowchart of IoT Based Solar Monitoring system

3.3 Block Diagram

The block diagram of the IoT-based solar power monitoring system consists of the solar panel, voltage sensor, current sensor, ESP32 microcontroller, LCD display, Blynk mobile application, and computer. These components work together to continuously measure and display the current, voltage, power, temperature, and light intensity data of the solar panel for real-time monitoring and analysis.

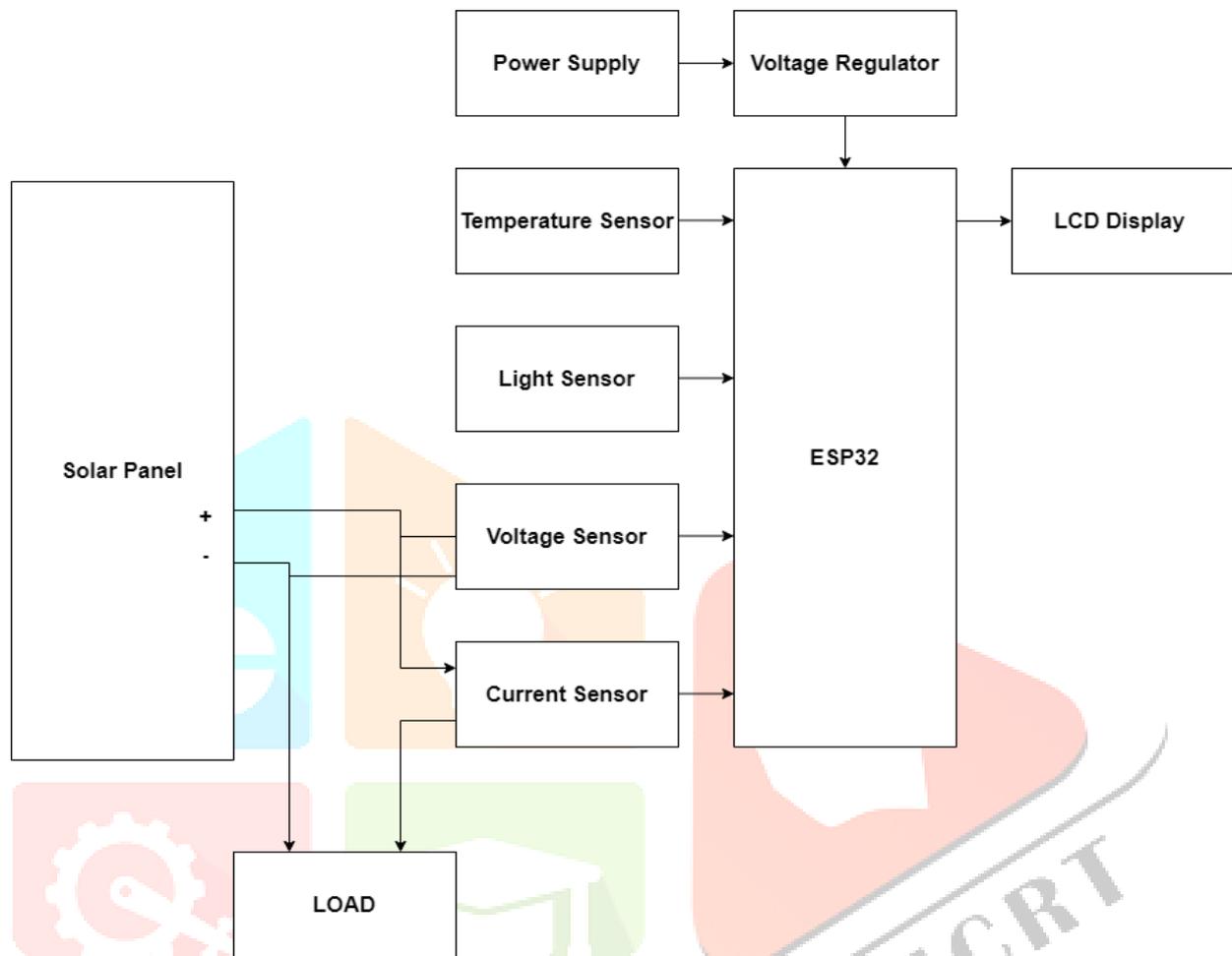


Figure 11: Block Diagram of the System

3.4 Circuit Diagram

The circuit diagram of the IoT-based solar power monitoring system includes several components, such as a solar panel, current sensor, voltage sensor, temperature sensor, ESP32 microcontroller, LCD display, and power supply. The solar panel generates DC electricity, which is then fed into the current sensor to measure the current flowing through the system. The voltage sensor is used to measure the voltage output of the solar panel. The temperature sensor measures the temperature of the solar panel to ensure that it is operating within a safe temperature range. The ESP32 microcontroller processes the data from the sensors and sends it to the LCD display for real-time monitoring. It also sends the data to a mobile application via the Blynk platform and to a computer for further analysis and monitoring. The power supply provides the necessary voltage and current to power the system, while the voltage regulator ensures that the voltage output is consistent and stable. Overall, the circuit diagram of the IoT-based solar power monitoring system is designed to provide accurate and reliable monitoring of solar panel performance, enabling users to optimize energy generation and consumption for maximum efficiency and cost savings.

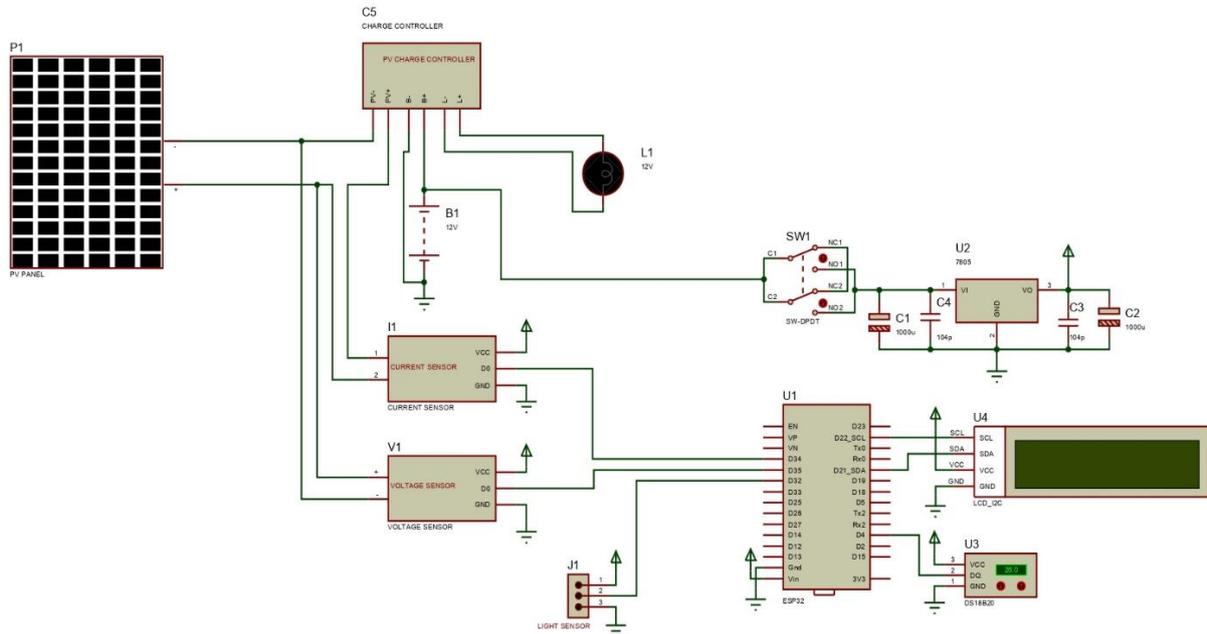


Figure 12: Circuit Diagram of Solar Monitoring System

III. RESULTS AND DISCUSSION

Working Done

4.1 Design of Model

The hardware parts are assembled properly and are shown below:



Figure 13: Solar Panel

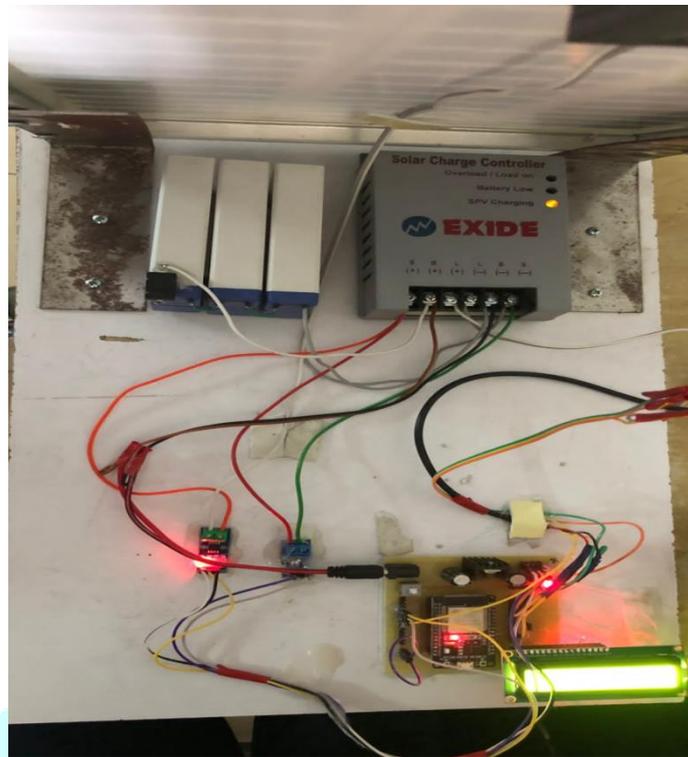


Figure 14: Circuit with LCD Display



Figure 15: Monitoring System in Mobile Application



Figure 16: Wave diagrams of Parameters

5.2 Conclusion

The IoT-based solar power monitoring system is an innovative project that provides real-time monitoring and analysis of various parameters of a solar panel. The system has several advantages, including efficient energy management, improved solar panel performance, reduced maintenance costs, and increased system reliability. The system's hardware components include the solar panel, voltage sensor, current sensor, ESP32 microcontroller, LCD display, and other components. The software modules of the system include the Blynk mobile application and the computer program. The ESP32 microcontroller acts as a bridge between the hardware components and the software modules, processing and displaying the collected data.

The system's working is straightforward, with the solar panel generating electrical energy that is measured by the voltage and current sensors. The ESP32 microcontroller processes and displays the collected data on the LCD display, the Blynk mobile application, and the computer program. The system continuously monitors and updates the data, providing real-time analysis and monitoring of the solar panel's performance. The IoT-based solar power monitoring system has several advantages, including efficient energy management, improved solar panel performance, reduced maintenance costs, and increased system reliability. The system can also help users make informed decisions regarding their energy consumption and reduce their carbon footprint.

In conclusion, the IoT-based solar power monitoring system is a valuable tool for efficient energy management and real-time monitoring of solar panel performance. The system's ability to continuously measure and analyze various parameters of the solar panel can help improve its performance, reduce maintenance costs, and increase system reliability. It can also help users make informed decisions regarding their energy consumption and contribute towards sustainable development.

5.3 Future Scope

The IoT-based solar power monitoring system has several potential future applications and advancements, including:

- **Integration with smart home systems:** The system can be integrated with smart home systems to provide real-time monitoring and control of energy consumption and solar panel performance.
- **Predictive maintenance:** The system can be further developed to include predictive maintenance capabilities, using machine learning algorithms to predict when maintenance will be required based on performance data.
- **Remote monitoring:** The system can be enhanced to enable remote monitoring of solar panels, allowing users to monitor their solar panel's performance from anywhere.
- **Energy trading:** The system can be integrated with energy trading platforms, enabling users to sell excess energy generated by their solar panels.

- **Expansion to other renewable energy sources:** The system can be expanded to include monitoring and analysis of other renewable energy sources, such as wind turbines and hydroelectric power.
- **Use in industrial and commercial settings:** The system can be adapted for use in industrial and commercial settings, providing real-time monitoring and analysis of renewable energy systems in larger settings.

Overall, the IoT-based solar power monitoring system has significant potential for future development and expansion, offering numerous benefits in terms of energy management, sustainability, and cost savings.

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