DESIGN AND IMPLEMENTATION OF A REAL TIME MONITORING SYSTEM FOR SOLAR PHOTOVOLTAIC SYSTEMS

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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Approval

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Fall, 2023 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on [14th December, 2023].

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Ethics Statement

In this project, we meticulously maintained the similarity index and looked for instances of plagiarism. The result was a similarity index of 23%.

Abstract/ Executive Summary

The aim of this project is to implement a comprehensive real-time monitoring system for solar Photovoltaic systems. The system measures important parameters such as light intensity, temperature, humidity, current, and voltage using various sensors. The ESP32 microcontroller collects the data from the sensors and transfers them to the Blynk platform, while also providing customers with an easy-to-use interface for remote monitoring. There is also an option for local monitoring. Furthermore, GSM connectivity enables real-time SMS alerts for problematic circumstances. The economic study highlights the project's feasibility by highlighting higher energy production, improved system reliability, and competitive benefits. This innovative approach supports the growth of renewable energy initiatives and promotes environmental care, all of which are goals of sustainability.

Acknowledgement

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Chapter 1: Introduction

1.1 Introduction

Renewable energy sources, such as solar photovoltaic (PV) systems, have emerged as critical elements of long-term energy solutions in the face of global climate change. These systems, which harness the power of sunlight, provide a cleaner and more environmentally responsible alternative to traditional energy sources. However, to ensure optimal performance, efficiency, and longevity of solar PV systems, advanced monitoring is required. There are two options for generating electricity. The first comes from non-renewable sources, whereas the second comes from renewable sources. Renewable energy sources, like the sun, geothermal energy, wind energy, and tidal energy, can be utilized repeatedly, whereas non-renewable energy sources, like fossil fuels, coal, natural gas, and nuclear fuel, are never regenerated by nature. Solar energy is therefore regarded as a sustainable energy source [1]. Solar power has gained in popularity due to its abundance, low environmental effect, and lower conversion costs. The photovoltaic effect converts light energy into electrical energy, sometimes referred to as solar energy [2]. Solar PV energy is now the third-largest renewable energy source, after wind and hydropower. In 2018, a key milestone in the field of solar PV systems was achieved: the 100 GW yearly installation threshold was surpassed. According to the International Energy Agency's (IEA) Renewable Energy Market Report 2018, solar PV system production capacity would increase from 572 GW to 720 GW between 2018 and 2023. Furthermore, the global solar PV power capacity is predicted to exceed 2840 GW by 2030 and 8519 GW by 2050 [3]. The "Design and Implementation of a Real-Time Monitoring System for Solar Photovoltaic Systems" project meets this requirement by offering a complete monitoring system. This project merges modern sensor technologies, microcontrollers, and communication modules to establish a strong real-time monitoring framework.

1.1.1 Problem Statement

We intend to solve the lack of real-time monitoring capabilities for solar photovoltaic systems. Traditional solar PV installations frequently lack advanced monitoring techniques, resulting in poor energy production and an increased failures and inefficiencies. The lack of real-time monitoring systems makes it difficult to detect and manage important issues such as voltage fluctuations, irregularities in current flow, extreme temperature and light intensity variations. These challenges threaten not just the overall efficiency of the solar PV system, but also its economic and long-term viability. PV system monitoring is currently complex and costly, and it is limited to large-scale, grid-connected solar PV installations [4]. The traditional methods of monitoring systems mostly include manual examination and remote wired monitoring. These techniques have some drawbacks, such as time consumption and wiring complexity [2]. A variety of environmental conditions, including temperature and irradiance, can influence the operation and performance of solar PV systems. Thus, using a good solar PV monitoring system can increase the accuracy and performance of your solar PV system. Monitoring is the continuous observation and documentation of the parameters of a solar PV system [3]. Solar photovoltaic system performance monitoring is vital for preliminary system evaluation and continuous output optimization [4]. Because solar energy is unpredictable, the amount of energy produced by this system cannot always be predicted. As a result, an adequate monitoring system is required to ensure that electricity is efficiently delivered. Monitoring system parameters is critical in all solar power producing systems. Several elements, including DC current and voltage, AC current and voltage, light intensity, angle, and duration of sunshine, panel temperature, and some environmental circumstances such as weather, wind, and dust, can all contribute to PV's overall energy output. Weather and operational losses cause variations in solar energy output, which can only be addressed by monitoring PV system performance and making the necessary changes to optimize output power. By monitoring the system, we can learn about its status and detect problems before they occur, which is incredibly beneficial. An effective monitoring solution for solar PV systems improves performance efficiency by providing up-to-date information and implementing preventive measures as problems arise. When unexpected occurrences occur in a solar PV system, the monitoring system warns users with an alert signal [1]– [5].

1.1.2 Background Study

Solar energy is readily available around the world and can help reduce dependency on energy imports. In 90 minutes, enough sunlight strikes the Earth to provide the entire planet's energy requirements for a year. During operation, solar PV produces no greenhouse gasses or other pollutants. The International Energy Agency (IEA) estimates that renewable energy will be the fastest growing source of electricity, with wind and solar PV already technologically mature and economically viable. Nonetheless, global demand for energy continues to rise. According to the current edition of the IEA's Medium-Term Renewable Market Report, renewables would increase 13% faster between 2015 and 2021 than anticipated last year [5].

According to the Bangladesh Power Development Board (BPDB), the country's total power generation capacity is around 25000 MW [6] and on average, 100% of the population has access to electricity. Bangladesh's power sector faces a variety of issues, including high system losses, delays in new plant completion, low plant efficiency, inconsistent power supply, electricity theft, blackouts, and a lack of funding for power plant maintenance. Besides, more fossil-based power plants are being built in different places in order to fulfill electricity demand. When it comes to the application of technology we fall far behind from developed countries. Here the main problem with countries with 100% electrification is our power plants are mainly fossil fuel-based. Still today many remote areas of our country are not getting the proper amount of electricity. And for this they face a lot of load shedding and they pay an excess price to get electricity. Solar systems are one of the most effective ways to provide power to remote off-grid places in both industrialized and developing countries. Solar energy has enormous potential in Bangladesh due to the country's location in the tropical region, where the sun shines almost year-round [7]. From Fig 1 and Fig 2 it is clearly visible that about half of the country’s electricity needs are fulfilled through natural gas, then oil, coal, and other substances and the amount has increased as the years progressed. Natural gas has remained the primary and most affordable source of energy during the last decade. However, a decrease in the number of explorations and rising demand have depleted our gas reserves. This has increased the reliance on imported LNG and Heavy Fuel Oil (HFO). The latest Russia-Ukraine war has raised the price of LNG by roughly 165%. The present fuel mix of Bangladesh's power plants relies heavily on natural gas, oil, coal, and diesel (jointly over 80%) [8]. As the population rate is increasing the demand for electricity will also increase and supplying electricity generated through fossil fuels to such a large population is not an easy task.

The advantages of using solar energy includes the solar panel's longer lifespan and it can be installed almost anywhere. However, the lack of proper monitoring systems for solar PV systems has been identified as a major barrier to their extensive use. In the past, wired monitoring systems were often utilized to transfer data via an RS232 or RS485 cable. However, as the solar PV system's size has increased, real-time monitoring via conventional wired lines has resulted in significant additional costs. Furthermore, the wires providing the data are vulnerable to environmental elements such as rain, humidity, and temperature [3]. Existing monitoring systems for solar PV systems in Bangladesh are often expensive and complicated, making them inaccessible to many consumers. The lack of proper monitoring and maintenance can lead to poor performance and failure at an early stage of the solar PV systems. This causes considerable financial losses for consumers and hinders progress in Bangladesh's renewable energy sector. Here, our aim is to design and develop a real-time monitoring system for solar photovoltaic systems to detect and troubleshoot problems in the system in real-time, thereby improving the overall system performance. The system will also provide accurate and timely information about the system's performance, optimize energy production, and reduce maintenance costs.

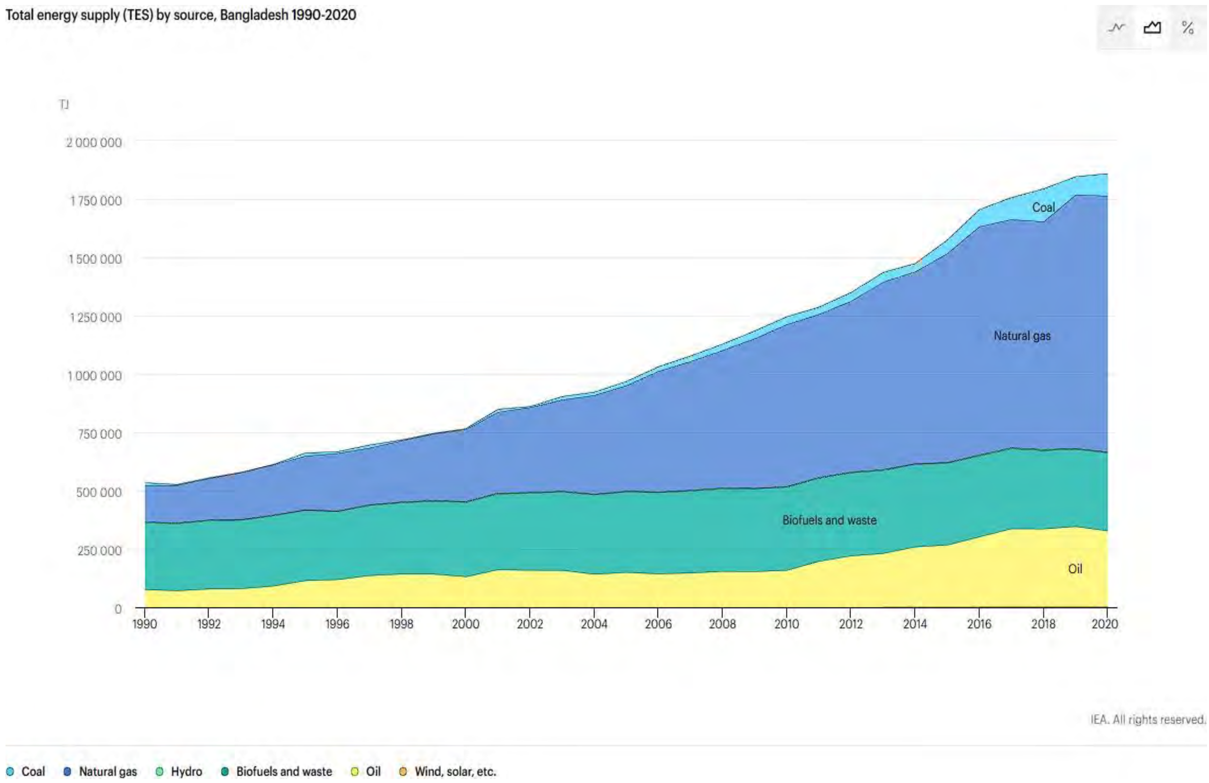

Fig 1.1: Total energy supply from sources in Bangladesh(1990-2000) [9]

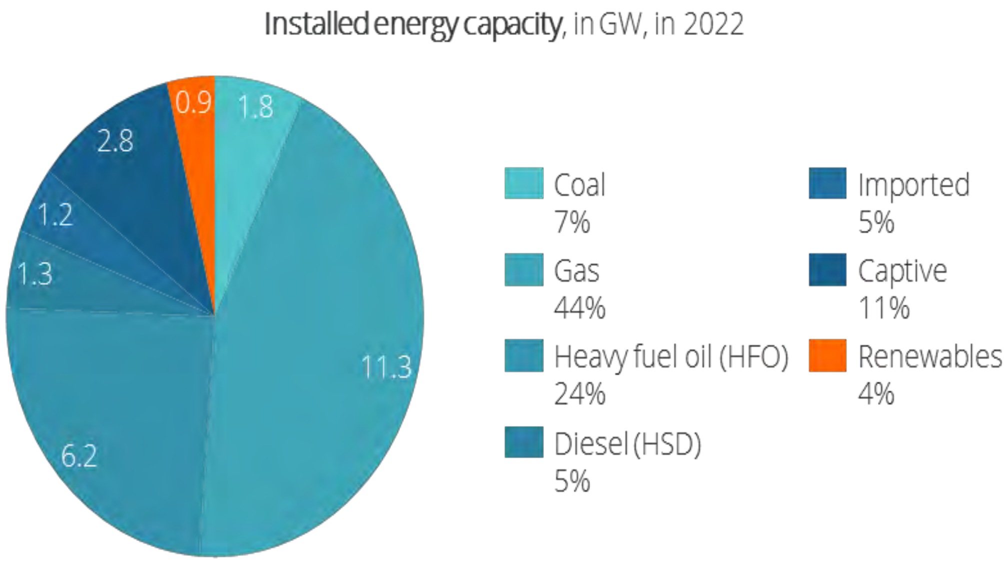

Fig 1.2: Total energy supply from sources in Bangladesh 2022 [8]

1.1.3 Literature Gap

As solar photovoltaic (PV) systems emerge as an important component of sustainable energy solutions, there is an important gap in the literature about the integration of complete, real-time monitoring systems. Researchers investigated IoT, which allows for the complete integration of the real world into computer-based systems, increasing efficiency, accuracy, and economic gain while requiring less human intervention. This will enable real-time monitoring, problem diagnosis, historical facility analysis, and preventative maintenance. Researchers created an Internet of Things (IoT) gadget that employs a sophisticated microcontroller platform to collect data on physical properties from many types of sensors via several forms of connection and then uploads the data to the Internet. It was demonstrated in the development and application of a connected SPU mechanism and the measurement of trustworthy parameters.The suggested system's architecture combines specialized IoT devices with data aggregation information systems. Few academics have investigated the application of innovative, low-cost IoT-based monitoring systems to remotely monitor and evaluate solar PV plant performance. This will enable real-time monitoring, defect diagnosis, historical facility analysis, and preventative maintenance. Variations in sun irradiation, temperature, and other factors cause power output from solar photovoltaic systems to vary [5]. Several factors may cause a change in the system's output, including the transition from a sunny to a cloudy sky, panel temperature, humidity, irradiance, mounting angle, and a discrepancy between manufacturer specifications and actual PV output. Given the number of projected concerns, further research is needed to develop an effective solar PV monitoring technology before implementing the system [3]. The MPPT-based technique requires additional improvement to cover failure detection and measurement of array current [4].

Although real-time monitoring systems for solar PV systems have several advantages, there is a lack of information in the literature about their use in Bangladesh. While studies on the prospects and challenges of solar energy in Bangladesh as well as performance analyses of solar PV systems have been conducted, there has not been as much research on the creation and application of reasonably priced and user-friendly real-time monitoring systems for solar PV systems in Bangladesh. Studies already conducted on solar PV systems in Bangladesh have concentrated on their technical and financial feasibility. However, they have not looked at how real-time monitoring systems might enhance the efficiency and dependability of these systems. This gap in the literature highlights the need for further research on the development and implementation of real-time monitoring systems for solar PV systems in Bangladesh. Furthermore, much of the material that is currently available on real-time monitoring systems for solar PV systems in other nations concentrates on sophisticated and pricey technologies that may not be appropriate for or available to most consumers in Bangladesh. Hence, there is a need for research to create monitoring systems that are inexpensive, simple to use, and successful in enhancing the performance of solar PV systems while taking into account the unique needs and difficulties of the Bangladeshi setting. Overall, the literature gap in the implementation of affordable and easy-to-use real-time monitoring systems for solar PV systems in Bangladesh highlights the need for further research in this area to promote the adoption and effectiveness of solar energy in the country. Addressing these knowledge gaps is critical for furthering our understanding of how real-time monitoring can improve the efficiency, dependability, and economic sustainability of solar PV systems. By thoroughly analyzing these factors, this research aims to contribute to the growing body of knowledge and drive the integration of advanced monitoring systems into mainstream solar energy practices.

1.1.4 Relevance to Current and Future Industry

The proposed project is extremely relevant to both present and future advancements in the renewable energy industry, focusing on the design and implementation of real-time monitoring for solar PV systems. As the global energy landscape shifts toward sustainability, this initiative aligns with and solves a number of critical issues that have a direct impact on the industry's future. The solar photovoltaic industry is growing rapidly around the world, and Bangladesh is no exception. Bangladesh’s solar photovoltaic (PV) business has expanded quickly in recent years, with both the government and the private sector making significant investments in solar PV projects. Bangladesh has set an ambitious target of generating more than 4,100 megawatts of electricity from renewable sources by 2030, as part of its attempts to substantially cut carbon emissions. Solar power will make up half of the energy (2,277 MW), followed by hydropower (1,000 MW) and wind (597 MW) [10]. As a result, there is a high need for economical and dependable solar PV systems in Bangladesh. However, there are still significant hurdles to maintaining and optimizing the performance of solar PV systems in Bangladesh, including frequent power outages, voltage fluctuations, and insufficient maintenance procedures.

Real-time monitoring systems can help ensure that solar PV systems work optimally and are properly maintained. These systems can provide useful insights into solar PV systems' energy generation and consumption trends, as well as provide remote monitoring and warning for any performance issues. This can assist reduce downtime and maintenance costs, while also improving the overall efficiency and dependability of solar PV systems. Furthermore, the increased interest in solar PV systems in Bangladesh has created a demand for low-cost, user-friendly real-time monitoring systems designed exclusively for the Bangladeshi market. By creating and implementing such systems, the project hopes to bridge the gap between the potential benefits of solar energy and the practical obstacles of deploying and maintaining solar PV systems in Bangladesh.

The relevance of the current and future industry for the project is underscored by the significant growth potential of the solar PV market in Bangladesh. According to estimations, Bangladesh receives approximately 1,900 kWh/m2 of solar radiation each year. This value equates to 4 to 6.5 kWh per square meter daily. The government has produced a draft of the National Solar Energy Roadmap (SREDA). It proposes a new solar objective to address slow renewable energy progress. The goal is to reach 40 GW by 2041, with rooftop solar accounting for 40% of that total. If the government prioritizes the accelerated action plan, by 2041, solar electricity might account for 50% of Bangladesh's installed capacity. Furthermore, with an estimated 1,500 km2 of ponds, Bangladesh has a large potential for floating solar. According to calculations, even using one-third of the ponds for solar systems might yield 15 GW. Furthermore, Bangladesh has 2,500 km2 of shallow water zones. Installing floating solar in just 10% of these regions would yield 25 GW. Large lakes, such as the Kaptai, and thousands of kilometers of river pockets might add 20 GW. In terms of land-based possibilities, Bangladesh is estimated to have over 5,000 km2 of possible roof systems. Fulfilling even 10% of this may create 25 GW [11]. Real-time monitoring systems can help ensure that the rising solar PV capacity performs well and is maintained.

To summarize, the development and implementation of real-time monitoring systems for solar PV systems in Bangladesh is critical to the country's current and future industries because it can help improve the efficiency and reliability of solar PV systems, lower maintenance costs, and bridge the gap between the potential benefits of solar energy and the practical challenges of implementing and maintaining solar PV systems in Bangladesh. By addressing important industry trends and issues, the project not only addresses current needs, but also establishes itself as a forward-thinking initiative with long-term ramifications for renewable energy.

1.2 Objectives, Requirements, Specification and Constraint

1.2.1 Objectives

Throughout the project our objectives are_

- To Design and implement a real-time monitoring system for solar photovoltaic systems that can measure parameters such as panel voltage, panel current, atmosphere temperature, atmosphere humidity and light intensity.
- To detect faults in the system such as high current, low voltage, high voltage, high temperature in real-time.
- To implement communication with the Blynk platform for remote access.
- To establish an SMS alert system for immediate notification of critical issues.

1.2.2 Functional and Nonfunctional Requirements

The functional and nonfunctional requirements of our project is as follows_

Functional Requirements

- The system shall be able to measure and monitor the key performance metrics such aspanel voltage, panel current, atmosphere temperature, atmosphere humidity and light intensity.
- The sensor's output data (voltage sensor, current sensor, temperature sensor, humidity sensor, LDR) should be sent to the user timely and the system should be capable of storing the collected data.
- The system should be able to monitor faults of the system such as high current, lowvoltage, high voltage, high temperature.
- The monitoring system should be capable of sending SMS alert notifications to users inthe event of any issues or abnormalities in the system.

Nonfunctional Requirements

- The system shall have a high degree of accuracy and precision in measuring andmonitoring the solar PV parameters.
- The monitoring system should have a user-friendly interface that allows users to access and analyze the collected data.
- The system shall be scalable and adaptable to different sizes and types of solar panel systems.
- The system should be able to collect and transmit data in real-time with minimallatency.

1.2.3 Specifications

Table 1.1: Specifications of our designed prototype

Sub system	Component	Specifications
Energy source	PV panel	Voltage: 6V, Current:0-200mA,Output power:1W, Size: 110X60 mm
Energy storage	Lead-acid battery	Voltage: 12v.
Solar charge controller		Voltage: 12V/24, Current: 10A, Maximum PV voltage: 50V, Max PV input power: 130W(12V), 260W(24V)
Sensor	Voltage sensor Current sensor Temperature sensor Humidity sensor LDR	**Voltage sensor:** Voltage input range: DC 0-25V Voltage detection range: DC 0.02445V-25V Voltage analog resolution: 0.00489V DC input connector: Terminal cathode connected to VCC, GND negative pole Output interface: "+" connect 5/3.3V, "-" connect GND, "s" connect the arduino AD pins **Current sensor:** Current sensor chip:ACS712 Operating voltage:4.5~5.5V DC Measure current range:-30~+30A Sensitivity:100mV/A **Temperature and Humidity sensor:** Model:DHT11 Input supply voltage(VDC):3.3~5 Temperature range:0~50 Temperature measurement error:+-2 degree C Humidity measurement range:20% ~95%RH Humidity measurement error:+-5%RH Resolution:16 Bit Output form:Digital **LDR 10mm:** Diameter:10mm No. of pins:2 Dark resistance: Max 20M ohm Spectral peak:560 nm Light resistance(10 lux):10-20K ohm Maximum voltage(V):250VDC Maximum power(W):0.2 W Operating temperature:-30 Degree C-70 Degree C Resistance illumination:3 Response time(uS):20(Rise),30(Down)
Output unit	Liquid crystal display	Display type: 7-segment LCD display 16 X 2 ;Digit size: Typically 0.5 inches to 2 inches Operating voltage: Typically 3V to 5V DC;Interface: parallel or serial (SPI or I2C)

	I2C LCD adapter module	Operating temperature: -20°C to +70°C IC chip:PCF8574 Input voltage range(VDC):5
Wifi module and processing unit	ESP32	Module model:ESP-WROOM-32s SPI flash:32Mbit(default) Support interface:UART/GPIO/ADC/DAC/SDIO/SD card/PWM/I2C/I2S Integrated crystal oscillator:40MHz IO port:38 Antena:Onboard antenna Power supply:Voltage 3~3.6V,Typical 3.3VCurrent >500ma Operating temperature:-40~85 Degree C Storage environment:-40~120 Degree C
Voltage converter	DC to DC buck converter	Input voltage:3-40 V Output voltage:1.5-35V(Adjustable) Output current:Rated 2A,Maximum 3A Switching frequency:150KHz Operating temperature:-40-85 degree C Conversion efficiency:92% highest Load regulation:+-0.5% voltage regulation:+-0.5% Dynamic response speed:5%,200uS
GSM module	SIM 800L	IC chip:SIM800L Operating voltage(VDC):3.7~4.2 Peak current(A):2

1.2.4 Technical and Non-technical Consideration and Constraint in Design Process

Technical Constraints:

- **Sensor Precision and Range Limitations:** The selected sensors, such as the LDR, DHT11, ACS712, and voltage sensor module, may have precision and operating range limits that must be considered during the design process.
- **Communication Protocol Limitations:** The communication protocol used between the ESP32 microcontroller and the Blynk platform may have constraints, such as bandwidth limitations or data volume limitations.
- **Power Supply Constraints:** The use of solar energy for power may impose limits on power supply during severe weather or at night. Considerations for energy storage or other power sources must be included in the design.
- **Compatibility Issues with Blynk Platform Updates:** If the platform's application programming interface (API) is updated or changed, the monitoring system's integration with the Blynk platform may suffer compatibility issues.

- **GSM Network Availability:** The GSM module's dependability for sending SMS alerts is dependent on the availability and stability of cellular networks, which introduces possible limits in remote or low-coverage locations.
- **User Interface Limitations:** Design constraints in the Blynk mobile app's user interface may develop as a result of platform-specific limits, screen sizes, or the necessity for specific functionalities that the platform may not readily support.

Non-Technical Constraints:

- **Budgetary Constraints:** Due to limited financial resources, the selection of components, sensors, and communication modules may be limited, thus affecting the overall operation of the monitoring system.
- **Environmental Impact Considerations:** Consider the many weather conditions that the solar PV system may be subjected to, such as extreme temperatures, extreme humidity and potential water exposure. Choose components wisely that can endure the severe weather conditions.
- **Overcurrent sensitive devices may burn or get damaged:** To minimize damage or burnout, sensitive equipment in a solar system must be protected from overcurrent. Overcurrent can arise as a result of a variety of events, including short circuits, system malfunctions, or unusual load conditions. Examine whether all solar system components, such as cables, fuses, circuit breakers, and inverters, are adequately prepared to sustain the expected current demands. Overcurrent protection should be considered while choosing components and their ratings should be greater than the expected currents.
- **End-User Adoption and Training:** The importance of designing a system that is easily adoptable by end-users with varied levels of technical skill may result in constraints, thereby influencing the complexity of the user interface.

1.2.5 Applicable Compliance, Standards, and Codes

Table 1.2: Applicable standards and codes

Product name	Name of standards
Solar module	● IEC 61215-1:2019 Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1-1: Special requirements for testing of crystalline silicon ● IEC 61215-2:2019 Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures ● IEC 61730-1:2019 Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction ● IEC 61730-2:2019 Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
Solar charge controller	● BDS IEC 62509:2016 Battery charge controllers for photovoltaic systems –Performance and functioning.
battery	● BDS IEC 61427-1:2016 Secondary cells and batteries for renewable energy storage -General requirements and methods of test - Part 1: Photovoltaic off-grid application. ● BDS IEC 60086-4:2005 Primary batteries - Part 4: Safety of lithium batteries.
Sensors	● DIN 1319-1:1995-01:In this standard, basic terms of metrology are defined, such as Calibration, Adjustment, Hysteresis, Sensitivity, Resolution, Measured Value, Measurement Result, Measurement Deviation, Uncertainty, Relative Uncertainty, Repeat Standard, Standard Deviation, Full Measurement Result, Repeatability Conditions, and Reproducibility Conditions. ● DIN 1319-3: 1996-05:Evaluation of measurements of a single measured variable, calculation of the measurement uncertainty for the case where the measured variable is measured directly or is calculated from other quantities by means of a given function. Terms measured variable, input quantity, result size, model ● DIN 1319-4: 1999-02:Evaluation of measurements of several jointly measured quantities. Consideration of assumptions and information of other kinds than statistical information.

1.3 Systematic Overview/Summary of the Proposed Project

The project is focused on developing a real-time monitoring system for solar photovoltaic (PV) systems. This innovative system makes use of a variety of sensors, including an LDR for light intensity measurement, a DHT11 for atmosphere temperature and humidity measurement, an ACS712 for current measurement and a voltage sensor module for voltage measurement. The ESP32 microcontroller acts as the central hub, collecting and relaying data to the Blynk platform's user interface. A GSM module offers another layer of functionality by sending operators quick SMS notifications in reaction to abnormal conditions. Furthermore, the project's economic analysis highlights its potential for cost-effectiveness, including considerations for return on investment and reduced maintenance expenses. The project is in line with sustainability objectives, and it contributes to the larger initiative of sustainable energy practices.

In summary, the project offers a comprehensive solution that utilizes new technology to fill gaps in solar PV monitoring. It promotes itself as a significant addition to the growing landscape of renewable energy systems by improving efficiency, dependability, and economic viability.

1.4 Conclusion

Finally, the completion of the project "Design and Implementation of Real-Time Monitoring System for Solar Photovoltaic Systems" represents a big step forward in addressing the inherent constraints of traditional solar monitoring procedures. The combination of advanced components has resulted in the construction of an advanced real-time monitoring system. In addition to the immediate benefits of proactive system management and optimization, this project is at the spotlight of current industry trends by adopting the Internet of Things (IoT). The economic analysis done highlights not only the system's financial sustainability, but also its potential to provide significant long-term advantages. This project is more than just a technological advancement; it represents a dedication to promoting sustainability and efficiency in solar energy techniques. It contributes to the ongoing development of renewable energy landscapes by filling important gaps. As the globe shifts toward cleaner, smarter energy solutions, this project demonstrates our commitment to entering in a more sustainable and technologically advanced era for solar PV systems.

Chapter 2: Project Design Approach

2.1 Introduction

In a world that is increasingly aware of the need for sustainable energy solutions, our project stands out as a game-changing initiative. This initiative marks a significant step forward in addressing major gaps in monitoring approaches, with an emphasis on optimizing solar photovoltaic (PV) systems. Real-time monitoring has the potential to redefine the efficiency and reliability benchmarks for solar PV installations. The project intends to provide a full perspective of the elements impacting solar energy generation by integrating a complex array of sensors, including LDR for exact light intensity measurement, DHT11 for ambient conditions, ACS712 for current monitoring and a voltage sensor module for voltage measurement. The utilization of modern technology, such as the ESP32 microcontroller, in combination with the deployment of user-friendly interfaces such as the Blynk platform and quick alert capabilities via a GSM module, demonstrates the dedication to user-centric design and proactive system management. As we investigate the project's design and implementation, it becomes clear that this initiative is about more than just technological improvement; it is also about changing the story about sustainable energy usage.

2.2 Identify Multiple Design Approach

2.2.1 Design Approach 1:(OFF Grid/Stand Alone Monitoring System)

In Design Approach 1, we've developed a real-time monitoring system for off grid solar setups, combining hardware, software, and cloud-based tools to create an all-inclusive monitoring and management solution. Sunlight is captured by solar panels, which then convert it into electrical energy. Various sensors, like voltage, current, temperature, humidity and LDR sensors, gather essential performance data from the solar power system. These sensors are connected to a microcontroller that processes the data and sends it to the cloud for analysis. The data can also be analyzed locally using an LCD display. The cloud-based platform serves as a central hub for data storage, analysis, and performance reporting. It can be easily linked to a web interface to provide real-time updates on system performance. Thanks to the Wi-Fi module connected to the sensors, we can also view these readings on our mobile device by connecting to the Wi-Fi network. This IoT technology allows for continuous monitoring and early problem detection. We've also incorporated an alert system into our Off-Grid Solar setup. This system is designed to promptly notify users of any irregularities in the solar system's performance, such as low voltage, high voltage, high current or high temperatures. When such issues arise, the system will alert users by sending text messages. This ensures that users are promptly informed of any problems with their solar system, allowing for timelyintervention and peace of mind.

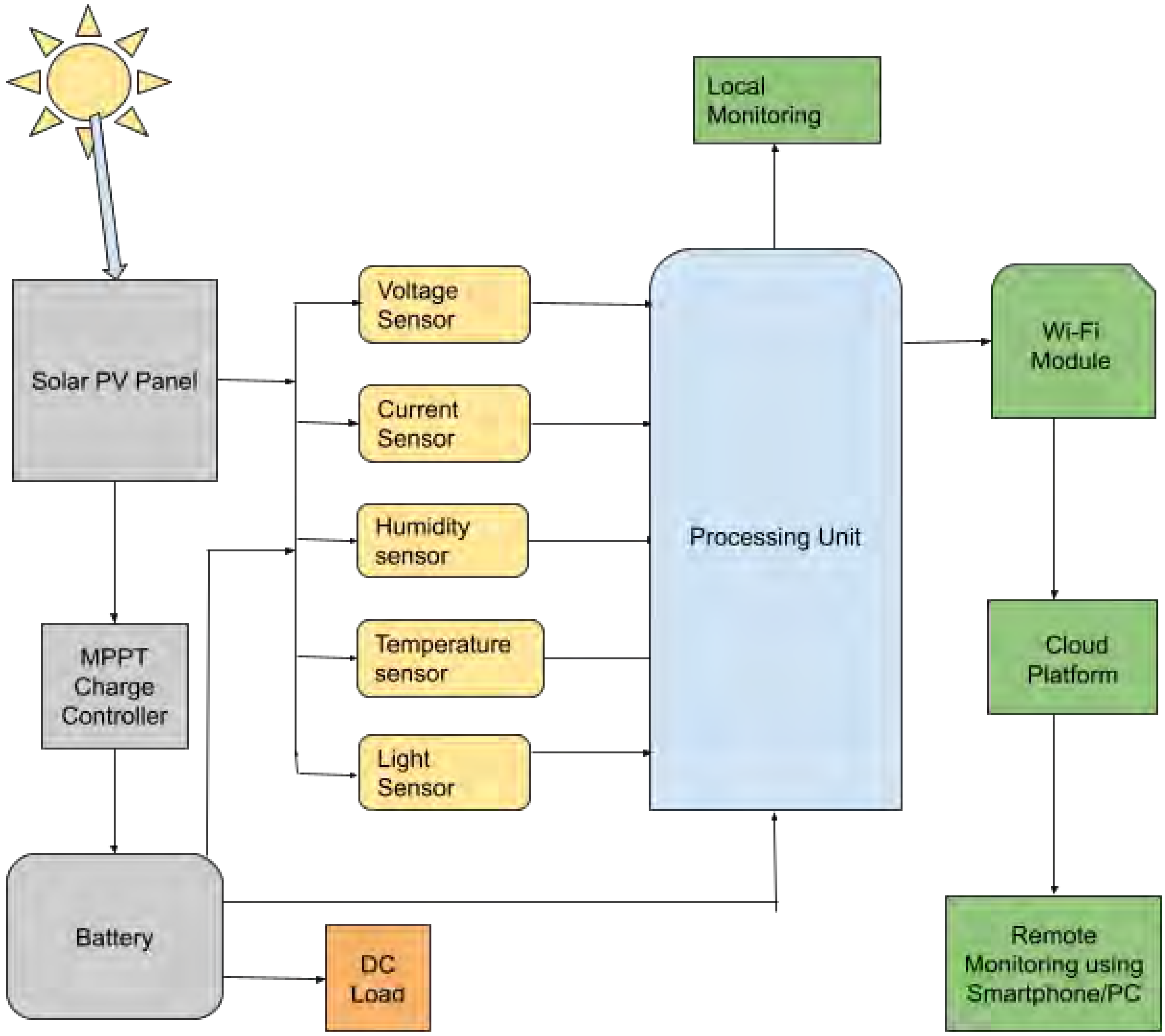

Fig 2.1: Block diagram of design approach 1(OFF Grid Monitoring System)

2.2.2 Design Approach 2:(ON Grid Monitoring System)

This design strategy focuses on creating a real-time monitoring system for on-grid solar systems, addressing the issues associated with grid-connected applications. The system will use monitoring software with a graphical user interface (GUI) for data visualization to measure critical parameters such as DC voltage, current, AC voltage, and power output in real-time. Continuous data gathering via sensors attached to the PV system, with subsequent transfer to the Data Acquisition Unit (DAU) and monitoring software, is part of the work process. The software processes and analyzes the data before showing it in a real-time graphical user interface for simple monitoring. The information gathered is saved for future analysis and troubleshooting. The solar panel charging process, sensor measurements, DC to DC conversion, PV inverter functioning, net metering for grid connectivity, and communication between PV array, sensor box, and PV inverter are all part of the design workflow. An alarm and notification system with IoT capabilities assures user safety by notifying in the event of parameter deviations.

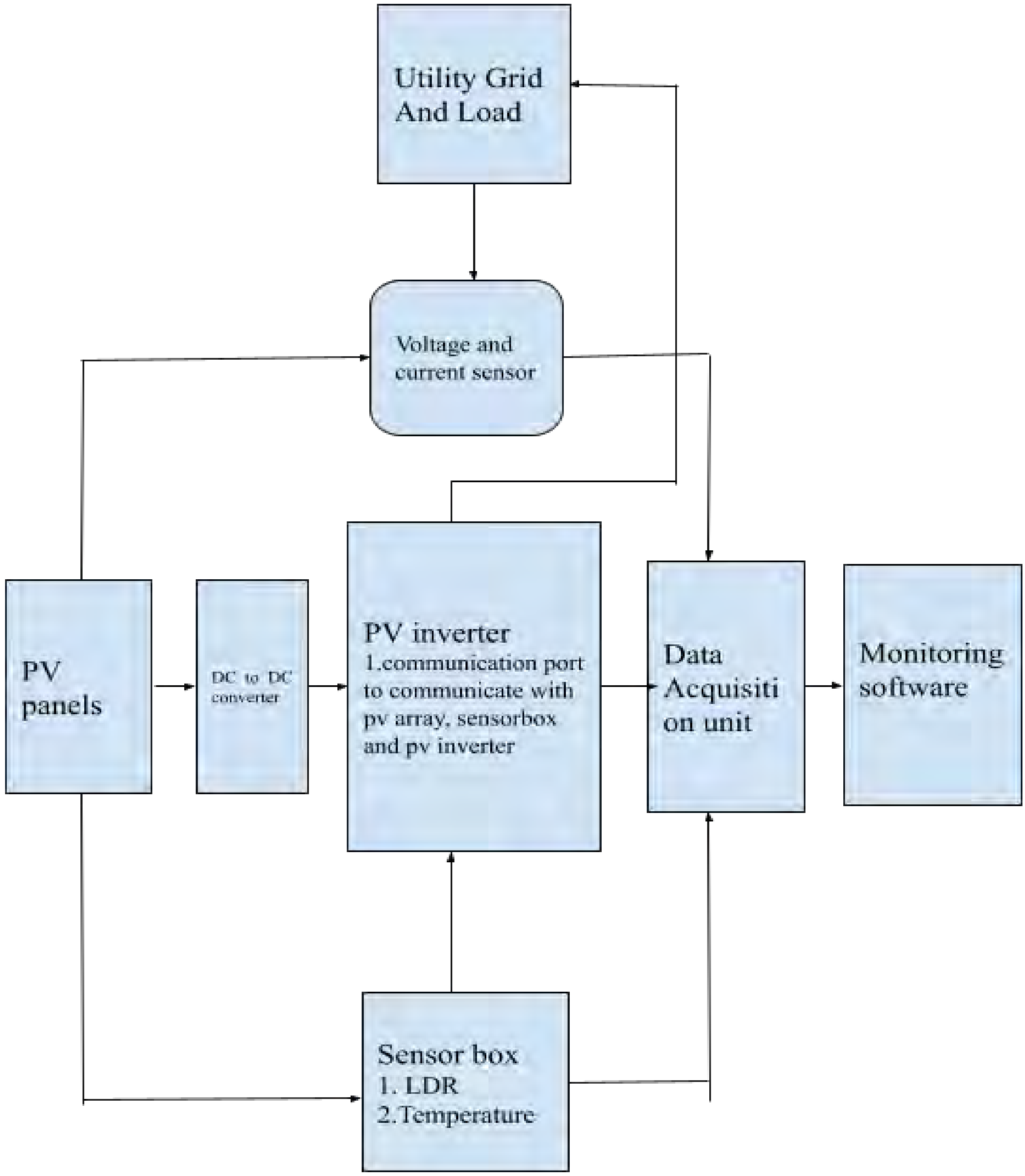

Fig 2.2: Block diagram of design approach 2(ON Grid Monitoring System)

2.3 Describe Multiple Design Approach

2.3.1 Design Approach 1:(OFF Grid/Stand Alone Monitoring System)

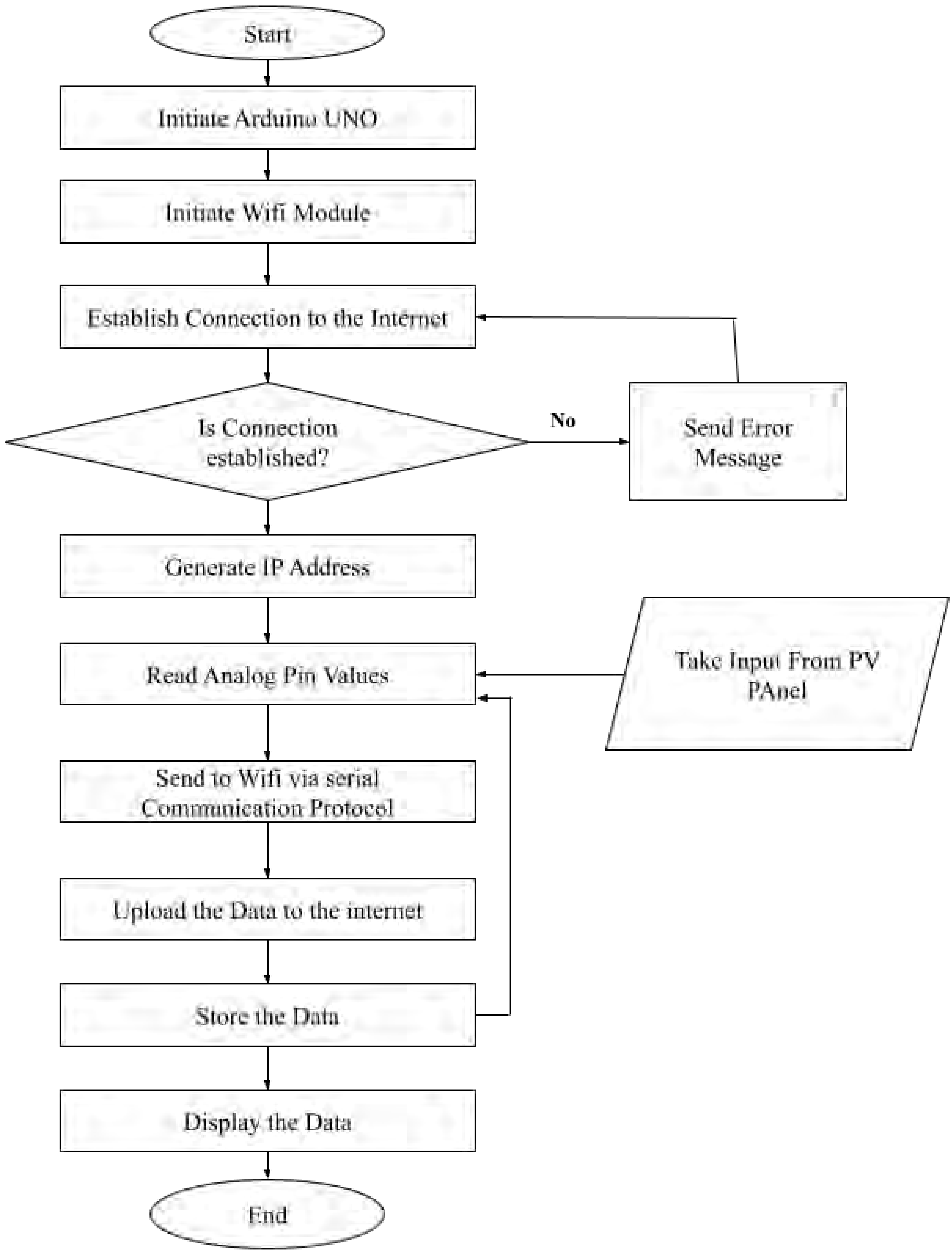

Fig 2.3: Algorithm of design approach 1(OFF Grid Monitoring System)

We have designed a comprehensive real-time monitoring system specifically tailored for off grid solar setups in this design approach, including a synergy of hardware, software, and cloud-based tools to produce an all-encompassing solution for monitoring and managing solar power systems.

- **Solar Energy Capture:** In off-grid solar systems, the process begins with solar panels capturing sunlight and transforming it into electrical energy.
- **Sensor Data Collection:** Sensors such as voltage, current, temperature, humidity, and LDR sensors play an important role in collecting essential performance data from the solar PV system. These sensors are linked to a microcontroller, which processes the data that is collected and sends the data to the cloud platform
- **Cloud-Based Analysis and Storage:** After processing the data, the microcontroller sends it to the cloud for further analysis, storage, and performance reporting. This cloud-based technology acts as a centralized hub, allowing for seamless interaction with a mobile or online interface for real-time system performance updates.
- **Local Monitoring with LCD Display:** Users can also monitor the system locally using an LCD display, which provides a simple on-site analysis of essential parameters.
- **Alert System for Proactive Monitoring:** Adding an alarm system to the off-grid solar setup provides a layer of proactive monitoring. In the event of an anomaly, such as low voltage, high voltage, high current, or elevated temperatures, users receive fast notifications via text messages. This function ensures prompt user involvement, adding to the overall peace of mind and dependability of the solar power system.

This design approach not only improves the efficiency of off-grid solar systems, but it also promotes sustainability, dependability, and user-centric functionality. It fits in perfectly with the project's goal of building a reliable real-time monitoring solution for off grid solar applications.

2.3.2 Design Approach 2:(ON Grid Monitoring System)

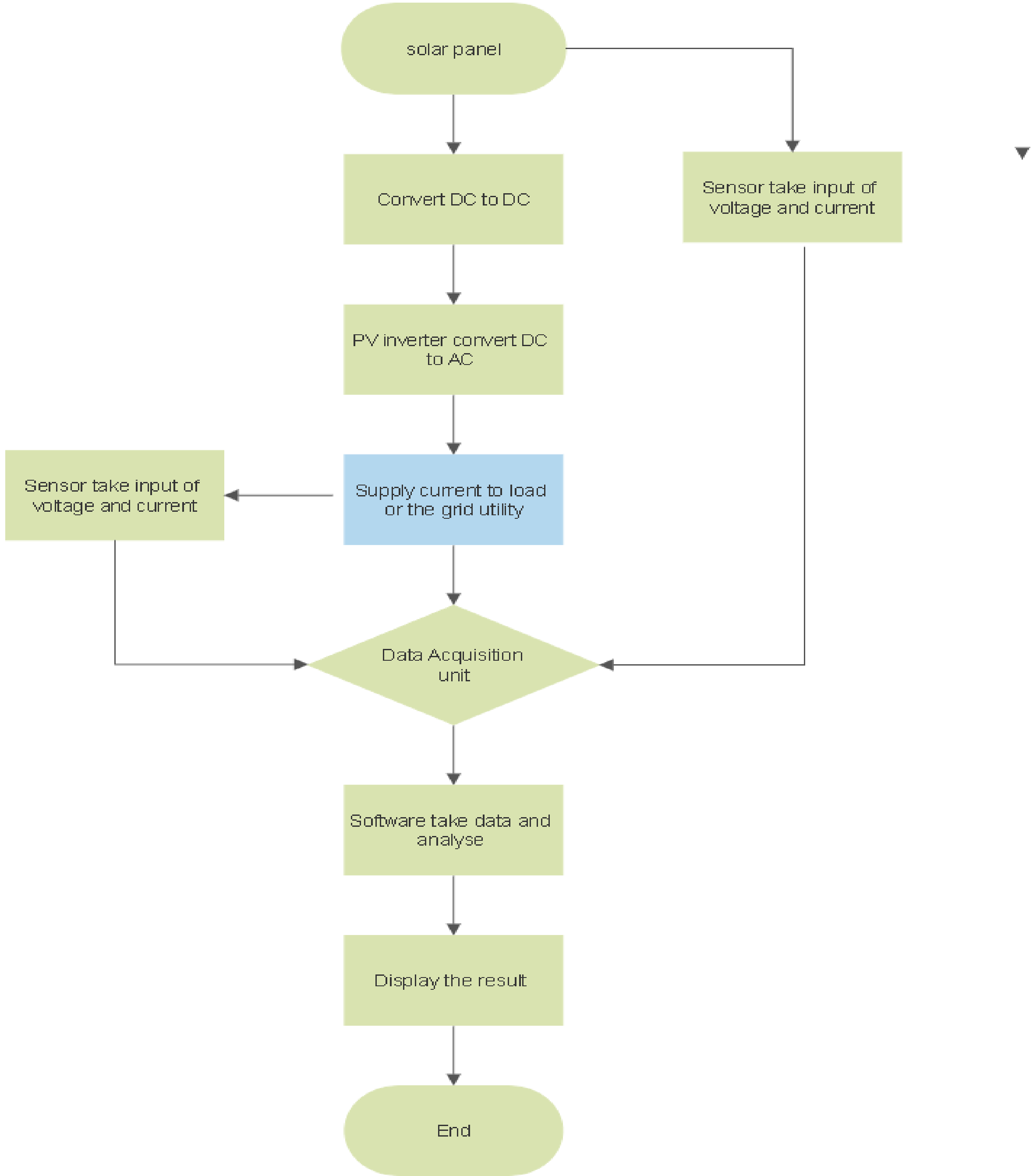

Fig 2.4: Algorithm of design approach 2(ON Grid Monitoring System)

In design approach 2 a real-time monitoring system for On-grid solar systems is proposed. Monitoring the performance of these systems can be challenging, particularly in grid-connected applications where the stability of the electrical grid is critical. We aim to develop a monitoring system for a grid-connected PV power generation system using monitoring software. The system will measure key parameters of the PV system, such as DC voltage, current, AC voltage and power output, in real-time. The data collected by the system will be visualized using the monitoring software's graphical user interface, which will allow us to monitor the performance of the PV system and take appropriate action when necessary.

The Work process will like the followings_

Collecting Data: The sensors connected to the PV system will continuously collect data on parameters such as DC voltage, current, AC voltage and power output. The collected data will be transmitted to the Data Acquisition Unit (DAU). After that data will be transmitted to the monitoring Software: The Data Acquisition unit (DAU) will transmit the collected data to the monitoring software in real-time for processing. Processing Data in monitoring software like the monitoring software will process the data received from the sensors in real-time. The software will analyze the data. Then the part of visualizing Data: the processed data will be displayed in a graphical user interface (GUI) developed using monitoring software which will display the key parameters measured by the sensors such as DC voltage, current, AC voltage and power output. The GUI will provide a real-time display showing the status of the PV system, enabling quick and easy monitoring of the system's performance. Last part Storing Data: The monitoring system will store the collected data in a database for future analysis and troubleshooting. The stored data may also be used to generate reports on the system's performance over time, which can be used to identify trends and make informed decisions regarding maintenance and repairs.

Overall, the monitoring software-based monitoring system will continuously collect, process, and display data about the PV system's performance, providing a real-time view of the system's status. By monitoring the PV system and analyzing the collected data, we can quickly identify potential issues and take corrective actions, improving the system's efficiency and reliability.

Work Process (how will we progress to design): Identify the components of the grid-connected PV power generation system that need to be monitored, including the PV array, DC-DC converter, and inverter. Design and develop the monitoring software-based monitoring system, which will include sensors for measuring the relevant parameters and a graphical user interface for visualizing the data. Test the monitoring system to ensure that it accurately measures the parameters of the PV system and that the data visualization is effective. Implement the monitoring system in a real-world grid-connected PV power generation system and evaluate its effectiveness in improving the performance and reliability of the system.

The work flow of the design: Firstly, the solar panel will be charged by the sun. Then there will be some sensor like voltage and current sensor which will measure the voltage and current initially. After that there will be a DC-to-DC converter by which the DC voltage from the output of the PV array is supplied to the PV inverter. The purpose of using the dc-to-dc converter is to boost the total solar energy produced by up to 30%. They are able to shut down the panel's DC voltage when the temperature or voltage is too high. DC to Dc converter can supply the different levels of voltage continuously. Like if the PV panel produces low voltage, it will continuously produce the fixed level by the use of stored voltage because this Dc-to-DC converter can store energy temporarily to for converting Dc current from one voltage level to another. Now the PV inverter which will be connected to the utility grid and also with the load. The PV inverter will convert the direct current to alternate current. The converted power can be used in the house appliances or ejected into the electrical grid. As On

Grid solar systems have the connection with the grid so that the consumer can draw the power from grid whenever the solar energy is not available so there will be a net metering system which will record the amount of energy given to the utility grid that will help to fix the bill for the consumers. The PV inverter will have a port of communication by which the PV array, sensor box and PV inverter will communicate with each other. The sensor box will be there for measuring the light intensity by LDR sensor and the temperature of the PV panel with the temperature sensor. The collected data will be sent to the Data Acquisition unit via a communication medium that can be RS485 which can communicate in both directions. After that the data acquisition unit will be connected to the software which will monitor the performance of the solar panel. Now the solar panel will analyze the data and will make a visual graph of the performance. That is how this design will work.

Alarm and Notification system (IOT part): By this protection system whenever parameters go to an inappropriate level the alarm will ring for these designs. We are measuring 4 types of parameters in our project that are temperature, voltage, current and light intensity. For the temperature as we all know that solar panel or photovoltaic panel works best in 25-35°C. In our designs the temperature is set like that also. Most of the cases panels cannot provide best performance due to high temperatures above 35°C. So here we set the highest temperature at 35°C. Whenever the temperature of the photovoltaic panel goes above 35°C the alarm will start. So, consumers will be informed about the safety issue. Then we have the voltage level for output voltage. Normally for our home supply the voltage is 220V. From 220-240V this is nominal voltage for every equipment, meaning that most equipment will operate between these voltages. So, if the output voltage goes over 240V it will hamper the total system for the house. So, we set the level for output voltage to be 240V. Whenever the voltage goes over 240V the alarm system will notify the consumer. After that there will be a current level also. As in proteus or other simulation software we are not able to show the current flow. Like how much current flows against the voltage level. So here we build a current circuit. Here we manually change the current level so that we can prove our concept. Here we set the highest current level to 1.40A. So, if the current of the circuit goes over 1.40A the alarm will notify the user. This part we can properly show in our next step which will be the hardware part. Then we also track the light intensity also in this project. That will show the light intensity in percentage. Moreover, here we added an option for the inverter too. We know that the photovoltaic panel will produce the DC voltage and the home appliances work in AC voltage. So, we have to convert the DC voltage to AC voltage so we need the inverter which will do this job. Here we added a switch for our inverter so that if the user decides not to use the solar system for a long period of time like the user will be out of the house for 2-3 days so the user will use the switch to turn off the system. If the solar panel is on and the inverter switch is off the alarm will start.

For design 2 we use a data logger which will keep the record of all the parameters when it changes also. In addition, we use an LCD panel in both the designs so that during simulation we can show the parameters in the display.

2.4 Analysis of Multiple Design Approach

Table 2.1: Comparative analysis on multiple design approaches of the system

Criteria	Design approach 1	Design approach 2
Based on	OFF grid/Stand alone	ON grid/Grid connection
Technical complexity	Easy	Difficult
Cost	Low	High
Appropriate customers	Suitable for remote areas where grid connection is not available or unreliable.	Suitable for urban or suburban areas where there is a reliable grid connection
Remote monitoring	Yes	No
Energy storage	Yes	No
Automatic monitoring	Yes	Yes
Ease of use	Easy	Hard

Our first design is an OFF-grid PV monitoring system. This is suitable for rural areas where grid connection is not available. In this design we can store energy in the battery. The technical complexity is easier for this design compared to our 2nd design approach. There is also option for remote monitoring via mobile phones or computers. The cost of implementing this design is also lower compared to the 2nd design approach which is ON grid PV monitoring system. The ease of use is quite easy for this design.

On grid monitoring system is suitable for urban or suburban areas where there is reliable grid connection. This design approach is quite complex compared to the OFF-grid monitoring system. Also, there is no energy storage system for this approach. There is no option for remote monitoring for this design approach. The cost of implementing this design is quite high compared to the OFF-grid monitoring system. The ease of use for this design approach isquite hard for this design

2.5 Conclusion

To sum up, the solar monitoring system design approach is an optimal solution for the consumer who is using a solar panel system and wants a better life span with better performance. By this design consumers can detect any performance issue for their system which has the facility of IoT and communication system. These facilities will notify the consumers about the performance and by this consumer can decide that any steps have to be taken or not for the better performance of their PV system.

The demand for renewable energy is going high day by day and for that people want improvement in this sector and also want smart solutions for their system. Manual monitoring of their system is going tough for the owner because everyone is busy with their work. So, they need a solution by which they can monitor their system automatically and remotely. Developing and implementing this solar monitoring system will help them to meet their needs and will make their life easy.

Chapter 3: Use of Modern Engineering and IT Tool

3.1 Introduction

We develop our project Solar monitoring system by using modern engineering tools like various sensors, cloud server, mobile application which makes this project more useful and beneficial to the consumer.

3.2 Select Appropriate Engineering and IT Tools

To design our project, we use some engineering tools and it is also required to fulfill ourproject. We can divide our project tools in three sections.

1. Simulation Tools
2. Coding Tools
3. Monitoring Tools

3.3 Use of Modern Engineering and IT Tools

Simulation tools:

Table 3.1: Selection of circuit simulation software

Criteria	Tinkercad	AutoCAD	Proteus
Ease of learning	X	X	√
Availability of component	X	X	√
User interface	√	√	√
Schematic design	√	X	√
PCB design	√	√	√
Cost	√	X	√

AutoCAD software is mainly used for designing printed circuit boards. It is more popular to most of the companies and high-level works. Though we need to do PCB in our project but compared to the other software this is not compatible cause this is mostly used for PCB design only.

Tinkercad is also a popular software for digital and analog electronic simulation but it is more likely an online 3D modeling software. Because it runs with the use of the internet so this has disadvantage for the user if they get disconnected from the internet.
Proteus is the popular software for the automation of electrical and electronic design. It also has the facility of PCB design, schematic design and also has the availability of components. As we are doing our project in Arduino IDE which needs to connect with the schematic design so Arduino and the simulation software both have the facility of having the same

component and library. Both of these softwares have the facility of getting the library from the internet and that is easy to download. Moreover, we are doing our most of the academic project by using this proteus software so it was easy for us to use this software in this project also.

Coding Tools:

Table 3.2: Selection of coding tools

Criteria	Arduino IDE	Geany	Platform IO
Component library	√	X	√
Ease of learning	√	X	X
User interface	√	X	X
Development board	√	X	X
Community help	√	X	X

Platform IO was the perfect one for our project but its software is not familiar to most people. The setup process is quite complicated for this software and as the lower number of user use this software so the tutorial of how to set up this software is not enough for us and we are troubled to set up this so we drop our plan to work on this software.

On the other hand, Geaney is used for the Raspberry Pi. It has many features but the type of development board of this software is not enough to use for our project. Because this is not supporting many components and don't have as much library as the Arduino IDE, we dropthis one also.

At the end we choose Arduino IDE to complete our project. This platform is used by many users nowadays so if we are stuck with any problem, we can get help from the community. It also offers various development boards and also easy to download the library from the internet. As we are using Proteus for the simulation it is easy to work with the Arduino IDE. Because of these facilities we selected the Arduino IDE for our project.

Monitoring Tools (cloud server):

Table 3.3: Selection of cloud server

Criteria	Blynk	Azure IoT Hub	Generic IoT
Ease of use	User friendly	Difficult to use	User friendly
Integration	User friendly support in various hardware platform	Well-integrated into the Azure ecosystem with extensive support	Limited ecosystem, may require additional tools
Cost	Free	Paid	Paid

3.4 Conclusion

In order to complete our project successfully we discussed the engineering tools described above. We compare those tools based on some criteria and also try to choose one tool from every sector which is most compatible with our design. In addition, we also think about our consumers so that they can easily use those tools. To ensure this we always tried to find user friendly tools. We also choose the tools by keeping it in mind that we have time restrictions to complete our project so we go for the easiest tools that are available and can be obtained easily. Moreover, we not only focused on the availability of the tools but also focused on the quality and accuracy of those tools. So, by following these things we choose the best tools for our design to complete it successfully and also work on that project without any error.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution

4.1 Introduction

To meet the functional and non-functional requirements, two different types of design approaches were proposed earlier. These two design approaches have been compared in terms of requirements. Moreover, from these two designs which is considered to be the optimal solution and has been selected to proceed for the implementation is optimum in terms of energy generation, successfully detection the value of solar voltage, battery voltage, temperature, humidity, light density resistor, error detection alert and forwarding the data through the mobile phone messages, web server and as well as in the mobile application. Lastly, the implementation of this design approach is cost effective as well as easy to install.

4.2 Optimization of Multiple Design Approach

4.2.1 Design Approach 1

Design Approach 1 Simulation:

This is the simulation of our Approach 1. We simulated the circuit in Proteus software.

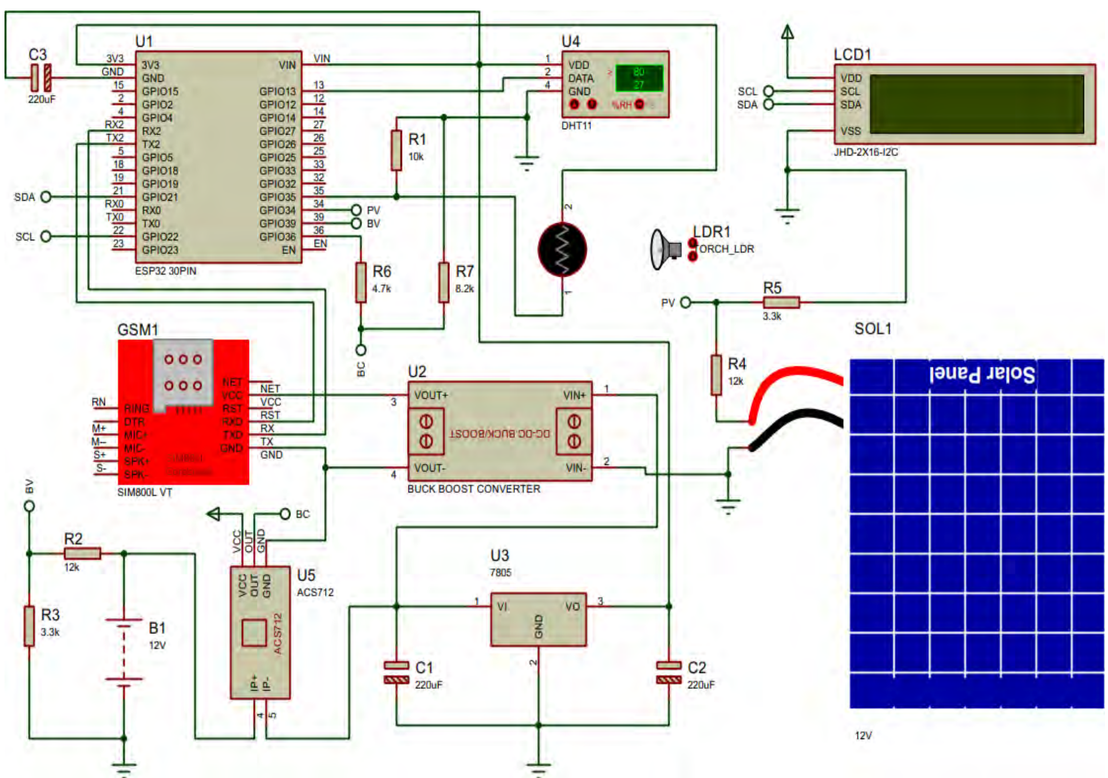

Fig 4.1: Proteus Simulation of design approach 1

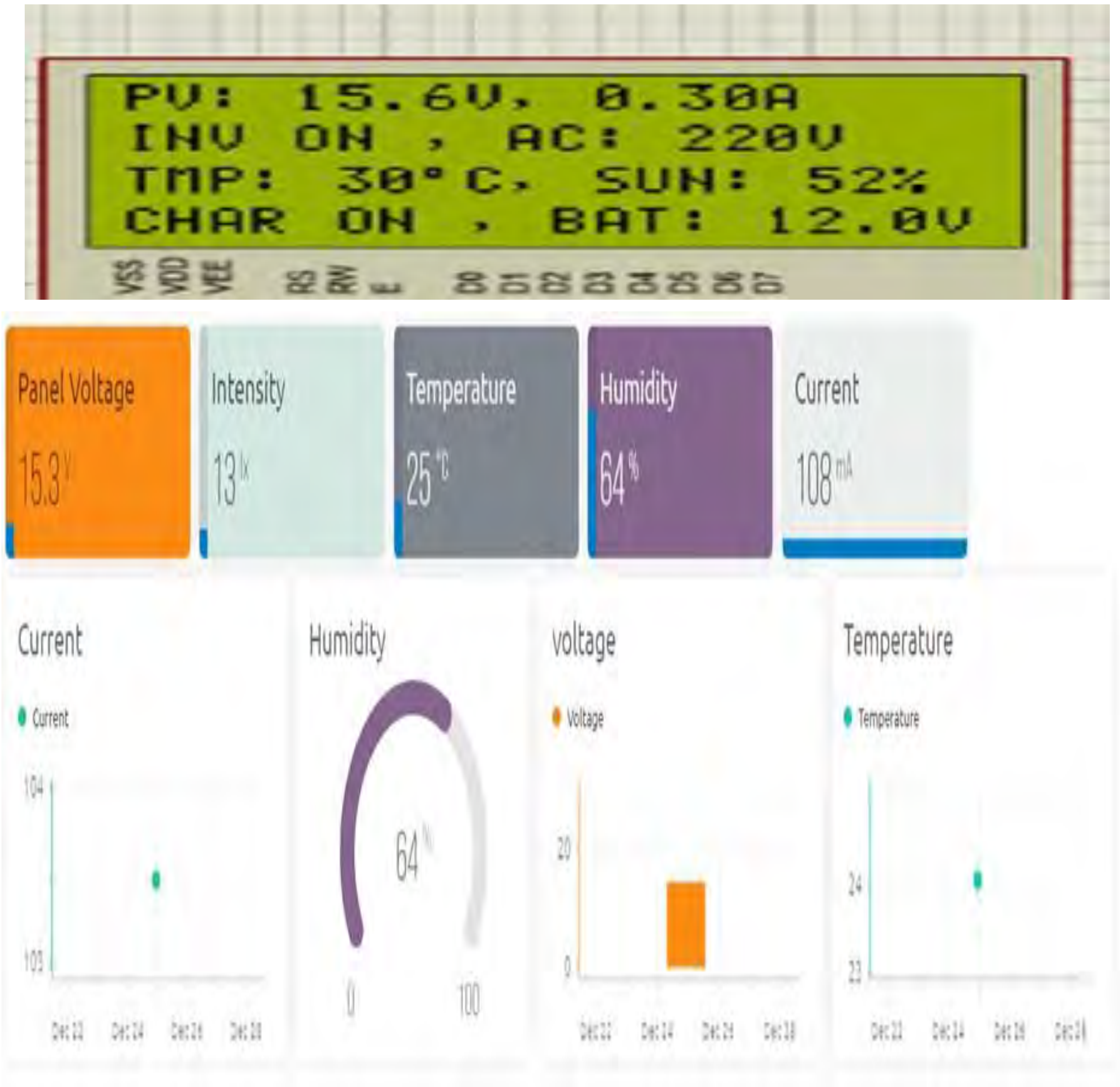

Fig 4.2: Displaying the data collected by sensors in LCD and in server (IoT).

Our design approach 1 is based on Off-Grid solar panel system and Internet of Things (IoT). Here we designed the system with some sensors and the sensors are voltage, current, temperature, humidity and light density sensor. Moreover, we used a GSM module to inform the consumer through mobile phone messages. After collecting the data through sensors data will be forwarded to the web server which is the IoT part of this approach. In addition to this forwarding system the collected value will be displayed in the LCD display as well so if anyone wants then they can check the value by looking into the display also it will be helpful if the consumer is outside of mobile network as well as outside of internet. When the sensor will get the value which will not be applicable for the service area (for example if the voltage of the battery supplies moreover the capacity) then the system will alert the consumer through the mobile messaging service by using the GSM module which we used in this design.

Alert system:

As we know solar panels have a certain life span and provide best performance for that period. If any harmful event happens with the solar panel, then its performance will also be reduced as well as its life span also. Consumer user solar panels are expected to use it for a certain period of time so anything unhealthy happens to it will reduce its performance. so that will be a drawback for the consumer. To reduce this problem, we are coming up with an alert system in this design. Where the system will alert the consumer if any harmful event occurs in the solar panel system. Here we introduce some problems related to solar panels which can reduce the performance and make an alert system to alert the user.

Table 4.1: Fault detection based on preset value and alert system

Issue	Impact	Preset parameter	Alert
Low voltage	If solar panel produce low voltage than battery cannot be charge	we set the parameter that if solar panel produce lower than 10.7V then the system will direct it as an error	Consumer will get a message through the mobile phone number like "Low Voltage!"
High temperature	Solar panels normally perform best in 25℃-35℃. If it goes higher than this the cells of the panel can be melted.	We set the parameter that if the temperature goes over the 35℃ then the system will detect it as an error	Consumer will get a message through the mobile phone number like "High Temperature!"
High current	If the solar panel produce high current, then the component connected with that can catches fire	We preset the value of current 3A. If solar panel produce more than this then system will detect it as an error	Consumer will get a message through the mobile phone number like "High Current!"
High humidity	If the humidity level is high in the air that means the performance of the solar panel will decrease. cause it will produce tiny water droplets in the panel	We preset the value of humidity to 80% if it goes over this then system will detect it as an error	Consumer will get a message through the mobile phone number like "High Humidity!"

4.2.2 Design Approach 2

Design Approach 2 Simulation:

This is the simulation of our Approach 2. We also simulate this in Proteus software.

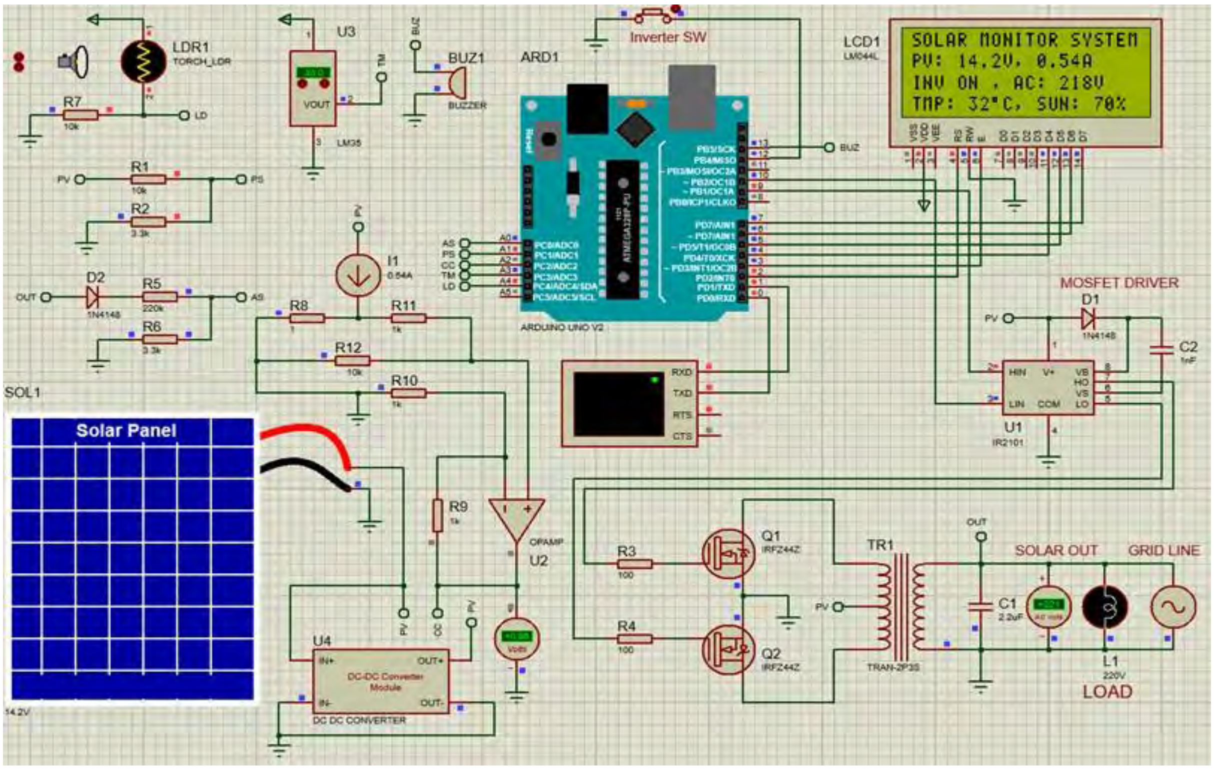

Fig 4.3: Proteus simulation of design approach 2

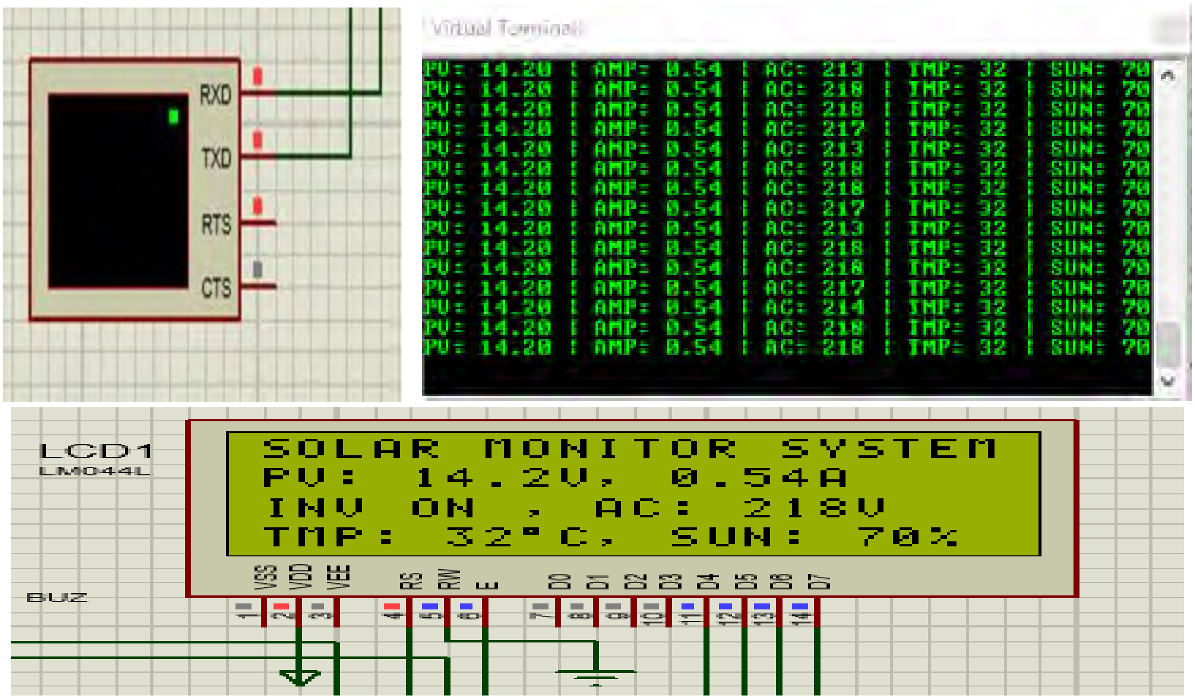

Fig 4.4: Displaying data in data logger and LCD.

In our design approach 2 we made a design based on the "On-Grid" solar panel system and Data Logger. Here we designed the system with an on-grid solar panel system. Firstly, we use a 14.2v photovoltaic panel which will be connected to a DC-to-DC converter. This DC-to-DC converter helps to supply a certain amount of voltage all the time. Here we use it because sometimes the voltage could be up and down and that can harm the system. This voltage will be connected in 2 ways. One with the home and another with the utility grid. Here we define the utility grid as the "Grid Line" and home as the "Load". Here the sensors of voltage, current, temperature, and LDR will collect the data from the sensor and will save it into the data logger so that we can check it later. Here we also use the LCD display to monitor it manually. Finally, as On Grid solar system has a connection with the utility grid so that if the solar panel cannot draw enough energy which is needed for the service area the consumer can draw the energy from the grid so there will be a net meter for record the given energy to the utility grid so that the billing way could be easy for the consumer.

Detecting the optimum design

We are considering our first design approach as the best design approach. This is based on "Off-Grid" solar panel systems and IoT. We are considering this approach as the best because in this system there is no need for a utility grid (connection of electricity) which is not available in rural areas. We know from the recent paper from The World Bank which states that in 2014 more than 2.4 million rural users use off-grid systems. So, it would be very beneficial for the rural area's consumers. In addition, it also offers a communication system using GSM module and web server which will keep the consumer up to date and It is also easy to monitor the whole system. Moreover, in this system GSM module will alert the consumer through the mobile phone message if the system faces any error. Here we use the word error for the low voltage, high current, over temperature and high humidity. These errors will also show up in the web server also. These errors show up in the system and will be helpful for the consumer. That is why we consider this design as the best design.

4.3 Identify Optimal Design Approach

Table 4.2: Validation of existing design approach 1

Requirement	Expected outcome	Status
Based on	Easy and beneficial for the consumer	Optimum
Technical complexity	Understandable for any consumer	Moderate
Cost	Budget should be cost effective	Yes
User friendly	Suitable for remote areas where grid connection is not available or unreliable.	Optimum
Remote monitoring	Locate performance outside the service area	Yes
Energy storage	Energy storage is needed to use anytime	Yes
Automatic monitoring	All the sensors and data should be monitored	Optimum

Table 4.3: Validation of existing design approach 2

Requirement	Expected outcome	Status
Based on	Easy and beneficial for the consumer	No
Technical complexity	Understandable for any consumer	High Complexity
Cost	Budget should be cost effective	No
User friendly	Suitable for remote areas where grid connection is not available or unreliable.	Moderate
Remote monitoring	Locate performance outside the service area	No
Energy storage	Energy storage is needed to use anytime	No
Automatic monitoring	All the sensors and data should be monitored	Moderate
Ease of use	Consumer can easily use	Moderate

Table 4.4: Analysis of both design approaches

Criteria	Design approach 1	Design approach 2
Based on	OFF grid/Stand alone	ON grid/Grid connection
Technical complexity	Moderate	Difficult
Appropriate customers	Suitable for remote areas where grid connection is not available or unreliable. (Optimum)	Suitable for urban or suburban areas where there is a reliable grid connection.
Remote monitoring	Yes (Optimum)	No
Storage	Yes	No
Automatic monitoring	Yes (Optimum)	Yes
Ease of use	Easy (Optimum)	Hard
Cost	Low	High
Acceptance	High	Low

By analyzing and evaluating the above tables we compare the 2 design approaches under some specific criteria like based on medium, technical complexity, Appropriate customer, remote monitoring, cost and acceptance. The first design approach is based on an Off-grid system which has low complexity with an easy monitoring system as well as offering a remote monitoring facility. So, approach 1 has a high acceptance to the mass people as most of the consumers are from rural areas. On the other hand, design approach 2 is based on an On-Grid system which has high complexity, does not have the remote monitoring facility, and is needed for grid connection. So that the acceptance of approach 2 goes down to approach 1.

4.4 Performance Evaluation of Developed Solution

Table 4.5: Performance evaluation of the proposed approach

Requirement	Expected outcome	Validation
PV panel working	The PV panel takes the energy from the sun and delivers it to the battery through a charge controller. Checking the value by calculating theoretically and practically.	Validated
Battery charging through charge controller	PV panel will take solar power and then store the energy to the battery through charge controller	Validated
Controlling charge by charge controller	Charge controller will take solar energy and keep the battery away from overcharge by controlling the charge.	Validated
Power up the sensors	Microcontroller, sensors and LED will take the power from the battery and start working.	Validated
Sensor value	Current sensor ACS712 will detect the AC/DC current value which will supply to the service area. Temperature sensor DHT11 will detect the temperature of the solar panel. Light density Resistor will detect the light density around the solar panel. By using voltage dividing rule the processing unit will detect the voltage which will supply to the service area.	Validated
Error detection	The processing unit will detect the error by analyzing the preset optimum value for the service area with the data coming from the sensors.	Validated
Alert system	If the system detects any error by analyzing data, then it will alert the consumer through the mobile messaging service.	Validated
Automatic monitoring	All the value will be delivered to the processing unit and there will be an LCD monitor which will display the value getting from sensors. Moreover, the Wi-Fi module NodeMCU 32 and this will deliver the data to the website.	Validated
Communication with consumer	The GSM module will be used for the communication through the mobile messaging service with the consumer.	Validated
Mobile apps and web server	The monitoring process can also be done by the mobile app as well as with the website also.	Validated
Physical implementation	Small prototype to see the full process	Validated
Fully physical implementation	All the process should be work in real life situation with the huge service area	Not Validated

4.5 Conclusion

In conclusion, after analyzing and evaluating the system, we reached the final decision that our first design approach not only fulfill the expectation of the consumer, it will also score high for the required objectives which allows this design approach to be considered as a reliable monitoring system.

Chapter 5: Completion of Final Design and Validation

5.1 Introduction

Completion of final design and Validation means full implementation of the best design which is optimally discussed in the previous chapter and validate the implementation by evaluating the performance of the design and its output. Here we will implement the optimum design and will evaluate the output and performance of that.

5.2 Completion of Final Design

5.2.1 Methodology

- Firstly, we used four 6V solar panels for our prototype and connected them in series so that it can give maximum voltage. So, theoretically these setups can giveup to 24V but practically it can produce 15.6V to 15.8V and 110mA current and supply to the battery for energy storage.

- We used a battery whose capacity is 13.7V and 3.7A current. Here we used a solar charger controller to keep the battery safe from overcharging. Our charge controller will allow the battery to charge up to 12.7V and that can ensure healthy battery life.

- The sensors will collect data from the system as well as from the environment.

- The output data will be displayed in the LCD display which will come with the design so that consumers can monitor data manually by just looking into the LCD.

- Moreover, the output data will be stored in the cloud server through the Wi-Fi module from where consumers can monitor the data and performance in real time.Consumers can check the previous data also which will be helpful for the consumer. In case of the consumer outside of the service area they can remotely observe the performance so that if any error occurs, they can take initiative, and this will be the most beneficial part of this design approach. This data will be shown in the mobile application also.

- The system will also analyze the data with preset optimum values for the service area. If any mismatch occurs, then the system will initiate an alert option so that consumers can know about that.

- The error detection process will notify the consumer about high voltage, high current, high temperature, humidity and about the light intensity by using the GSM module through mobile messaging service. This messaging service could also be beneficial for the consumer. In addition, if the consumer stays outside of the service area and also out of internet range at that moment if any error happensthen the consumer can get a message through their mobile phone.

By following these steps, the system will work and can be helpful for the consumer to monitor their photovoltaic system easily.

5.2.2 Data/Information Analysis of the Design

To implement this project successfully an information analysis is required. The data we will get from the sensor should be real and 100% correct. To check that value, we need to use the manual way of calculation and also, we need to analyze long-time data so that we can sure that the system is working correctly.

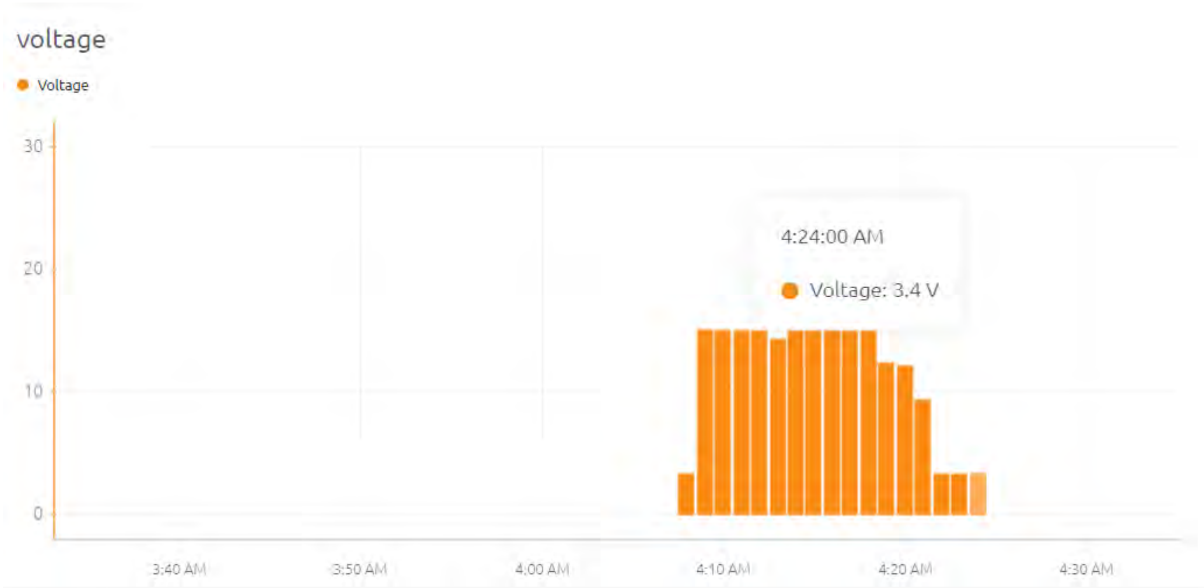

Fig 5.1: Hourly voltage supply

Fig 5.2: Hourly current supply

Fig 5.3: Hourly temperature changes

From the above graphs we can analyze the hourly workings and data from the system. We also check data value manually by using measurement tools like multimeter and temperature gun that tools also show the similar value. That is how we reached the end decision that the system is working correctly.

5.2.3 Physical Implementation and Prototype Design

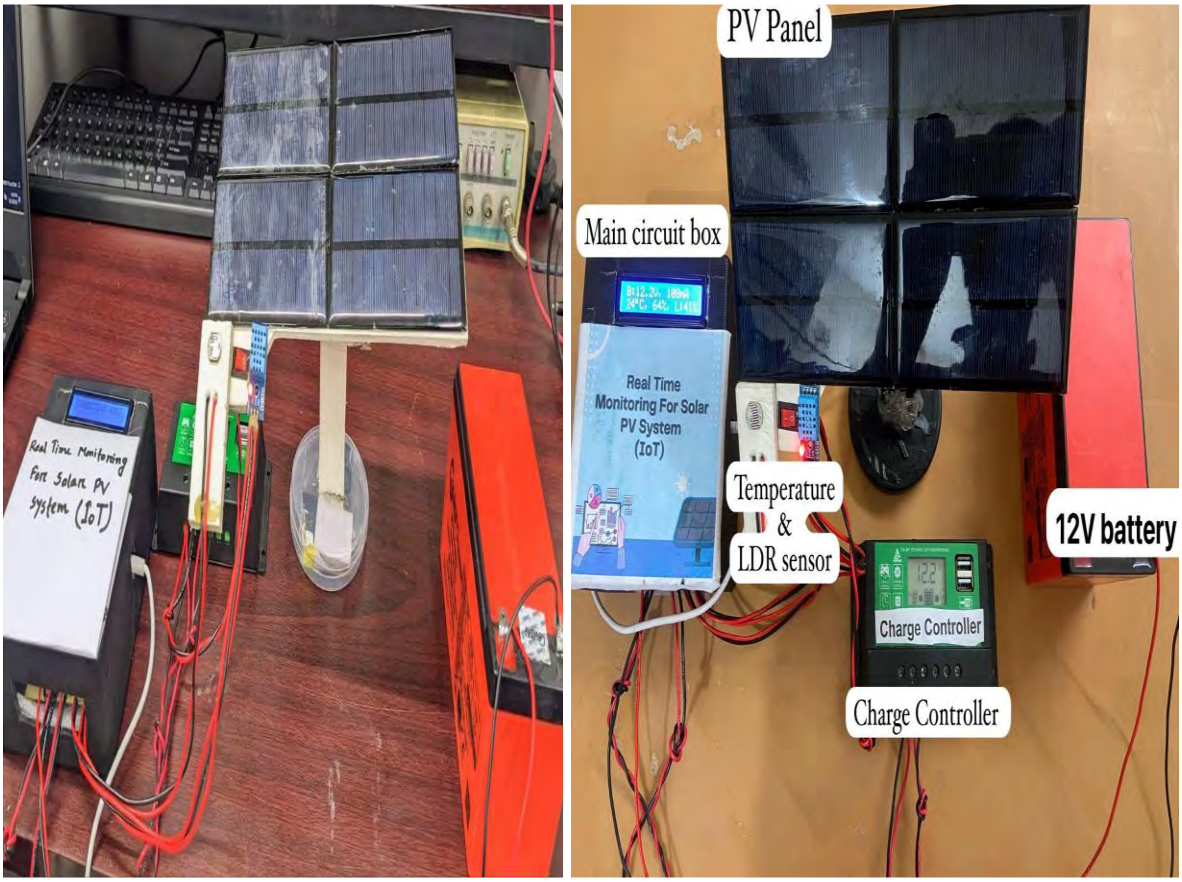

Fig 5.4: Testing the prototype.

This is the physical implementation and prototype design of our best approach. Here we test the solar panel inside a room where sunlight was minimum. So that we can know how it works outside of daylight and in this case the solar panel produces low voltage in between 12V to 13V. After that we also tested our prototype under the direct sunlight. There we got better value which is produced by the solar panel and here the solar panel produced 15V to 15.5V which is the desired value from this setup, and we discussed how much voltage we can get from this prototype in chapter 5.2.1 (Methodology) part.

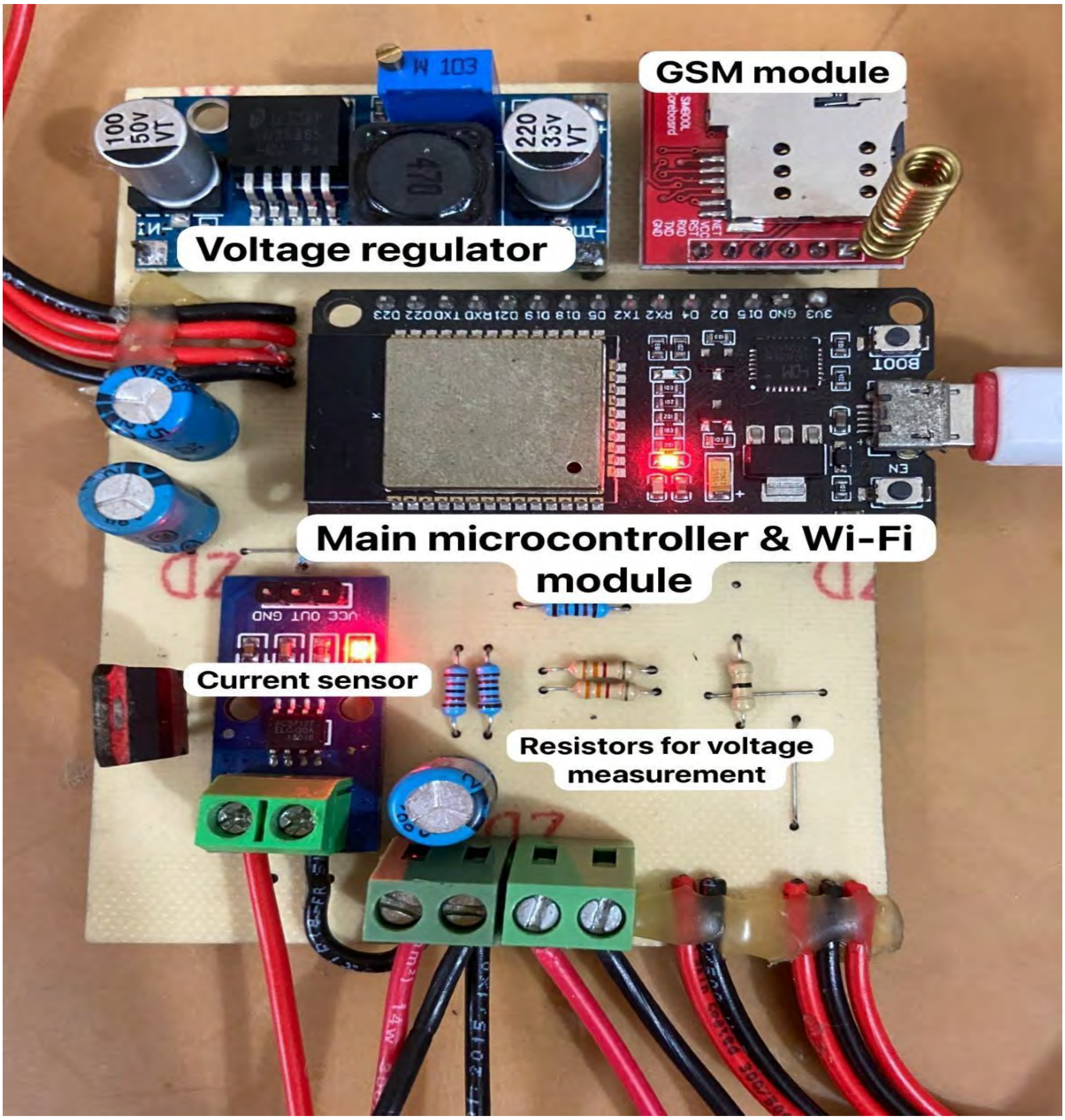

Fig 5.5: Processing unit

Fig is our main processing unit where everything of the system will be processed. Our main microcontroller is the ESP32 which has the capability of a Wi-Fi module. The data from the sensors will be delivered to the microcontroller and there the microcontroller will process them and send them to the cloud server from where the consumer will monitor the information. In this main circuit we also insert the GSM module which will be used for the alert system for sending messages to the consumer. For this GSM module we have to use a voltage regulator because our microcontroller can work on 3.5V but the GSM module needs 4.5V to work. So, we have to generate 4.5V by the regulator and then send it to the GSM module to work perfectly. The current sensor is also in the main circuit. It will collect data from the solar panel and as well as from the battery and will send it to the microcontroller. In addition, here we use some resistors which will be used for voltage sensors. The resistors are placed by following the voltage divider rule so that they can be used as a voltage sensor.

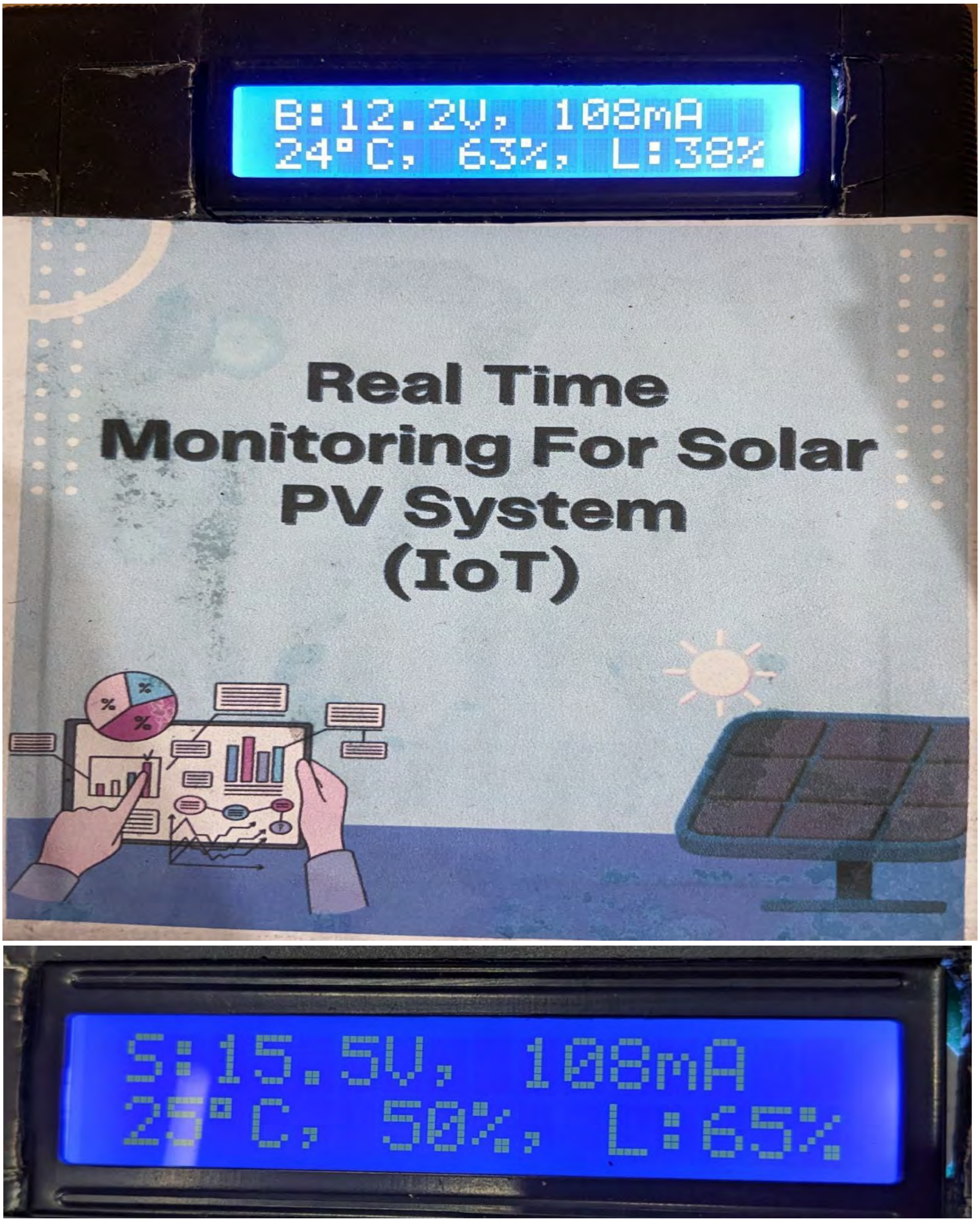

Fig 5.6: LCD display for manual monitoring (Showing battery, solar panel voltage and other values)

After processing all data, the microcontroller will also send them to the LCD display from where consumers can monitor the information manually. Here we show the value of battery voltage, solar voltage, current, temperature, humidity and light density.

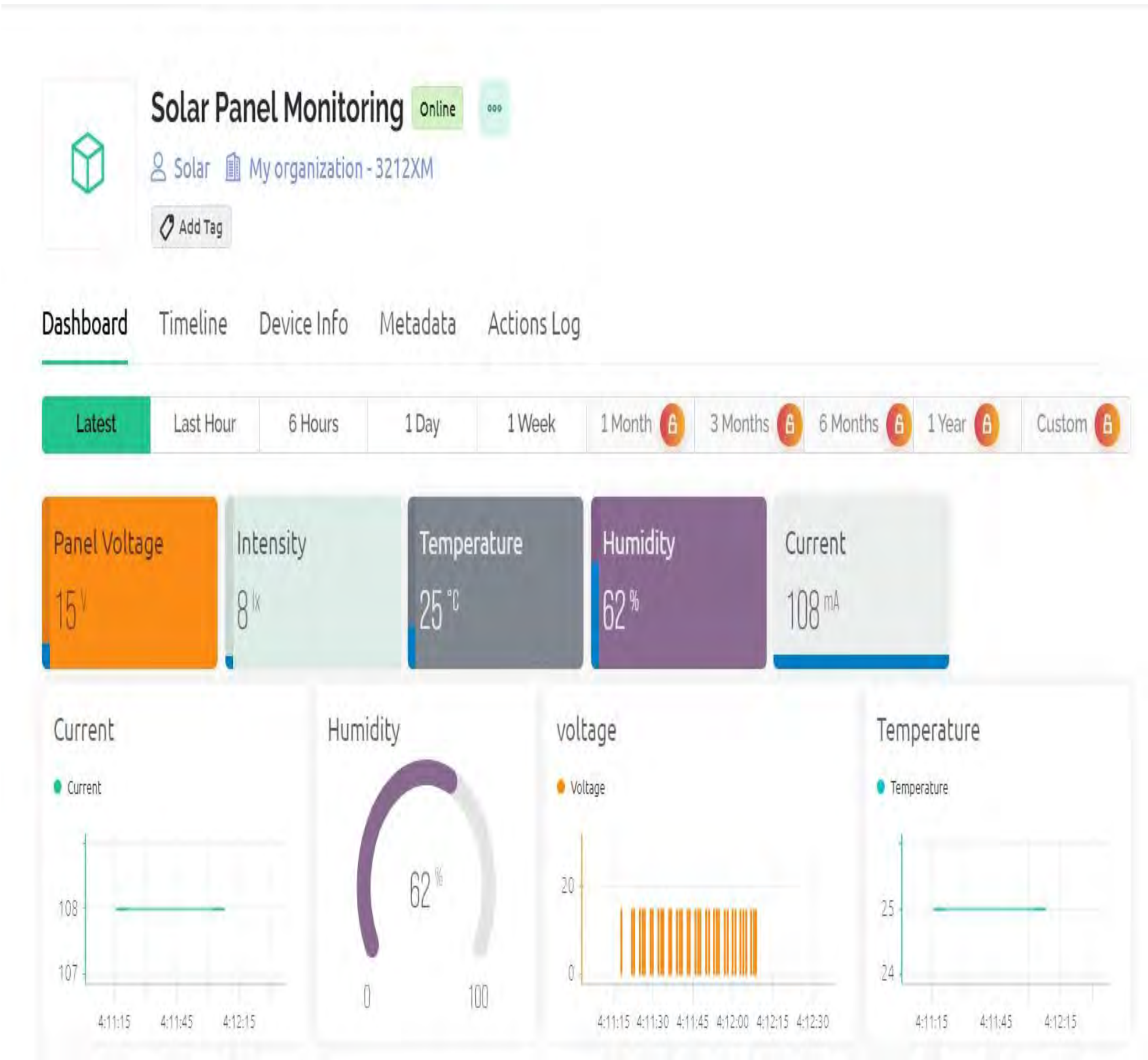

Fig 5.7: Dashboard from cloud server

This is the cloud server dashboard where the data from the processing unit will be stored. From this dashboard consumers can monitor their system remotely from any location. As well as this cloud server will store the data for a long time by this consumer can view the previous performance.

Fig 5.8: Alert system through message service

This is the screenshot from the alert system. Our prototype is having this facility through the mobile phone messaging service. When the processing unit can detect any error, it will send messages about that to the consumer. So that consumers can take action against that. By this feature consumers can be alert from any location and any situation like if they stay outside of an internet facility as well.

5.3 Evaluate the Solution to Meet Desired Need
Verification of the workings

Fig 5.9: Charge controller (keep the battery safe from overcharging)

When the solar panel charging the left most solar sign will be shown in the display. Then the battery will start charging from the solar energy. It will be shown like the above solar panel to battery and battery to load when any load is being connected with battery.

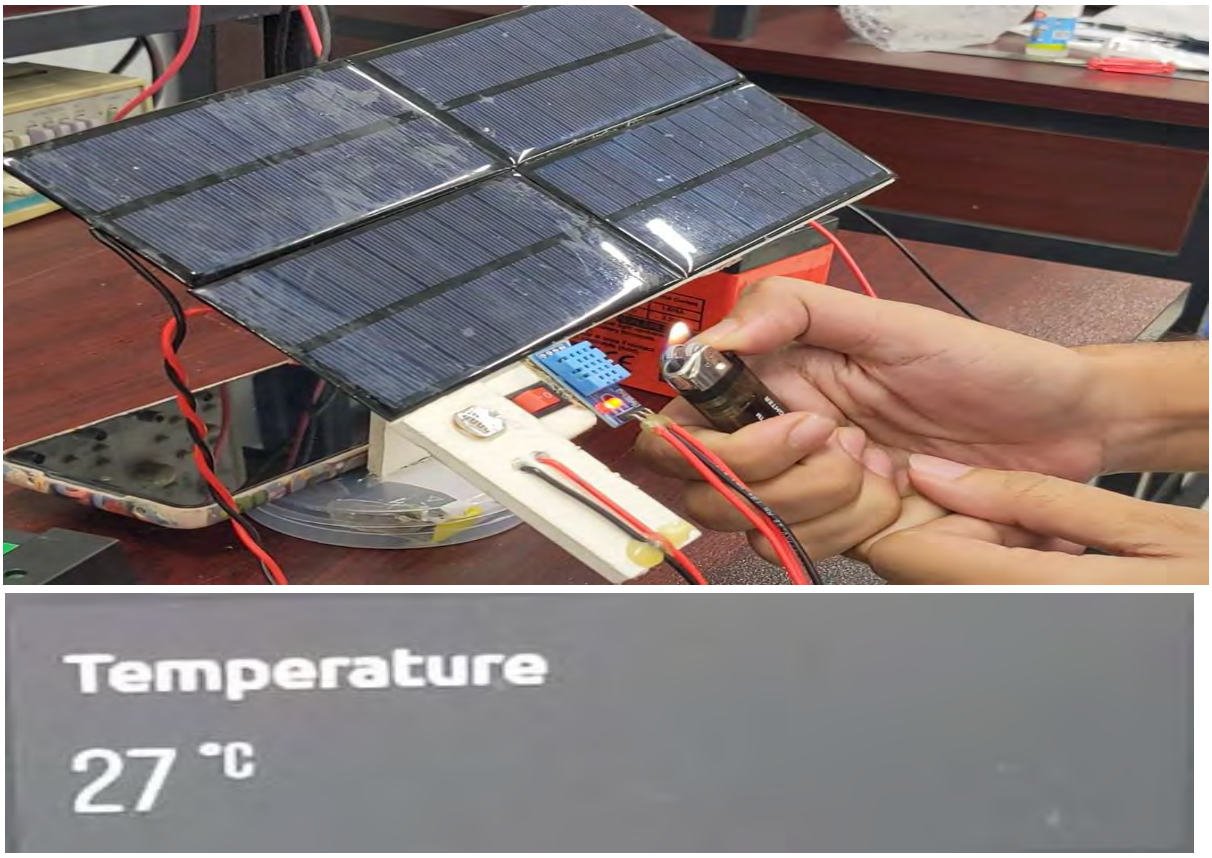

Fig 5.10: Verification of the temperature sensor

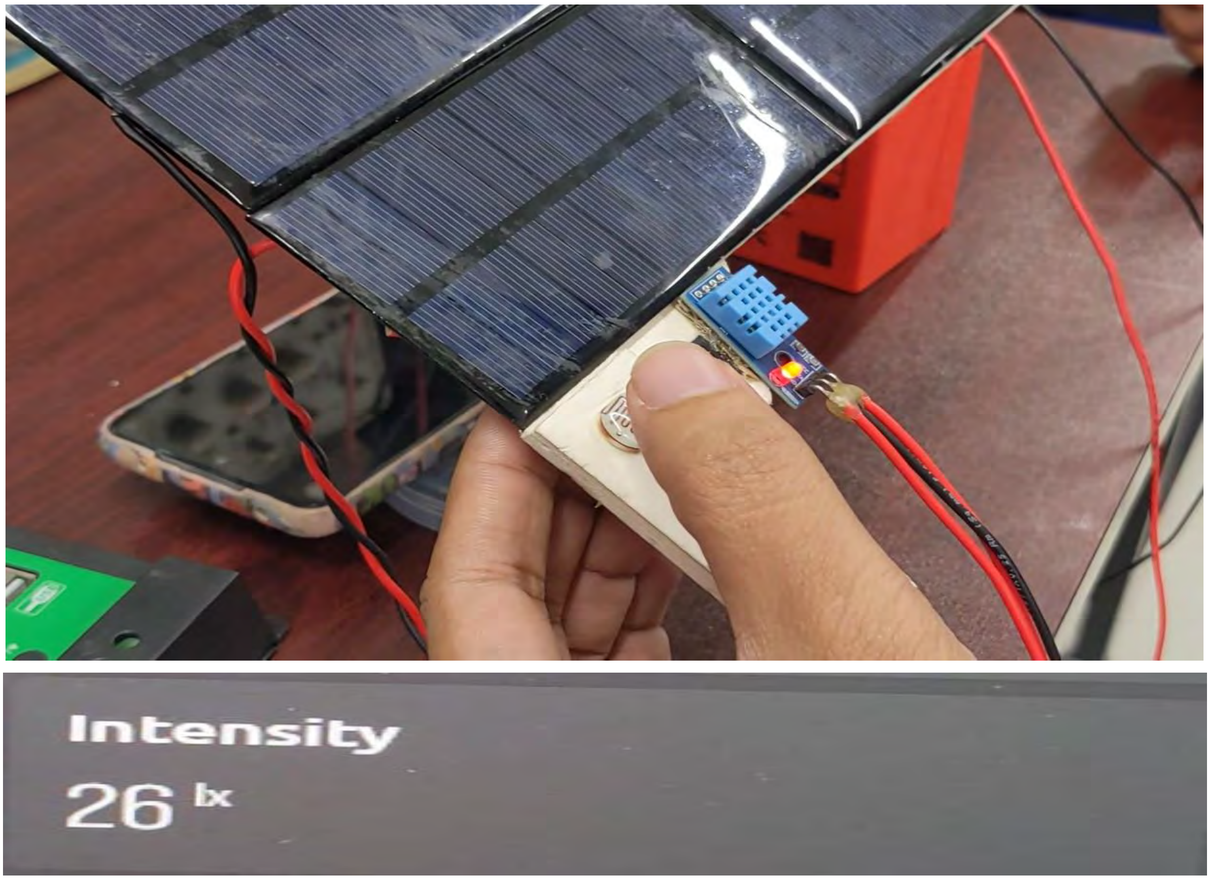

Fig 5.11: Verification of the LDR sensor

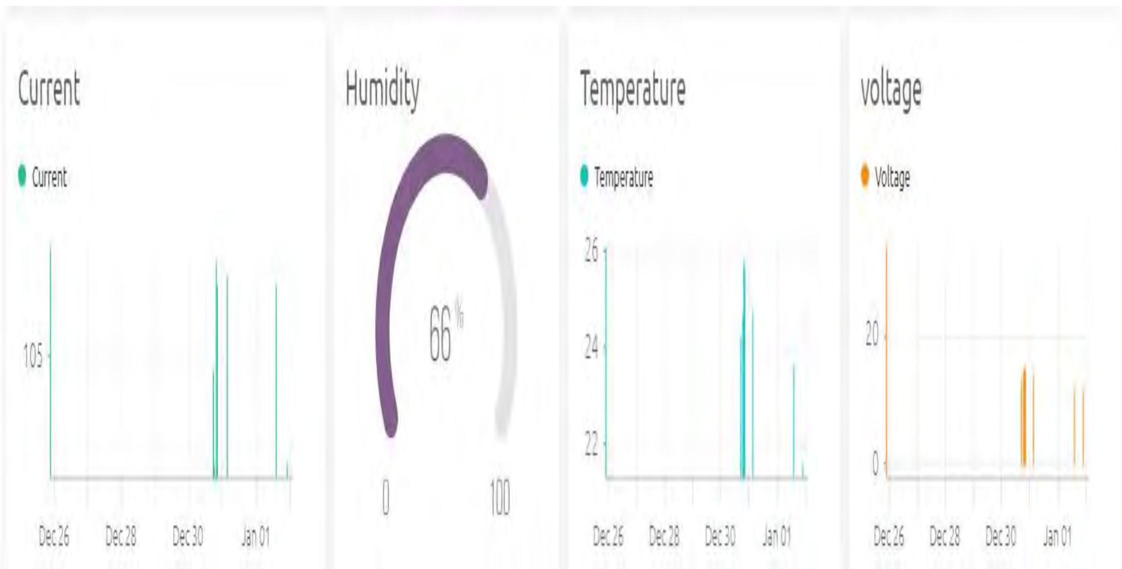

Fig 5.12: Long-term value for verification the changes

Voltage and current sensors also work properly. We tested the system both outside and inside the home. From there we verified the voltage and current value, and we also verified all the values from the cloud storage where the data stored for the log time.

Fig 5.13: Verification of the alert system

This is the verification of the GSM module and we preset the optimum value of every parameter so that if the parameters detected are harmful for the service area or for the solar panel then the GSM module will alert consumers through the mobile message service.

5.4 Conclusion

Finally, we implemented the hardware part and completed the design of our prototype which is the best design approach we discussed in the previous chapter. Though we tested it for the small service area and just tested it so that the system is working correctly or not it scored up to the mark and fulfilled all objectives and gave the required output. This design passed all the tests and all the parts of the system worked correctly from taking the energy to store the data in the cloud server and also the alert system every section worked perfectly. Furthermore, to validate the design the prototype needs to work perfectly and this is the most important part of a project whether the design meets the requirement or not. Completing the design with perfect execution of the objective guarantees that the final product meets all requirements. Lastly, verification of the result will also ensure the consumer/stakeholder that the product is perfectly working with the desired objectives and this design meets all these sections.

Chapter 6: Impact Analysis and Project Sustainability

6.1 Introduction

The adoption of a real-time monitoring system for photovoltaic systems is a significant development in the field of renewable energy. This section explores the solution's thorough impact analysis, looking at both its short- and long-term impacts. In addition, it assesses the project's sustainability while taking social, economic, and ecological factors into account.

6.2 Assess the Impact of the Solution

- **Environmental Impact:** The real-time monitoring system's primary effect is that it promotes environmental sustainability. Through the project's enhancement of solar PV systems' efficiency, more energy may be generated from renewable sources. As a result, there is less need for conventional energy sources, which lowers carbon emissions and promotes environmental cleanliness. Furthermore, the proactive alarm system reduces the possibility of system failures, averting possible environmental risks.

- **Economic Impact:** The initiative has major economic consequences, especially in the context of the renewable energy market. As the popularity of solar energy grows, the real-time monitoring system positions itself as a useful asset for consumers, businesses, and energy providers. It improves the overall performance of solar PV systems, resulting in higher energy yield and lower costs for end users. Furthermore, the anticipated reduction in maintenance costs and the extension of system lifespan contribute to the project's economic viability.

- **Social Impact:** From a societal standpoint, the project raises awareness and participation in sustainable energy methods. Individuals can actively monitor and operate their solar systems thanks to user-friendly interfaces such as smartphone apps and web interfaces. The incorporation of an alarm system assures user safety and helps to a sense of security, hence increasing faith in solar energy technology. Furthermore, the project's versatility for both residential and industrial uses encourage greater inclusivity in renewable energy adoption.

- **Technological Impact:** The implementation of a real-time monitoring system accelerates improvements in solar technology. It promotes renewable energy industry innovation in sensor technologies, data analytics, and cloud computing. This technological advancement not only improves the efficiency of the current project, but it also lays the framework for future improvements in smart and sustainable energy solutions.

6.3 Evaluate the Sustainability

- **Ecological Sustainability:** The project promotes the use of clean, renewable energy, which is in line with ecological sustainability. It reduces environmental impact by maximizing the efficiency of solar PV installations through real-time monitoring and optimization. This not only minimizes the carbon impact, but it also aligns with worldwide efforts to move to a low-carbon, sustainable energy future.
- **Economic Sustainability:** Economically, the initiative provides long-term viability through the possibility of long-term cost savings. Solar PV system efficiency increases energy production and reduces dependence on traditional energy sources, adding to economic resilience. Furthermore, the solution's adaptability to various scales of solar setups improves its economic sustainability by catering to a diversified user base.
- **Social Sustainability:** The empowering of people to actively participate in sustainable energy practices demonstrates social sustainability. The project promotes the use of cleaner energy options while instilling a sense of environmental responsibility. The incorporation of educational components into user interfaces raises societal awareness and involvement, which contributes to the long-term viability of renewable energy adoption.

Table 6.1: SWOT analysis

Strengths	**Weaknesses**
● Remote Accessibility and accurate monitoring. ● User-Friendly Interface. ● Proactive Alerts.	● Initial Setup Complexity ● Cost Implications. ● Dependency on Connectivity.
Opportunities	**Threats**
● Increase performance and efficiency of the system. ● Smart Grid Integration. ● Predictive Analytics	● Electrocution or another electric hazard. ● Environmental Challenges. ● Security Concerns.

6.4 Conclusion

Finally, the impact analysis highlights the project's positive impacts on the environment, economy, and society. The real-time monitoring system not only improves the efficiency of solar PV systems, but it also empowers consumers to participate actively in sustainable energy practices. The sustainability assessment reveals a thoughtful balance of ecological, economic, and social concerns, establishing the project as a catalyst for a more sustainable and resilient energy future. As renewable energy continues to play an important part in global energy transitions, this project serves as a model for efficient and long-term solar energy management.

Chapter 7: Engineering Project Management

7.1 Introduction

The process of assembling a team to tackle a difficult engineering challenge while taking into account a number of variables, such as planning, budget estimation, component availability, a carefully thought-out timetable, task assignment, and progress tracking, is known as engineering project management. A comprehensive project plan is created by combining project management techniques with technical engineering skills to keep a project moving ahead.

7.2 Define, Plan, and Manage Engineering Project

7.2.1 Defining Project Management

Engineering project management is the process of allocating, scheduling and overseeing the resources needed to finish an engineering project. It comprises determining the project's scope, drafting a strategy, managing the funds and timeline, and ensuring that the project meets its objectives. A project consists of several phases. To ensure that the project is completed on schedule and with the appropriate efficiency, planning for each phase and creating a timeline for each one is necessary.

7.2.2 Project Management in Phase 1 (Planning & Proposal Preparing Phase)

Finding a difficult engineering challenge with complex engineering features is necessary in this step. In this phase, the project's scope is established, and the proposal and project plan are created. The tasks that must be completed, the supplies needed, and the project timeline are all listed in the project plan. The planning and proposal preparation phase is essential since it sets the foundation for the rest of the engineering project. Bangladesh suffers from a power deficit, which is why the project "Design and Implementation of Real-Time Monitoring System for Solar Photovoltaic System" was chosen. By generating sustainable energy, our initiative can assist in solving this issue. It was essential to conduct background research in order to comprehend and develop the project. Three design approaches were chosen following the literature research. Project schedule, financial strategy, moral concerns, and risk assessment follow. anticipated results, and relevant codes were identified.

7.2.3 Gantt Chart for Phase 1

This is the Gantt chart of phase 1,[Table 12] where the tasks for this phase were divided between the group members and there was a timeline so that everything was completed within the time period.

Project Title: Design and Implementation of a Real Time Monitoring System for Solar Photovoltaic Systems

Group no: 06 (Tonny,Adil,Utsho,Diganta)
Semester: Spring 2023(**FYDP-P**)
Project Start Date: 9th February 2023

Table 7.1: Phase 1 Gantt chart

Task	Assigned to	W1	W2	W3	W4	W5	W6	W7	W8	W9	W 10	W 11	W 12	W 13
Discussion regarding Topic selections	All													
Topic Finalization	All													
Literature review: Finding gaps, multiple design approach and spec	All													
Specifications, Requirements & Constraints analysis	All													
Concept Note drafting & Progress Presentation 1	All													
Optical solution finding	All													

Component selection	**All**													
Assess impact and Sustainability Check	**All**													
Applicable standard and codes	**All**													
Planning & Budget	**All**													
Ethical issues, safety consideration and Project proposal drafting	**All**													
Preparation for progress presentation 2	**All**													
Project proposal report	**All**													

7.2.4 Project Management in Phase 2 (Design and Development)

Our project goals for FYDP-D were to build an optimal design approach based on several criteria. To do this, we had to create a task list and assign tasks to the members, such as creating simulation files and writing microcontroller control codes.

To guarantee efficient cooperation before beginning work on phase 2, FYDP-D, we created a Gantt chart. Throughout this time, we completed all of the work under the Gantt plan. Phase 2 culminates in the optimal design approach, which is our intended outcome. It is determined by many elements, including stakeholder demand, power calculations, and safety and risk management considerations. As of right now, the project is moving along satisfactorily and we are ahead of time. The intended milestone has been reached, and there is no more work to be done on this phase.

7.2.5 Gantt Chart for Phase 2

In order to start working on the project phase 2, we created a Gantt chart to ensure effective teamwork and task completion. The Gantt chart of phase 2 is given below.

Project Title: Design and Implementation of a Real Time Monitoring System for Solar Photovoltaic Systems

Group no: 06 (Tonny,Adil,Utsho,Diganta)
Semester: Summer 2023(**FYDP-D**)
Project Start Date: 1st June, 2023

Table 7.2: Phase 2 Gantt chart

Task	**Assigned to**	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W 10**	**W 11**	**W 12**	**W 13**
Evaluation criteria Discussion & Literature review about system design.	All													
Software finding & designed draft circuit for Approach 1 & 2	All													
Draft circuits of All design approach	All													
Progress presentation and discussion on the corrections suggested in progress presentation	All													

Update in the Design Approaches	All													
Simulation Report of all design approaches	All													
Preparation for Final Presentation	All													
Report writing and Submission	All													

7.2.6 Project Management in Phase 3 (Completion & Execution)

In the Final Year Design Project-D phase, the two suggested design approaches were combined to create the final design approach. Initially, we purchased every single part needed to create a project prototype. Second, we examined whether or not each component was operational. After that, we assembled every subsystem, which comprised every sensor—such as the temperature, humidity, and light intensity sensors—and verified that the circuit was operating as intended. According to the project management execution method, the budget was created together with the cost-benefit analysis for both prototype and actual field deployment. As a result, the suggested design approach's execution is successful.

7.2.7 Gantt Chart for Phase 3

The Gantt chart of phase 3 is given below.

Project Title: Design and Implementation of a Real Time Monitoring System for Solar Photovoltaic Systems

Group no: 06 (Tonny,Adil,Utsho,Diganta)
Semester: Fall 2023(**FYDP-C**)
Project Start Date: 1st October, 2023

Table 7.3: Phase 3 Gantt chart

Task	**Assigned to**	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W 10**	**W 11**	**W 12**	**W 13**
Component verification & testing	All													
Testing and Evaluation	All													
Adjustment	All													
Test 1 on breadboard	All													
Test 2 on veroboard	All													
Final Test	All													
Project Observe	All													
Project Debugging	All													
Preparing Project Report	All													

7.3 Evaluate Project Progress

In this project, the group meetings were the most crucial component. Through the group gathering, the majority of the problems were resolved. Each person split the job and completed it on schedule.

The ATC panel assisted in resolving any significant issues that arose. Every statement and critique from the ATC panel was captured and documented in the book. This made it possible to finish the job perfectly and on schedule. Keeping track of the progress was made easier by recording in the logbook. Every step had a Gantt chart produced before it began, which made it easier for everyone to finish the project on schedule.

7.4 Conclusion

Being relatively new to project management, we encounter challenges such as limited supply, budgetary concerns, work distribution, and so on to reach the project's milestone. In these situations, we must show that we have scenario management skills to get beyond the obstacles and accomplish the necessary goals. During our Final Year Design Project (FYDP), we had many challenges, but with our skills and the appropriate choices, we were able to successfully handle every problem with the aid of the ATC panel members and round-robin.

Chapter 8: Economical Analysis

8.1 Introduction

The financial consequences and possible rewards of adopting a solar monitoring system must be understood through an economic study of the system. This research explores more than just the technical elements of energy production monitoring; it also explores the economic feasibility, return on investment, and other factors that impact how cost-effective it is to integrate a monitoring infrastructure overall. The main components of a thorough economic analysis of a solar monitoring system will be examined in this paper. This report intends to give stakeholders, investors, and decision-makers a comprehensive knowledge of the economic environment around solar monitoring systems, including everything from the upfront costs and operational considerations to prospective energy yield increases and regulatory factors.

8.2 Economic Analysis

Here we are providing the price for a sample system with our processing unit which can provide the monitoring facility. Normally people who are using solar panel systems in rural areas can follow this budget and apply it for their service area and can monitor their system easily. We are giving this budget because in market there are many solar inverter available with the monitoring features like “Growatt” but the price of that inverter closely 1 lac tk and the consumer have to buy the other solar system materials so the cost could be near 2 lac tk which is a huge amount for a rural area’s consumer.

We are showing the budget table for a consumer who can use a normal solar panel system with a normal inverter and use our processing unit to easily monitor their system with low cost.

Table 8.1: Breakdown of budget for a rural area's consumer for a home setup

<table>
<tr><th colspan="2">Sub System</th><th>Component</th><th>Price</th></tr>
<tr><td colspan="2">Power
generation</td><td>Solar panel (165W x 4)
Wire</td><td>40,000 TK
2,500 TK</td></tr>
<tr><td colspan="2">Data & processing Unit</td><td>Microcontroller</td><td>500TK</td></tr>
<tr><td colspan="2">Energy storage</td><td>Lead-acid battery (40A)</td><td>7000 TK</td></tr>
<tr><td colspan="2">DC-AC conversion system</td><td>Inverter (1000W)</td><td>5000 TK</td></tr>
<tr><td rowspan="5">Processing unit</td><td>Sensor</td><td>Voltage sensor
Current sensor
Temperature sensor
LDR</td><td>250 TK
300 TK
200 TK
50 TK</td></tr>
<tr><td>Output unit</td><td>Liquid crystal display</td><td>400 TK</td></tr>
<tr><td>Communication module</td><td>ESP8266
GSM module</td><td>680 TK
600 TK</td></tr>
<tr><td>Medium</td><td>PCB board</td><td>2000 TK</td></tr>
<tr><td>DC to DC converter</td><td>HW-411A LM2596</td><td>200 TK</td></tr>
<tr><td colspan="2"></td><td>Total</td><td>59,680 TK</td></tr>
</table>

Table 8.2: Designed prototype budget breakdown

Sub System		Component	Price
Power generation		Solar panel Wire Solar charge controller	1000 TK 200 TK 850TK
Energy storage		Lead-acid battery Battery charger	1250 TK 900 TK
Processing unit	Sensor	Voltage sensor Current sensor Temperature & humidity sensor LDR	250 TK 300 TK 200 TK 50 TK
	DC to DC buck converter	HW-411A LM2596	200 TK
	Output unit	Liquid crystal display	400 TK
	LCD adapter	12C LCD Adapter	120 TK
	Communication module	ESP32	680 TK
	GSM module	SIM 800L	600 TK
	Connection board	Veroboard	100 TK
		Total	**7,110 TK**

8.3 Cost Benefit Analysis

A solar monitoring system's cost-benefit analysis (CBA) is necessary to evaluate the advantages and financial effects of putting it into place. This study compares the expected advantages of the monitoring system against the expenses associated with installing and maintaining it for the solar power infrastructure.

In terms of expenditures, the initial outlay includes those for software, hardware, and installation. Ongoing operating and maintenance expenses, such as software upgrades, sensor replacements, and any membership fees for monitoring services, are additional factors to take into account. Given the lifespan of the monitoring system's components and the possibility of future updates, it is imperative to account for all lifecycle costs.Conversely, there are some advantages. Real-time data on energy generation, system performance, and environmental variables are provided by a solar monitoring system. With the use of this data, problems like soiling, shading, and equipment faults may be promptly identified and fixed, improving overall production and energy efficiency. Enhanced system efficiency results in increased energy production, which can shorten payback times and generate income.

Further enhancing the financial benefits is the potential for reduced maintenance expenses and downtime as a consequence of early detection and correction of inefficiencies. Predictive maintenance is made easier by the data gathered by the monitoring system, which lowers the possibility of unplanned breakdowns and lowers repair costs.There are indirect benefits to take into account in addition to direct financial rewards. Optimized solar systems may produce more energy and reduce greenhouse gas emissions, which is in line with sustainability objectives and may qualify for environmental certifications or incentives.

Even if a solar monitoring system has clear financial benefits, it's crucial to carry out a careful risk analysis in order to pinpoint any potential disadvantages and uncertainties. The total economic viability may be impacted by variables such unexpected system breakdowns, legislative changes, and technological obsolescence. However, a well-conducted cost-benefit analysis offers a thorough grasp of the financial ramifications, enabling decision-making about the installation of a solar monitoring system and guaranteeing a harmony between sustainable energy practices and economic feasibility.

8.4 Evaluate Economic and Financial Aspects

A solar monitoring system's effects on financial returns, environmental sustainability, and energy efficiency are all included in the system's economic and financial evaluation. To provide a satisfactory return on investment, initial hardware and installation expenses must be balanced against advantages like higher energy yield and less downtime. To maintain the system's long-term economic sustainability, ongoing operating costs and associated risks—such as technological obsolescence—should be taken into consideration. Scalability, incentives, and financing alternatives are important factors that influence how the solar monitoring system is seen financially and economically overall.

8.5 Conclusion

To sum up, the financial analysis of a solar panel monitoring system makes a strong argument for its financial feasibility while highlighting how important it is for maximizing the performance of solar systems. Reductions in energy costs and improved yields more than make up for the initial costs of hardware, software, and installation. Reduced downtime and maintenance costs offset the continuous operating costs, resulting in a good return on investment overall. The economic impact is further enhanced by the development of jobs, environmental sustainability, and industrial expansion. A well-managed solar monitoring system, while not without hazards, provides a route to financial and commercial success while supporting the larger objectives of sustainability and renewable energy.

Chapter 9: Ethics and Professional Responsibilities

9.1 Introduction

Real-time solar PV monitoring requires a strong sense of ethics and professional responsibilities. Concerns about surveillance systems' ethical implications grow in significance as technology develops. As more and more homes choose for solar and storage, a moral conundrum is about to arise. The media and consumer groups have concentrated their efforts on defining consent and the duty of care due by both parties engaged in personal or commercial transactions, even though the concepts of permission and duty of care are not new.

9.2 Identify Ethical Issues and Professional Responsibility

Real-time solar PV (photovoltaic) systems offer several benefits, but they also present ethical difficulties and need a dedication to professional responsibility. Here are a few key considerations:

- **Data Privacy and Security:** Compiling sensitive energy production and usage data is necessary for real-time monitoring. Safeguarding confidential information from unwanted access and maintaining its confidentiality are essential. Use robust cybersecurity measures, encryption techniques, and access restrictions to secure data. Observe data protection laws and notify relevant parties of security updates.

- **Accuracy and Reliability of Data:** Data which is inaccurate or misleading might result in bad decisions that have detrimental effects on the environment and finances. Regularly calibrate and maintain monitoring devices to ensure the accuracy of data. Be upfront about any limitations or possible mistakes.

- **Environmental Impact:** The production process and final disposal of solar photovoltaic components may impact the ecosystem. Careless ways of manufacturing and disposal might make pollution worse. Adopt solar PV component manufacture, deployment, and disposal procedures that are environmentally responsible. Think about life cycle analyses and search for environmentally sustainable options.

- **Community Engagement:** Solar panel projects might impact nearby populations. Social instability might arise if the populace is not involved and their issues are not addressed. Involve local communities, pay attention to their concerns, and involve them in the process of making decisions. Make an effort to positively impact the communities' social and economic well-being.

- **Emergency Response and Safety:** Human and community damage may arise from accidents caused by inadequate safety measures during installation, maintenance, or emergencies. Establish and carry out safety protocols. Safety regulations must be observed, and emergency response procedures should be taught to staff members.

- **Social and Economic Impact:** Solar PV installations may have an effect on local economies and employment markets. From an ethical perspective, unfair labor practices or a disrespect for regional economic realities might be detrimental. Think about the effects solar PV installations will have on society and the economy. Give local employment creation, fair labor practices, and economic growth first priority.

9.3 Apply Ethical Issues and Professional Responsibility

There are a few key factors to take into account when applying professional responsibility and ethical concerns to real-time solar PV monitoring. This is an explanation of how these ideas may be used in this situation.

- **Data Privacy and Security:** When transmitting and storing data, use strong encryption techniques. To prevent unwanted access, put authentication procedures and access restrictions in place. Update and check security measures on a regular basis. Train staff members on data privacy procedures and adhering to privacy laws.

- **Accuracy and Reliability of Data:** To ensure reliable and precise data, select dependable sensors, perform regular calibrations on monitoring equipment, and implement redundancy measures. Make a timetable for system maintenance for the monitoring systems. Openly discuss any errors that may exist, and work to continuallyenhance the quality of the data.

- **Environmental Impact:** Select manufacturers and suppliers who practice environmental responsibility. While choosing materials and components for monitoring equipment, take the environment into consideration. Encourage eco-friendliness in the planning and implementation of monitoring systems. Look on strategies to reduce the environmental impact of solar PV monitoring.

- **Accessibility and Inclusivity:** Create accessible features and user interfaces that appeal to a wide range of people. Make sure that all stakeholders have access to the data and insights. Assess accessibility while getting feedback from people with a range of requirements. When creating and implementing monitoring interfaces, aim forinclusion.

- **End-of-Life Considerations**: Develop an approach for the ethical recycling or disposal of monitoring equipment. Examine your choices for recycling or reusing parts. Respect environmental laws on the disposal of electronic trash. Work together with recycling centers and inform interested parties about disposal protocols.

- **Emergency Response and Safety:** Establish safety procedures and have staff members who install and maintain monitoring systems go through them on a regular basis. Give emergency response training. Update and conduct safety exercises on a regular basis. Put community and individual safety first in all monitoring operations.

- **Compliance with Regulations:** Remain aware of the laws that apply to solar PV monitoring on a local, national, and international level. Update processes often to comply with legal obligations. A compliance officer should be appointed to oversee regulatory developments. Conduct regular audits to make sure the law is being followed.

9.4 Conclusion

A sustainable, ethical, and responsible deployment of solar energy technology may be facilitated by stakeholders by implementing these ethical principles and adopting professional accountability in real-time solar PV monitoring. This methodology fosters environmental stewardship, builds stakeholder confidence, and guarantees that solar PV installations have a beneficial effect on nearby communities as well as the larger ecosystem.Set aside funds for ongoing professional growth. To keep up with ethical and technical developments, cultivate a culture of learning and adaptability.

Chapter 10: Conclusion and Future Work

10.1 Project Summary/Conclusion

The design and implementation of the real-time monitoring system for solar photovoltaic systems is a significant step towards sustainable and efficient energy management. The project has successfully created an efficient system capable of monitoring critical parameters such as voltage, current, temperature, humidity, and light intensity through the precise integration of sensors, data processing units, and cloud-based platforms. The addition of an alert system improves the system's operation by providing users with timely notifications in the event of abnormalities, assuring the safety and optimal performance of solar PV systems. The comprehensive impact analysis reveals the project's positive contributions across environmental, economic, and social dimensions. The system's capacity to maximize solar energy use not only decreases carbon emissions but also generates economic benefits for users through increased energy efficiency and potential cost savings. The project's user-friendly interfaces and scalability for different scales of solar systems contribute to social sustainability by encouraging individuals and communities to participate actively in sustainable energy practices. However, the accomplishment of this project is only the beginning of a path toward ongoing progress and innovation in the field of solar energy monitoring. This project's future work will include several routes that can improve the system's capabilities and contribute to the expanding landscape of renewable energy technology.

In conclusion, the project serves as a foundation for ongoing advancements in real-time monitoring for solar photovoltaic systems. The future work directions mentioned provide a roadmap for continued innovation, ensuring that the monitoring system remains at the cutting edge of technological breakthroughs and contributes to the long-term growth of solar energy management. The initiative can shape the future of renewable energy technologies and their adoption into mainstream energy habits by committing to continued research and improvement.

10.2 Future Work

Real-time solar PV monitoring is expected to evolve in the future with an emphasis on resolving present issues, greater efficiency, and technological breakthroughs. Future research in the following areas might be conducted for real-time solar PV monitoring:

- **Advanced Sensor Technologies:** Investigate the use of modern sensor technologies to improve data accuracy and precision. To gather more detailed environmental data, investigate the use of advanced sensors for temperature, humidity, and light intensity.
- **Machine Learning Algorithms:** Implement machine learning techniques for historical data prediction analysis. Generate models that can predict system behavior, optimize energy generation, and provide information for preventive maintenance.
- **Enhanced Cybersecurity Measures:** Enhance cybersecurity components to ensure the system's resistance to potential cyber threats. Explore advanced encryption techniques and secure communication protocols to protect data integrity and user privacy.
- **Smart Grid Integration:** For optimal energy exchanges, investigate bidirectional communication with the electrical grid. Investigate smart grid integration potential to engage in demand response programs and contribute to grid stability.
- **User Interface Enhancements:** Improve the user interface for better user experience. Explore immersive interfaces such as augmented reality (AR) or virtual reality (VR) to provide users with more intuitive and interactive monitoring experiences.
- **Community-Based Monitoring Solutions:** Investigate the viability of community-based monitoring solutions. Investigate methods for collecting data from multiple PV systems within a community, potentially generating collective insights and optimizing energy distribution.
- **Advanced Data Analytics:** Employ more advanced data analytics methods to glean insightful information from real-time monitoring data. enhanced performance optimization, anomaly detection, and predictive analytics for solar PV systems.

These future paths reflect areas where innovation and research may contribute to more safe, sustainable, and efficient solar energy systems as the field of solar PV monitoring develops. In order to shape the future of real-time solar PV monitoring, academics, industry experts, and policymakers must continue to collaborate.

Chapter 11: Identification of Complex Engineering Problems and Activities

11.1 : Identify the Attribute of Complex Engineering Problem (EP)

In this project we identified 5P's and below in the table we ticked (√) the P's which have relevance with the project

Attributes of Complex Engineering Problems (EP)

Table 11.1: Attributes of complex engineering problems (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	√
P3	Depth of analysis required	√
P4	Familiarity of issues	
P5	Extent of applicable codes	
P6	Extent of stakeholder involvement and needs	√
P7	Interdependence	√

11.2 Provide Reasoning How the Project Address Selected Attribute (EP)

P1-Depth of knowledge required:

To do this project we need to have the knowledge of using microcontrollers, different types of sensors and about some components like Wi-Fi and GSM modules. In addition, we also need broad knowledge about Solar photovoltaic cells, how the solar panel system works, type of solar panel systems and types of monitoring system. We reviewed some literature about our project so we got huge knowledge about these topics from literature. Moreover, knowledge of different simulation software like proteus, Arduino IDE was also required to analyze the data so this knowledge was also required for our project. Lastly, we can say that for the above-mentioned reason this project fulfills the criteria of P1.

P2-Range of conflicting requirements:

Same energy is required to run the monitoring process is the conflicting case in our project. To run the monitoring process there is some energy needed to power up the microcontroller and processing unit. So, this power needed to be drawn from the battery. That means the solar panel will charge the battery and from that energy the processing unit will work the process and if the solar panel fails to produce energy, then the whole monitoring system will fail to process the work. So, we can say that this project has the P2 criteria.

P3-Depth of analysis required:

The processing unit which is responsible for the monitoring system to work has to analyze the data coming from the sensors connected for the monitoring purpose. For example, Temperature sensor, LDR sensor, Current sensor will take the data from the solar system and will deliver these data to the processing unit, here the processing unit have to analyze the data so that it can find any error is happening or not and send them to cloud server and LCD for the consumer to see the data. That is why we can say that this project has the criteria of P3.

P6-Extent of stakeholder involvement and needs:
This solar panel monitoring system has been designed for the users of solar panel systems who are from rural areas and don't have the electricity facility. Also, the companies who are using solar panel systems can also be the stakeholder of this project. This project has been done for the stakeholder to monitor the solar panel performance and be aware about any kind of performance issue.

P7-Interdependence
The monitoring process of this project is dependent on the produced energy by the solar panel. In addition, to provide the monitoring parameters to the consumer it also depends on the output of the sensor's data. So, this project has interdependence.

11.3 Identify the Attribute of Complex Engineering Activities (EA)

In this project we identified 3A's. The Attributes are ticked (√) bellow in the table with the relevance of our project

Attributes of Complex Engineering Activities (EA)

Table 11.2: Attributes of complex engineering activities (EA)

	Attributes	Put tick (√) as appropriate
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	

11.4 Provide Reasoning How the Project Address Selected Attribute (EA)

In this project we identified three attributes below and we are providing the reasons for identification

A1-Range of resources:
In our project we required many resources to complete it. PV panels, microcontroller, sensors, cloud server, communication module and different types of software like proteus and Arduino IDE and most importantly money is required for this project.

A2-Level of interaction:
For this project the interaction is needed with the owner who is taking the solar panel service. Also, the sensors which are responsible for collecting the data and passing it to the cloud

server and communicating with the consumer through the mobile phone messages is also required for this project.

A4-Consequence for the society and environment

The main goal of our project is to make the consumers aware of solar panels about the performance of their solar panels and get service for a long time. The reason behind our project goal is in most cases we saw that the solar panel was dealing with some performance issue and the life span of the solar panel was getting reduced. For this reason, we are coming up with this project where consumers can monitor their solar panel service and can take action about any issue so that the performance of the solar panel stays the same for a long period of time.

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Appendix

Logbook:

FYDP (C) Spring 2023 Summary of Team Log Book/ Journal

	Final Year Design Project (C) Fall 2023		
Student details	**Name & ID**	**Email**	**Phone**
Member 1	Sanzida Islam Tonny - 18221025	sanzida.islam.tonny@g.bracu.ac.bd	01905517849
Member 2	MD Adil Islam Shopno – 18321039	md.adil.islam.shopno@g.bracu.ac.bd	01828001756
Member 3	K.M Nafiul Islam Utsho – 19121072	km.nafiul.islam.utsho@g.bracu.ac.bd	01886481124
Member 4	Nafiul lslam Diganta – 19310003	nafiul.islam.diganta@g.bra cu.ac.bd	01789647840
ATC Details:			
ATC 6			
Chair	**Dr. A.S. Nazmul Huda**	**nazmul.huda@bracu.ac.bd**	
Member 1	**Nahid Hossain Taz**	**nahid.hossain@bracu.ac.bd**	
Member 2	**Raihana Shams Islam Antara**	**raihanashams.antara@brac u.ac.bd**	

General Notes:

1. In addition to a detailed journal/logbook fill out the summary/key steps andprogress of your work

2. Reflect planning assignments, who has what responsibilities.

3. The logbook should contain all activities performed by the team members(Individual and team activities).

FYDP - P Logbook (Spring 2023)

Date/Time/ Place	Attendance	Summary of meeting	Responsible	Comment by ATC
09.02.23 on campus	1.Sanzida Islam Tonny 2.MD Adil Islam Shopno 3. K.M Nafiul Islam Utsho 4.Nafiul Islam Diganta	1. Need to finalize topic 2. Need to finalize Problem Statement	Task 1:Utsho and Diganta Task 2: Sanzida and Adil	An Introductory Meeting with ATC
14.02.23 Google Meet & Facebook messenger	Everyone	1. Finalizing Topic 2. Ensuring it's a complex engineering problem	Task 1:Utsho and Diganta Task 2: Sanzida and Adil	No meeting with ATC Task 1: Completed Task 2: Partial
14.02.23 Google Meet & Facebook messenger	Everyone	1. Background Research 2. Tentative Objectives	Task 1:Utsho and Diganta Task 2: Sanzida and Adil	No meeting with ATC Task 1: Partial Task 2: Completed
16.02.23 Google Meet & Facebook messenger	Everyone	1. Progress Presentation Preparation 2. Making Slides and Fulfilling CO and PO	Task 1:Utsho and Diganta Task 2: Sanzida and Adil	No meeting with ATC Task 1: Completed Task 2: Completed
19.02.23 Google Meet & Facebook messenger	Everyone	1. Multiple Design Approaches	Utsho, Diganta ,Sanzida and Adil	No meeting with ATC Task 1: Completed
23.02.23 On Campus	Everyone	1. Understanding of Specifications 2. Difference of Functional and Non-Functional Requirements 3. Overall Introduction to Draft Concept Note	Utsho, Diganta ,Sanzida and Adil	Introduction to Draft Concept Note
23.02.23 Google Meet & Facebook messenger	Everyone	1. Finalizing Specifications 2. Requirements and Constraints	Task 1:Utsho and Diganta Task 2: Sanzida and Adil	No meeting with ATC Task 1: Completed Task 2: Partial
27.02.23 Google Meet & Facebook messenger	Everyone	1. Applicable Standards and Codes 2. First Draft of Concept Note	Utsho, Diganta ,Sanzida and Adil	No meeting with ATC Task 1: Completed Task 2: Completed

01.03.23 Google Meet & Facebook messenger	Everyone	1. Changes to First Draft of Concept Note	Utsho, Diganta ,Sanzida and Adil	Review of First Draft of Concept Note
01.03.23 Google Meet & Facebook messenger	Everyone	1. Comparison Table of Multiple Design Approaches 2. Specifications Table	Task 1:Utsho and Diganta Task 2: Sanzida and Adil	No meeting with ATC Task 1: Completed Task 2: Completed
03.03.23 Google Meet & Facebook messenger	Everyone	1. Final Draft of Concept Note	Utsho, Diganta ,Sanzida and Adil	No meeting with ATC Task 1: Completed
05.03.23 Google Meet & Facebook messenger	Everyone	1. Final checkup and changes to Draft Concept Note	Utsho, Diganta ,Sanzida and Adil	Review of Final Draft of Concept Note
07.03.23 Google Meet & Facebook messenger	Everyone	1. Research Gap 2. Aligned Objectives	Task 1:Utsho and Diganta Task 2: Sanzida and Adil	No meeting with ATC Task 1: Completed Task 2: Partial
02.04.23 Google Meet & Facebook messenger	Everyone	1. Review of Proposal Report	Utsho, Diganta ,Sanzida and Adil	Problem Solving of Proposal Report
16.04.23 Google Meet & Facebook messenger	Everyone	1. First Draft of Proposal Report	Utsho, Diganta ,Sanzida and Adil	No meeting with ATC Task 1: Completed

FYDP – D Logbook (Summer 2023)

Date/Time/Place	Attendance	Summary of meeting	Responsible	Comment by ATC
01.06.2023 11.00 AM On Campus	1.Sanzida Islam Tonny 2.MD Adil Islam Shopno 3. K.M. Nafiul Islam Utsho 4.Nafiul Islam Diganta	It was an introductory class for 400D.	Equal Contribution	N/A as it was an introductory class.

04.06.2023 9.30 PM Google Meet	Everyone	Visited Nazmul Huda Sir for the consultation time and some suggestion about the procedure of the 400D procedure	Equal Contribution	N/A
06.06.2023 10.30 PM Google Meet	Everyone	Introductory meeting and discussed the procedure and probable ways to execute.	Equal Contribution	N/A
12.06.2023 9.00 PM Google Meet	Everyone	1. Discussion of Project COs(dividing the tasks to identify the terms) 2. Software Analysis/Review (Researching the advantages and disadvantages of several softwares)	Task 1:Utsho -CO5, CO9, CO11 Diganta- CO9,CO11,CO13 Adil- CO9, CO11, CO15 Tonny- CO6,CO9, CO15 Task 2: Everyone -completed	Task 1: Completed Task 2: Completed
15.06.2023 9.30 PM Google Meet	Everyone	Researched about approach 2 and planned how to execute the simulation.	Equal Contribution	Completed
17.06.2022 9.30 PM Google Meet	Everyone	1.Discussion of software (Modern IT Tools) 2.Review on Background Research (Projects similar to ours)	Everyone	Partially completed
23.06.2023 1.30 PM On Campus	Everyone	Discussion on approach 1 procedure and make some draft plan about our work.	Bring up with proper components that is findable in our country.	Completed
06.07.2023 11.00 PM Offline	Everyone	Gave Progress presentation	Equal Contribution	Completed
09.07.2023 1.00 PM On Campus	Everyone	1. Progress discussion on assigned tasks 2. Meeting with Huda Sir	Equal Contribution	Task 1: Partially completed Task 2: completed
14.07.2023 9.00 PM Google meet	Everyone	1.CO term discussion 2. Software review	Task 1: Adil & Tonny Task 2: Utsho & Diganta	Task1: Completed Task 2: Partially completed

21.07.2023 11:00 – 11:45 AM Google meet	Everyone	1.CO Analysis 2.Software Review 3.Collecting Equations for Project 4. Gantt Chart	Task1: Everyone Task 2: Everyone Task 3: Utsho,Diganta & Tonny Task 4: Adil	Task1: Everyone Completed Task 2: Everyone Partially Completed Task 3 : Partially Completed Task 4 : Partially Completed
28.07.2023 7.00 PM Google Meet	Everyone	1. Discussed and reformed progress plan. 2. Update on Design approach 2	Task 1: Everyone Task 2:Utsho, Diganta	Task 1: Partially completed Task 2: Completed Task 3: completed
04.08.2023 9.00 PM Google Meet	Everyone	1.Update on Design approach 1 2.Update on Design approach 2	Task1:Utsho Task2:Diganta	Task1: Completed Task 2: Partially completed
18.08.2023 10.00 PM Google Meet	Everyone	1. Testing Simulation 2. Finding error for all designs	Task1:Utsho Task2:Diganta	Task 1- Completed Task 2- Partially Done
19.08.2023 10.00 AM On campus	Everyone	1. Approach 1 Circuit update 2. Report Update	Task1:Utsho,Diganta Task 2 : Everyone	Task 1- done Task 2- partially done
20.08.2023 12.00 PM On Campus	Everyone	1. Update on slide 2.Update on Report. 3.Taking Feedback from Huda Sir	Equal Contribution	Task Completed
21.08.2023 11.00 AM On campus	Everyone	Gave Final Year Design Project Design's Final presentation	Equal Contribution	Task Completed
31.08.2023 12.30 PM Google classroom	Everyone	Submitted the FYDP_D report	Equal Contribution	Task Completed

FYDP – C Logbook (Fall 2023)

Date/Time/Place	Attendance	Summary of meeting	Responsible	Comment by ATC
05.10.2023 11.00 AM On Campus	1.Sanzida Islam Tonny 2.MD Adil Islam Shopno 3. K.M Nafiul Islam Utsho 4.Nafiul Islam Diganta	It was an introductory class for 400C. Also as a final Class of this course.	Equal Contribution	N/A as it was an introductory class.
08.10.2023 2.00 PM on Campus	Everyone	Visited Dr. A.S. Nazmul Huda sir for the consultation time and some suggestions about the procedure of the 400C procedure	Equal Contribution	Sir gave us the weekly consultation time and room number also give suggestion on 400C
11.10.2023 10.30 PM Google Meet	Everyone	1. Discussion of Project COs (dividing the tasks to identify the terms) 2. Software Analysis/Review 3. Discus about applicable compliance, standards, and codes.	Task 1 : Everyone Task 2: Utsho & Diganta Task 3: Everyone	N/A
13.10.2023 12.30 PM ATC Meeting (Physical Meeting Nazmul Huda Sir's Room, UB5)	Everyone	1. Discuss the COs and POs on FYDP-400C 2. Updating about our project progress	Equal Contribution	1. Give a broad lecture about 400C COs and POs. 2. Help us by giving suggestions and sharing his ideas.
14.10.2023 11.00 PM Google Meet	Everyone	1. Discussion on ATC meeting and hardware. 2. Choosing IEEE standards Modern IT tools.	Equal Contribution	N/A

19.10.2023 11.00 AM (Physical Meeting Thesis LAB, UB5) On Campus	Everyone	Discussion on Project, things speak software, procedure and how we can assemble our hardware part. Buying hardware tools for the project.	Equal Contribution	N/A
25.10.2023 3.00 PM (Physical Meeting Thesis LAB, UB5) On Campus	Everyone	1. Progress discussion on assigned tasks 2. Start to assemble components.	Equal Contribution	N/A
27.10.2023 12.00 PM ATC Meeting (Physical Meeting Nazmul Huda Sir's Room, UB5)	Everyone	1. COs term discussion 2. Software review 3. Discussion on hardware progress	Equal Contribution	Completed
1.11.2023 11:00 – 11:45 AM Google meet	Everyone	1. Making progress presentation slide 2. writing progress report	Equal Contribution	Completed
2.11.2023 11:00 AM - 2.00 PM Google meet	Everyone	**Online Progress Presentation**	Equal Contribution	Completed
15.11.2023 12.30 PM Google meet	Everyone	Discussion on Progress presentation.	Equal Contribution	Completed
16.11.2023 10.00 AM Google Meet Digonto's house	Everyone	Updated codes, assembling hardware tools , demo test 1	Equal Contribution	Partially done
24.11.2023 3.30 PM Google Meet	Everyone	Providing our progress to Huda Sir	Equal Contribution	Sir told us to complete our project as soon as possible

28.11.2023 Digonto's House	Everyone	Demo Test 2 Calculations of cost Reporting our testing to Huda Sir	Equal Contribution	Completed
5.12.2023 Google Meet	Everyone	Finalizing our project prototype Making Poster for the final project Showcase	Equal Contribution	Completed
14.12.2023 On Campus	Everyone	**FYDP-C Project Showcase (Fall 2023)**	Equal Contribution	Completed

Related Code/Theory

```
#define BLYNK_TEMPLATE_ID "TMPL6BrCmnTxu"
#define BLYNK_TEMPLATE_NAME "solar panel monitoring"
#define BLYNK_AUTH_TOKEN "JfNkTnrEdtAQVItTs6M6eMAwSo0ifJHw"
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <SoftwareSerial.h>
#include <LiquidCrystal_I2C.h>
#include <Wire.h>
#include <DHT.h>
char ssid[] = "Nurul Islam"; //Here use the Wi-Fi name of your router
char pass[] = "harrypotter321"; // Wi-Fi password of your router
char number[] = "01789647840"; // In which phone number you want to get the alert message
#define HI_VOLT 15.0
#define LO_VOLT 10.0
#define HI_AMP 3000.0
#define HI_TEMP 35.0
#define HI_HUMI 80
#define BAT_ADJ  0.01603
#define SOLAR_ADJ 0.01603 //0.01603 (to show the battery voltage) 0.01967(to show the
solar panel voltage)
#define AMP_ADJ  0.25229
#define currPin  36
#define batPin   39
#define solarPin 34
#define lightPin 35
#define dhtPin   13
#define GSM_TX 16
#define GSM_RX 17
// Blynk IDs
#define BAT_VOLT V1
#define CURRENT    V2
#define TEMP       V3
#define HUMIDITY V4
#define LIGHT      V5
#define SOLAR_VOLT V6
SoftwareSerial gsm(GSM_TX, GSM_RX);
LiquidCrystal_I2C lcd(0x27, 16, 2);
DHT dht(dhtPin, DHT11);
float batt, solar;
byte temp, hum, light;
```

```
int amp;
long prevMs;
bool isSMSSent;
void setup() {
  Serial.begin(115200);
  gsm.begin(9600);
  dht.begin();
  lcd.init();
  lcd.backlight();
  lcd.clear();
  lcd.print("CONNECTING WIFI");
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
  Blynk.virtualWrite(BAT_VOLT, 0);
  Blynk.virtualWrite(CURRENT, 0);
  Blynk.virtualWrite(TEMP, 0);
  Blynk.virtualWrite(HUMIDITY, 0);
  Blynk.virtualWrite(LIGHT, 0);
  Blynk.virtualWrite(SOLAR_VOLT, 0);
  analogReadResolution(10);
  gsmInit();
}
void loop() {
  //Blynk.run();
  readSensors();
  updateServerLCD();
}
void updateServerLCD() {
  if (millis() - prevMs >= 1000) {
    // server update
    Blynk.virtualWrite(BAT_VOLT, batt); //use BAT_VOLT, solar to see the solar voltage in
lcd and use batt to see the battery voltage
    Blynk.virtualWrite(CURRENT, amp);
    Blynk.virtualWrite(TEMP, temp);
    Blynk.virtualWrite(HUMIDITY, hum);
    Blynk.virtualWrite(LIGHT, light);
    Blynk.virtualWrite(SOLAR_VOLT, solar);
    // LCD update
    lcd.setCursor(0, 0);
    lcd.print((String)"B:" + String(batt, 1) + "V, " + amp + "mA  "); // use "S:" +
String(solar,1) to see the value of solar volatge in lcd wirh the name of S
    lcd.setCursor(0, 1);
    lcd.print((String) temp + (char)223 + "C, " + hum + "%, L:" + light + "% ");
    alarmLSystem();
    prevMs = millis();
```

```
  }
}
void alarmLSystem() {
  // SMS alarm system
  //if (batt < LO_VOLT && !isSMSSent) sendSMS("Solar Voltage Low!");
  //else if (batt > HI_VOLT && !isSMSSent) sendSMS("Solar voltage High!");
  //else if (amp > HI_AMP && !isSMSSent) sendSMS("High Current!");
  //else if (temp > HI_TEMP && !isSMSSent) sendSMS("High Temperature!");
  if (batt < LO_VOLT) sendSMS("Solar Voltage Low!");
  else if (batt > HI_VOLT) sendSMS("Solar voltage High!");
  else if (amp > HI_AMP) sendSMS("High Current!");
  else if (temp > HI_TEMP) sendSMS("High Temperature!");
  if ((batt > LO_VOLT && batt < HI_VOLT) && amp < HI_AMP && temp < HI_TEMP) {
    isSMSSent = false;
  }
}
void readSensors() {
  batt = readAdc(batPin) * BAT_ADJ;
  solar = readAdc(solarPin) * SOLAR_ADJ;
  amp = readAdc(currPin) * AMP_ADJ;
  int ldr = analogRead(lightPin);
  light = map(ldr, 0, 1023, 0, 100);
  float h = dht.readHumidity();
  float t = dht.readTemperature();
  if (isnan(h) || isnan(t)) return;
  temp = t;
  hum = h;
}
int readAdc(int channel) {
  const byte AVG_NUM = 10;
  int sum = 0, temp;

  for (byte i = 0; i < AVG_NUM; i++) {
    temp = analogRead(channel);
    sum += temp;
    delayMicroseconds(50);
  }
  return (sum / AVG_NUM);
}
void sendSMS(const char msg[]) {
  lcd.clear();
  lcd.print("SENDING SMS...");
  gsm.print(F("AT+CMGF=1\r\n"));
  delay(500);
```

```
  gsm.print("AT+CMGS=\"");
  gsm.print(number);
  gsm.print("\"\r\n");
  delay(500);
  gsm.print(msg);
  gsm.write(0x1A);
  gsm.print("\r\n");
  delay(4000);

  isSMSSent = true;
  lcd.clear();
}
void gsmInit() {
  lcd.clear();
  lcd.print("GSM INIT...");
  for (byte i = 0; i < 15; i++)
    {lcd.setCursor(i, 1);
    lcd.print("-");
    delay(1000);
  }
  gsm.print(F("AT\r\n"));
  delay(500);
  gsm.print(F("ATE0\r\n"));
  delay(500);
  gsm.print(F("AT+CMGF=1\r\n"));
  delay(500);
  gsm.print(F("AT+CNMI=1,2,0,0,0\r\n"));
  delay(500);
  lcd.clear();
}
```