IoT-based Smart Battery Management and Monitoring System For Electric Vehicle

An Undergraduate CAPSTONE Project
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Fall Semester 2022-2023
January, 2023

Faculty of Engineering
American International University - Bangladesh

IoT-based Smart Battery Management and Monitoring System For Electric Vehicle

A CAPSTONE Project submitted to the Faculty of Engineering, American International University - Bangladesh (AIUB) in partial fulfillment of the requirements for the degree of Bachelor of Science in their mentioned respective programs.

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DECLARATION

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APPROVAL

The CAPSTONE Project titled **IOT-BASED SMART BATTERY MANAGEMENT AND MONITORING SYSTEM FOR ELECTRIC VEHICLE** has been submitted to the following respected members of the Board of Examiners of the Faculty of Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in the respective programs mentioned below on **January 2023** by the following students and has been accepted as satisfactory.

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ACKNOWLEDGEMENT

Frist of all we thank our almighty Allah for protecting and give us a chance to determination our project task. We would like to express our deep sense of gratitude to our supervisor, **Dr. Md. Rifat Hazari**, Senior Assistant Professor, Faculty of Engineering, American International University-Bangladesh, for his invaluable encouragement, guidance and support from initial to final stage. without his guidance and persistent help it was impossible to finish this project. with that we would like to express our gratitude to our External Supervisor, **Prof. Dr. Muhibul Haque Bhuyan**, Professor, Faculty of Engineering, American International University-Bangladesh, for his suggestion and supporting to the final level enable us to develop an understanding of our undergraduate project. **Prof. Dr. Md. Abdur Rahman**, Pro Vice Chancellor, Faculty of Engineering, American International University-Bangladesh, and **Prof. Dr. ABM Siddique Hossain**, Dean, Faculty of Engineering, American International University-Bangladesh, received our hearty gratitude. Finally, to our parents we would like to thank to them for supporting us in our daily life for completing this project and having them by our sides to guide us always their prosperity and love for us.

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ABSTRACT

The Internet of Things (IoT) is a new wireless technology platform that is mostly used in the manufacturing of electric vehicles. The use IoT for monitoring the performance of electric vehicle batteries is necessary to solve all problems with current vehicles and to protect the environment. This project objective is to develop an intelligent, IoT based battery management system for electric vehicles. Electric vehicles are currently growing in popularity on a worldwide scale. On the other hand, the cost of fuel is rising every day. These conditions have prompted vehicle manufacturers to search for alternate fuel-free energy sources. The great majority of electric vehicles use rechargeable lithium ion batteries. In the case of lithium-ion batteries, for example, overcharging the battery significantly decreases battery life and raises the possibility of disastrous safety risks like fire. To minimize the identified issues, electric vehicles must have a battery monitoring system (BMS), which can notify the user about battery condition. Due to improvements in the architecture of the notification system, IoT technology can be used to notify the manufacturer and users about the condition of the battery. The present generation's battery packs don't have the energy density or efficiency for the upcoming generation. In battery management system c ell blanching in a lithium battery will help to improve the situation by using a battery management system. Finding nearby electric vehicle charging stations is another necessary stage that will enable the technology supporting them develop and maintain pace with the needs of the modern world.

Chapter 1

INTRODUCTION

1.1. Overture

In today's world, using green energy is becoming more and more crucial. As a result, when it comes to both personal and public transportation, electric vehicles are now the most environmentally friendly option. Lithium-ion batteries have a high energy and current density, which makes them a common component in electric vehicles. Unfortunately, if used outside of its Safety Operation Area, lithium-ion batteries can be hazardous. Therefore, every lithium-ion battery, especially those used in electric vehicles, must include a Battery management system (BMS). The goal, duties, and topologies of the battery management system are thoroughly explored in this paper. This chapter also discusses the hardware and system designs for BMS as well as early battery models. Electric vehicles employ BMS to monitor and regulate the charging and draining of rechargeable batteries, which facilitates operation. Battery management technology keeps the battery secure, dependable, and senile without going into a destructive state. As electric vehicle technologies develop, automakers are starting to embrace lithium ion batteries as their preferred electrical energy storage option for usage in both current and future vehicles. However, a precise assessment of battery performance, health, and life forecast is essential to ensure that batteries are dependable, efficient, and capable of delivering power and energy when required. There are numerous ways to recharge an electric vehicle's battery, but charging stations will be the primary energy source. The locations of charging stations are crucial; they need not only be widespread enough for an electric vehicle to easily access one within driving distance wherever it is. It is therefore challenging to locate the closest charging station. Using the GPS system, we examined and enhanced this system in this chapter [1-4].

1.2. Engineering Problem Statement

This concept is an actual solution that utilizes alternative energy sources as fuel for electric vehicles. Lithium ion batteries, which have a long life, use safety, large capacity, environmental protection, and other advantages, are primarily utilized in electric vehicle batteries today.

Electric vehicles (EVs) are being developed as a potential way to attain this ambitious objective of creating a cleaner environment and enabling better modes of transportation. The primary objective of our research is to notify and monitor the battery life cycle, such as discharging, overcharging, and temperature issue in battery cell, as it is typically difficult to monitor and maintain the battery life in a good manner. Using a BMS and cell balancing in each lithium-ion battery cell can resolve this issue. When an electric vehicle's battery is depleted, it is nearly impossible to locate the closest charging station. To integrate a GPS system into our project in order to transmit the nearest location via a mobile device link. This is the simpler solution to this type of problem [7].

1.3. Related Research Works

It is essential to thoroughly explore the work of others before beginning any research or review project in order to have a strong understanding of our own. A survey of relevant work on related themes is offered, and a general comparison between our work and that of others is established. Management of batteries is required for safety reasons. There are numerous causes of battery failure, including battery degeneration and design flaws. Manual battery monitoring systems are similar to conventional battery monitoring systems in that they do not store data in a database. However, only display data collected in real time [8].

1.3.1. Earlier Research

The battery management system in any electric vehicle is essential. Currently, the power battery management system just controls and monitors the voltage of the group of power batteries. A single battery could be overcharged and over discharged as a result, reducing the power battery's cycle life. In this study, every battery cell is tracked and managed to avoid any overcharging or over discharging of the batteries. Power battery management system hardware and software have been developed.

1.3.1.1. History of Electric Vehicle

In the late 1890s, at the dawn of the automobile age, steam, gasoline, and electric automobiles all battled to be the dominant automotive technology. By the beginning of the 20th century, internal combustion had won the war. In the context of the history of American transportation, the author investigates the interaction between technology, society, and the environment and system selection and economic progress. The author also examines current discussions regarding the social and environmental implications of the automobile, the arrival of new hybrid automobiles, and initiatives to revert to battery-powered vehicles [9].

1.3.1.2. Battery Management System in Electric Vehicle

An appropriate battery management system is essential for assuring the safe and dependable operation of batteries in several high-power applications, such as electric cars (EVs) and hybrid electric vehicles (HEVs). The purpose of this work is to provide a concise overview of various important BMS technologies, including battery modeling, state estimation, and battery charging. First, a survey of prevalent battery types utilized in EVs is presented, followed by an overview of main BMS technologies.

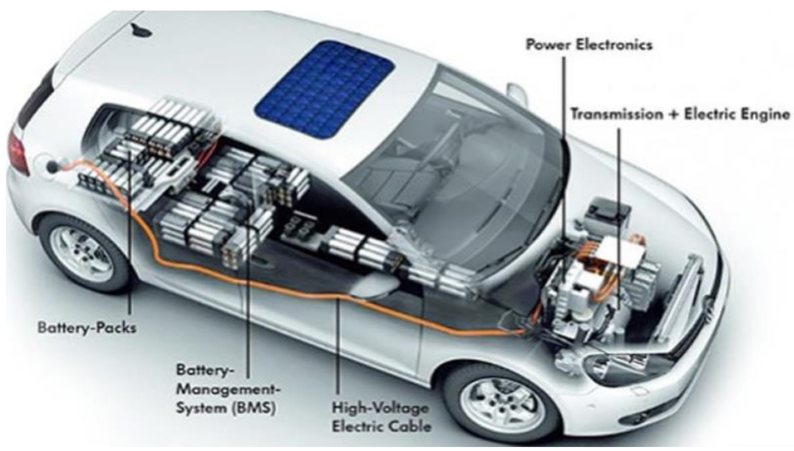


Figure 1.1: Battery Management System in Electric Vehicle [8].

1.3.1.3. Battery Cell Balancing

Cell balance is one of the BMS's primary responsibilities. A balanced battery is one in which all the cells have the same state of charge (SOC) at a given SOC. A battery's cells may be unbalanced in a number of ways, including SOC, self-discharge current, internal resistance, and capacity. Passive and active balancing topologies can be used to broadly classify the balancing topologies.

- **Passive cell balancing topologies**

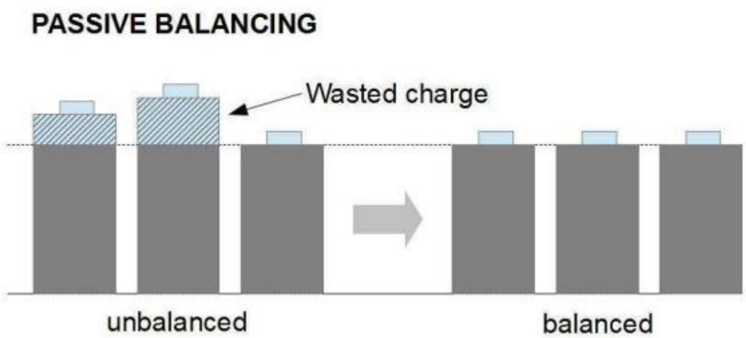


Figure 1.2. Passive balancing [10].

Passive balancing circuits execute their function by sampling all cell voltages, identifying the lowest voltage cell in the stack, and leveling all remaining higher voltage cells to this level by discharging these higher potential cells.

- **Active cell balancing topologies**

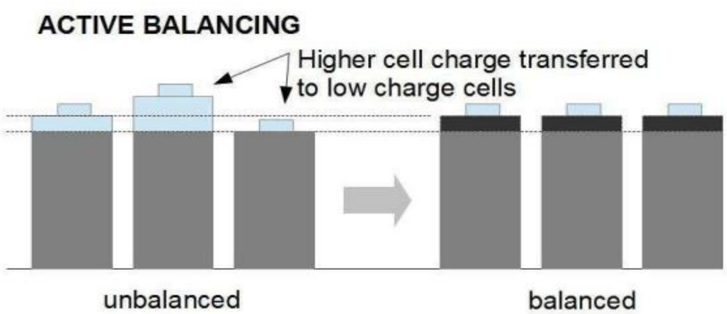


Figure 1.3. Active balancing [10]

1.3.1.4. Overview on Lithium-ion Battery

The battery was the only source of electricity at the turn of the 20th century because the power generator and grid supplies had not yet been invented. Numerous varieties of batteries have been developed as a result of the technology's continual advancement. The "wet cells" had liquid electrolytes and metallic electrodes in an open container and were widely utilized. This sort of battery was recycled by replacing the components. Due of their lack of portability, early EVs utilized semi-sealed wet cells.

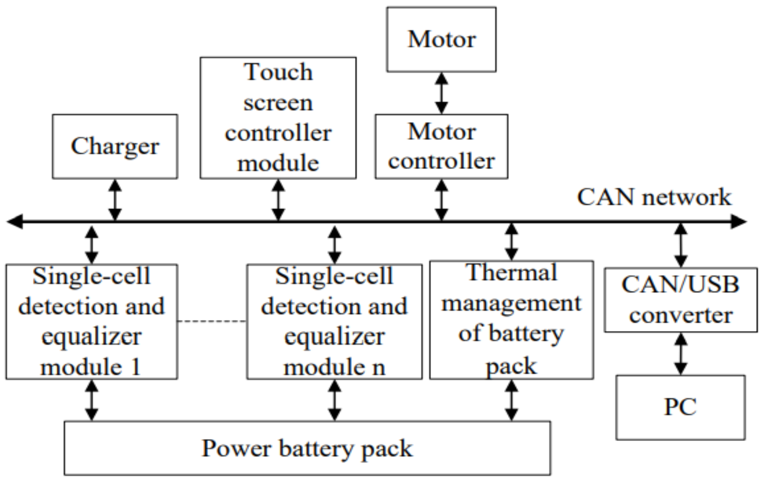


Figure 1.4: Overview of Lithium-ion Battery [11]

In the early days of battery technology, the current was produced by the built battery; unfortunately, this battery could not be electrically replenished when its active parts ran out. When rechargeable varieties of lead-acid batteries that could be recharged with electrical energy were developed, a significant advancement was made. It could repeatedly store energy and extend its lifespan [11].

1.3.1.5. Performance Comparison Lithium-ion Battery

Li-ion batteries are the most viable option for achieving equitable and efficient transportation for sustainable global development. Soon, battery-powered vehicles, such as EVs, HEVs, PHEVS, and BEVS, will dominate the automobile and aircraft sectors and industries.

1.3.1.6. Battery Thermal Management System

Due to the varied battery charge-discharge behaviors at different temperatures and the fact that battery temperature will affect the cycle life of the battery, it is necessary to detect and control the temperature of the battery pack. Under conditions of high power discharge and high temperature, thermal management of a power battery pack is crucial. In battery pack thermal management systems, battery pack cooling has been extensively explored. However, at low temperatures, battery energy storage would be diminished, hence heating of the battery pack has also been explored for low temperature environments to maintain battery safety [11].

1.3.1.7. Charging Machine Control System

When the battery pack requires charging, the touch screen controller module chooses between rapid and standard charging. Touch screen controller module parameters for charge current and charge cutoff voltage must be entered for rapid charging. When the current size of the setup is complete, the touch screen controller module will communicate charge orders and the charging current size to the charger through the CAN bus. The charger then begins charging. BMS has monitored and regulated the charging and discharging processes of the battery pack. In the charging process, the battery management system sets the charging parameters and charging mode, and in the discharging process, the battery BMS controller receives the voltage and state of charge of the battery pack [12].

1.3.1.8. Key technologies for BMS

Battery requires special consideration in EV applications. Incorrect operations, such as excessively high or low temperatures, overcharging, or discharging, will dramatically accelerate the battery's degeneration. In addition, the battery pack of electric vehicles often consists of hundreds of battery cells coupled in series or parallel to meet the high power and high voltage requirements of the vehicles [13].

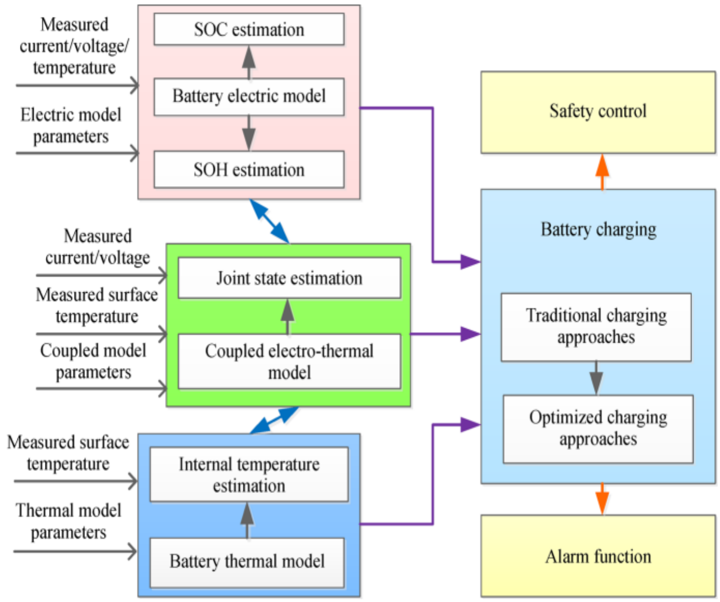


Figure 1.5: The BMS relationship with critical technologies [13].

1.3.2. Recent Research

An appropriate battery management system is essential for assuring the safe and dependable operation of batteries in several high-power applications, such as Electric Vehicle (EVs) and Hybrid Electric vehicles (HEVs). A smart BMS is a crucial component of electric vehicles; it not only measures the charge states precisely, but also assures safe operation and extends the battery life. State of charge (SOC) assessment of a Li-ion battery is extremely difficult due to the battery's highly time-variant, nonlinear, and complicated electrochemical system [14].

1.3.2.1. Battery Management System (BMS) for EVs

The BMS of EVs is comprised of several sensors, actuators, and control. An effective BMS performs the following primary functions:

- Battery protection
- Battery operation within safe limits of current, voltage, and temperature and
- Exact measurement and estimation of battery states.

Installed voltage and current measurement unit measures the voltages and currents of the entire string as well as a single cell. The temperature control unit is included to measure the battery and coolant temperatures. Through this machine, the cooling and heating system can be controlled.

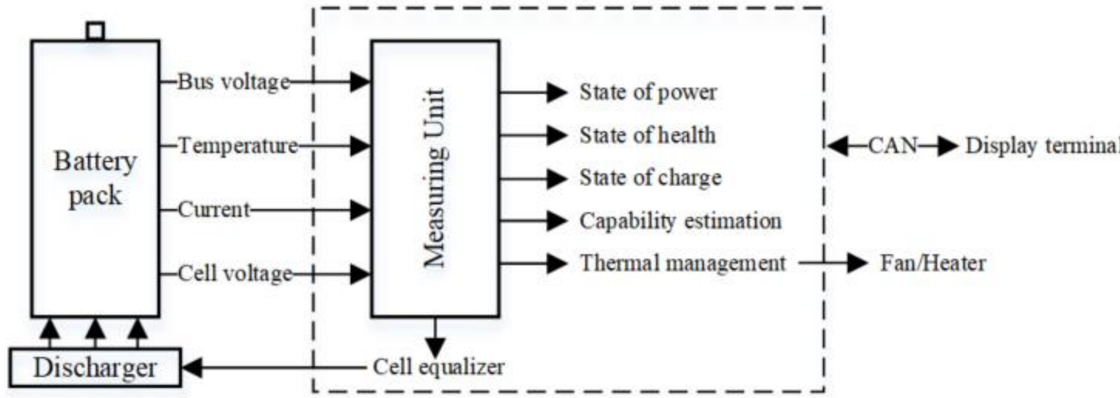


Figure 1.6: General diagram of a BMS [14]

The safety unit is used to protect the battery packs from physical harm. Additionally, the technology safeguards the battery packs against overcharge and over discharge circumstances. The digital output of the BMS includes the State of Charge (SOC), State of Health(SOH), indicator for balancing work, and failure alarm. Given the non-linear and irregular behavior of a battery, it is difficult to estimate the SOC with precision and accuracy.

1.3.2.2. Methods to Estimate SOC

As previously said, an accurate SOC estimation is the most important aspect of the BMS design in electric vehicles. This not only offers information on the battery's useable energy, but also prevents overcharging and undercharging. Therefore, the SOC estimation has garnered substantial interest, and various approaches have been published in the literature to accurately and precisely estimate the SOC. Ampere hour method is a general and simple method to calculate SOC, which is illustrated as follows,

$$SOC(k) = SOC(k_0) + \int_{k_0}^{k} \eta I(t) \mathrm{d}t / C_n, \quad \text{———— (1.1)}$$

Figure 1.7: Estimate equation of SOC

where means the effectiveness of battery charging or discharging, SOC indicates the known initial SOC, and C_n indicates the battery nominal capacity.

1.3.2.3. Technology Based on Wireless Battery Monitoring System

Battery management must be reliable for safety reasons. There are numerous causes of battery failure, including battery degeneration and design flaws. Manual battery monitoring systems are similar to conventional battery monitoring systems in that they do not store data in a database. However, only display data collected in real time. Developed a battery health monitoring system for an uninterruptible power supply (UPS) using GSM modules and SCADA by giving alert messages when batteries are in critical condition and room temperature. The system could monitor the battery's voltage, current, and temperature. Using wireless communication, created a battery monitoring system for UPS to detect dead battery cells [14].

1.3.2.4. Review Battery Management System

The BMS also communicates with the contactors to ensure safety and to manage the battery system's input and output current. The Battery Thermal Management System is the equipment responsible for managing/dissipating the heat created by electrochemical processes in cells, allowing the battery to operate safely and efficiently.

- **Typical Battery management system**

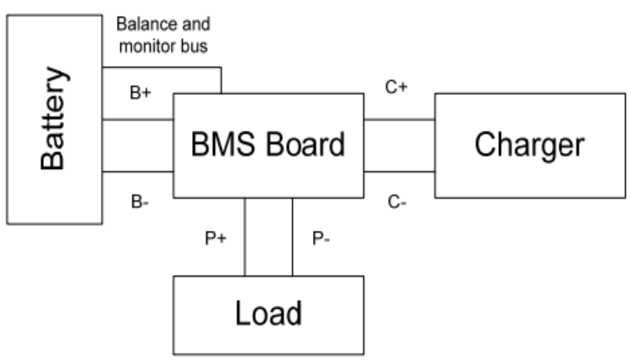


Figure 1.8: Block diagram of a typical battery management system [15]

The current BMS design is offline and local, meaning it operates without an Internet or server. For applications requiring a higher level of control and monitoring, the "master" unit may also be in communication with a user interface

- **Current Battery Management System**

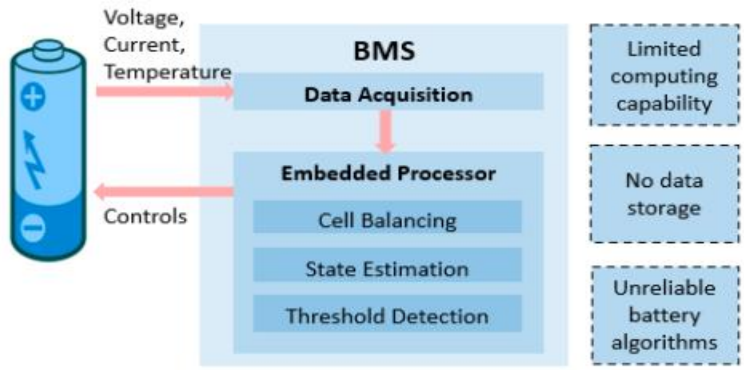


Figure 1.9: Current battery management system [15]

Due to their high energy density, low self-discharge rate, extended cycle life, and wide operating temperature range, Li-ion batteries are widely employed in the electric vehicle and energy storage industries. A battery management system is essential for ensuring the safety and extending the useful life of Li-ion battery packs [15].

1.3.2.5. Electric Vehicle Charging System

This project demonstrates a smart charging system for electric vehicles using cloud-based monitoring and administration. Charging Management System is essential for the ever-changing needs of charging infrastructure, including the viewpoints of manufacturers, electricity providers, car owners, and charging service providers. Through a dedicated interface, the developed system is able to provide real-time information to electric vehicle (EV) users regarding the nearest charging station with the shortest waiting time and the lowest charging cost, as well as a secure online access mechanism for accessing the EV's State of Charge [12].

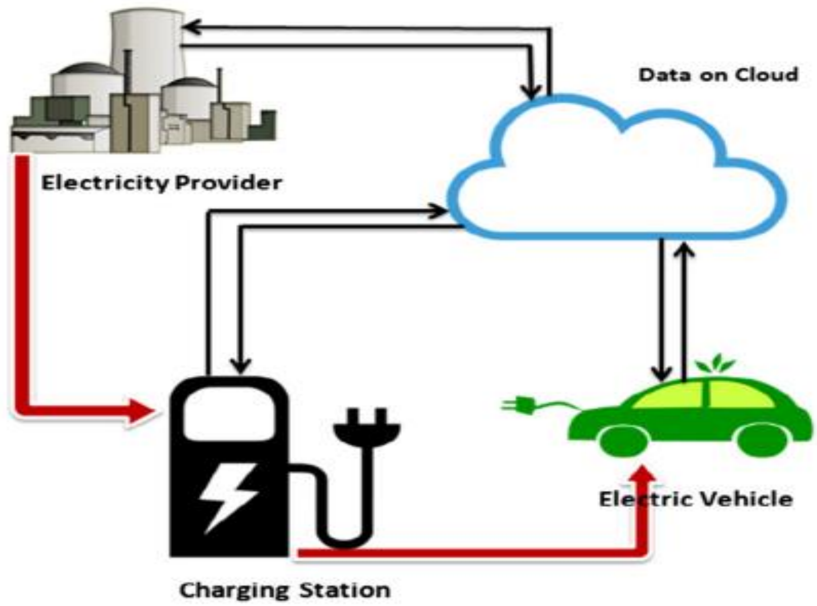


Figure 1.10: Data and energy flow for EVs charging Management [17]

1.3.2.1. Electric Vehicle Charging

Figure 1.11: Electric Vehicle Charging [19].

Charging of electric vehicles should be done in a balanced manner, taking into consideration prior experience, data-mined meteorological information, and simulation techniques. A mobile application was also developed to support the EV driver with these activities in order to enable information interchange and to aid user mobility. In order to connect electric vehicles and renewable energy sources to smart grids, this proposed smart electric vehicle charging system leverages vehicle-to-grid (V2G) technology [19].

1.4. Critical Engineering Specialist Knowledge

Due to rising concerns about global warming, greenhouse gas emissions, and the depletion of fossil fuels, electric vehicles (EVs) have gained immense popularity in recent decades as a result of their performance and efficiency. Considering the most potential replacements for lowering CO_2 emissions and worldwide environmental challenges, EVs have already received widespread acceptance in the automotive industry. Lithium-ion batteries have attracted a great deal of interest for use in EVs due to its advantageous characteristics, which include their light weight, rapid charging, high energy density, low self-discharge, and extended lifespan [18].

This project aims to develop an Internet of Things-based intelligent battery management solution for electric vehicles. Lithium-ion batteries have found widespread use in consumer electronics due to their superior energy density, power density, service life, and environmental friendliness in comparison to other regularly used batteries. However, lithium-ion batteries for vehicles have high capacity and big serial-parallel numbers, which, together with safety, durability, uniformity, and cost issues, restricts their widespread deployment in the vehicle industry [24-25].

This following topic are utilized this system

- **Programming:** To configure the smart battery management system to do the essential tasks, it must be suitably programmed, which demands in-depth programming skills.
- **Communication:** In this proposed system, communication and interfaces are crucial components. To interface with the various sensor types utilized by this system, distinct interfacing protocols are required.
- **IoT Communication:** The Internet of Things (IoT) is the future of communication and should be incorporated into all smart technologies. To properly configure this IoT connection, much knowledge and testing are required [26].

1.5. Stakeholders

This project ideal for manufacture of electric vehicle all over the world. As the automotive industry shifts from Internal Combustion Engine (ICE) vehicles to Electric vehicles, many countries are setting new strategies in their transportation sector. The Li-ion battery is currently the most common battery used in EVs due to its high energy density, durability, safety, and cost competitiveness. The strategies of the key stakeholders involved in the development and commercialization of EV and their charging infrastructure. Using the perspective of sociotechnical transitions, we relate the stakeholder strategies to their existing and future interests, as well as their expectations for EVs. Our study is predicated on a series of 38 semi-structured interviews with representatives of various Dutch stakeholders. The strategies of the key stakeholders involved in the development and commercialization of electric cars (EVs) and their charging infrastructure. Using the perspective of sociotechnical transitions, Relate the stakeholder strategies to their existing and future interests, as well as their expectations for Electric Vehicle System [20]

The construction of charging infrastructure is essential for the spread of electric vehicles. However, there appears to be significant dispute regarding when, how, and what type of charging infrastructure should be constructed, and most crucially, why. The perspective of the stakeholders on the future conceals these motives. Due to popular demand, electric vehicles emerge as a viable method for decarbonization and green mobility. As the demand for sustainable development in the electric car industry increased, numerous initiatives and efforts were undertaken by researchers. The results are displayed in cluster, timeline, and time zone views in order to examine the industry's dynamic direction and future developments. The significance of stakeholders and their interdependence is implied by additional trend detection and prospective analysis. This paper suggests the stakeholder engagement system from a complete standpoint in response to the important problems of sustainable development [22]

Electric vehicle as a green transportation tool has superior energy conversion efficiency and zero green gas emissions compared to traditional internal combustion car as the trend toward green transportation grows. According to a statement by the Chinese government, a national strategic plan for the electrification of transportation for the years 2011–2015 has been developed. In addition, the Chinese government establishes a 'ten cities and thousands units' strategy to boost the New-Energy Vehicle (NEV) penetration levels in public transportation, with a goal of five million NEVs by 2020 [23]

1.6. Objectives

The project's ultimate purpose to create an IoT Based Smart Battery Management and Monitoring System for Electric Vehicle. A battery for an electric vehicle is an energy accumulator that stores electricity for delivery to an alternating current or constant current engine. However, its significance goes far beyond this. The battery is what makes these vehicles sustainable, reducing their need on fossil fuels. The main objective of this project is to design and monitoring battery management system of electric vehicle. In this section there are two parts one is primary objective and another is secondary objective.

1.6.1. Primary Objectives

- To Develop Battery Management System, which manages the electronics of a rechargeable battery, whether a cell or a battery pack, becomes an essential element in assuring the safety of electric vehicles.
- Communicate the wireless information using IoT (Internet of things)/website.
- Implement the proposed Battery Management and Monitoring system in Proteus Software.
- Develop Mobile Application to use GPS system for find nearest location of EV charging station
- To design and implement an IoT-based Smart Battery Management System that can be seamlessly integrated into any consumer or industrial application.

1.6.2. Secondary Objectives

- Provide Internet-based monitoring of the battery charge.
- Simulate all the function of Lithium-ion battery.
- Enhance fuel economy, minimize fuel expenses, and cut emissions.
- Test the hardware implantation overall.

1.7. Organization of Book Chapters

Chapter-2: Project Management

- This chapter will examine this project's analytic theories from a different angle. The S.W.O.T (Strengths, Weaknesses, Opportunities, and Threats) study will be performed on the project, while the P.E.S.T (Political, Economic, Social, and Technological) analysis will be performed.

Chapter-3: Methodology and Modeling

- This chapter will provide an in-depth analysis of the project's modeling. Here, system block diagrams and simulations will be discussed.

Chapter-4: Implementation of Project

- This chapter will focus primarily on the completed project. The operating principle of all the designed electronic components and systems will be detailed here.

Chapter-5: Results Analysis & Critical Design Review

- This chapter will contain the system's conclusion. In addition, an examination of the system's performance and a comparison of the practical outcome with the theoretical and simulated results will be presented.

Chapter-6: Conclusion

- This is the final chapter of the thesis. This chapter will cover the overall project, its limits, and opportunities for development. This chapter will also include the environmental impact survey results.

Chapter 2

PROJECT MANAGEMENT

2.1. Introduction

A Smart Battery Management System for Electric Vehicles offers a two-way communication channel between customers and service providers. The Battery Management System, or BMS, plays an essential function in electric vehicles. A BMS is required to monitor and maintain the battery pack for appropriate use. The battery management system is an integral part of electric vehicle (EV) and hybrid electric vehicle (HEV). In electric vehicles, BMS is used to monitor and control the charging and discharging of rechargeable batteries, making the operation more efficient. In order to boost energy efficiency, consumers must become more conscious of their consumption. The purpose of this part is to go deeper into the project management strategy.

2.2. S.W.O.T. Analysis

Strengths, Weaknesses, Opportunities, and Threats (SWOT) are names that stand for these four concepts. Used as a strategic planning tool by project managers to evaluate the advantages and drawbacks of their initiatives, as well as any future prospects and potential problems. This popular strategy enables project managers to identify areas for improvement and select the most appropriate research methodologies for the task, which can be advantageous.

2.2.1. Strengths

- Electric Vehicle are propelled by most rechargeable lithium-ion battery that is stored electricity in a battery pack.
- No need to check the battery pack condition or reading manually.
- Electric vehicles can be charged at home, at work, or while anywhere.
- It sends the reading battery health and percentage of charge to the user though notification via the mobile app.
- If the battery temperature across the temperature limit then it notified an alert to the consumer.

2.2.2. Weaknesses

- Battery Management system is unable to detect the structure of the internal battery pack to provide monitoring of each cell
- When opposed to internal combustion engines, driving electric vehicles has some drawbacks, including a lengthy recharge period for the batteries.

2.2.3. Opportunities

- Accurately measuring battery percentage of charge is made possible by integrating IoT into battery management system.
- Users of an android app can browse through all cloud-stored data.
- It gives users with inclusive and continuing access to check the battery condition usage readings with the use of IoT.

2.2.4. Threats

- An increase in the cost of power as well as the availability and cost of raw materials.
- Charging times, greater initial prices, limited driving range, and replacement costs for battery packs are all disadvantages of electric vehicles.

2.3. Schedule Management

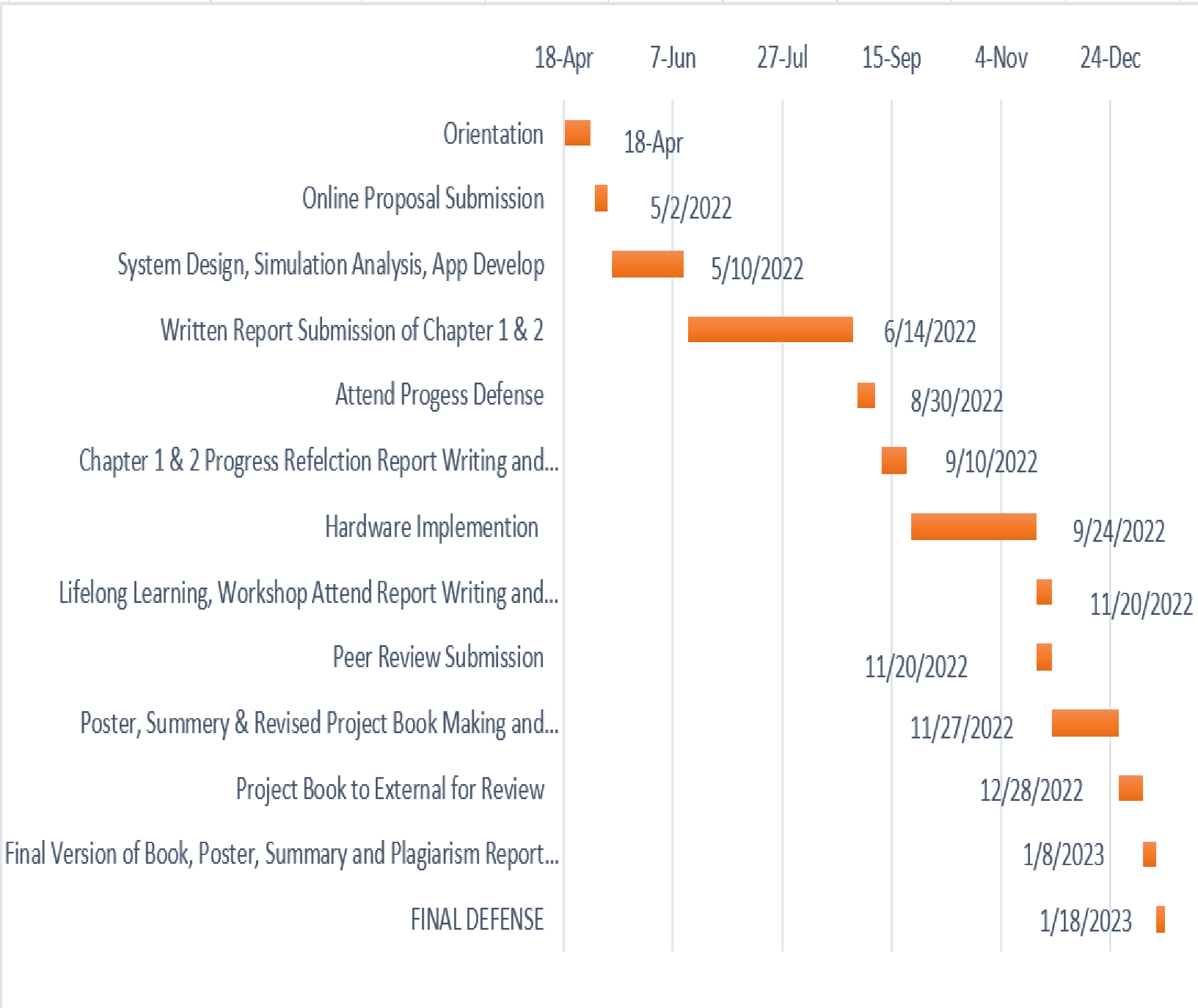


Figure 2. 1: Schedule Management

2.4. Cost Analysis

Table 2. 1: Cost Analysis of the Project

Component Name	Model	Quantity	Estimated Price	Final Cost (BDT)
Micro Controller	Arduino UNO	1	1200	1400
Current Sensor	ACS-712 - 30A	2	200	280
Voltage Sensor	ZMPT101-b	2	350	360
Relay Module	5V-220V	4	450	400
Wi-Fi Module	ESP-3266	1	500	550
Buzzer Module		2	60	40
LED	5W	5	30	25
Lithium-ion Battery	14500 1300 mAh	3	600	800
DC Brushless	5V DC	2	100	80
Bread Board		4	600	600
Temperature Sensor	DHT11	2	150	120
GPS Module	U-Blox NEO-6M	2	400	450
Android APP				22000
LCD Display	LCD1602	1	450	380
Jumper Wire	M-M, M-F, F-F	4	350	240
Resistor	1K, 4.7K	10	30	20
Glue Gun		1	200	250
Glue Stick		10	250	200
PV Panel	12V, 5 Watt	1	600	550
Arduino Battery	9V	4	350	320
PVC Board		1	300	400
Multimeter		1	1200	850
Miscellaneous				2500
			Total	**32815/-**

Table 2. 2: Calculation of Standard Deviation for Estimated Price

Previous Cost (Xi)	Mean X	(Xi-X)	$(Xi-X)^2$	$S^2=\frac{(Xi-X)2}{n-1}$	S
1200		810.84	657461.5056		
200		-189.16	35781.5056		
350		-39.16	1533.5056		
450		60.84	3701.5056		
500		110.84	12285.5056		
60		-329.16	108346.3056		
30		-359.16	128995.9056		
600		210.84	44453.5056		
100		-289.16	83613.5056		
600		210.84	44453.5056		
150	389.16	-239.16	57197.5056	96082.40584	309.97162
400		10.84	117.5056		
450		60.84	3701.5056		
350		-39.16	1533.5056		
30		-359.16	128995.9056		
200		-189.16	35781.5056		
250		-139.16	19365.5056		
600		210.84	44453.5056		
350		-39.16	1533.5056		
300		-89.16	7949.5056		
120		-269.16	72447.1056		
350		-39.16	1533.5056		
150		-239.16	57197.5056		
1200		810.84	657461.5056		

Table 2. 3: Calculation of Standard Deviation for Final Cost

Previous Cost (Xi)	Mean X	(Xi-X)	$(Xi\text{-}X)^2$	$S^2 = \frac{(Xi - X)2}{n-1}$	S
1400		981.875	964078.515		
280		-138.125	19078.5156		
360		-58.125	3378.5156		
400		-18.125	328.5156		
550		131.875	17391.0156		
40		-378.125	142978.5156		
25		-393.125	154547.2656		
800		381.875	145828.5156		
80		-338.125	114328.5156		
600		181.875	33078.51563		
120	418.125	-298.125	88878.51563	112905.2445	336.7564
450		31.875	1016.0156		
380		-38.125	1453.5156		
240		-178.125	31728.51563		
20		-398.125	158503.5156		
250		-168.125	28266.01563		
200		-218.125	47578.5156		
550		131.875	17391.0156		
320		-98.125	9628.5156		
400		-18.125	318.5156		
850		431.875	186516.0156		
120		-298.125	88878.51563		
400		-18.125	318.5156		
1200		781.875	611328.5156		

Since it improves in understanding measurements when the data is distributed, standard deviation is significant. The standard deviation of the data will be higher the more evenly dispersed the data appears. Standard deviation is significant because it enables consumers to evaluate security.

2.5. P.E.S.T. Analysis

An evaluation of the political, economic, social, and technical (PEST) elements that potentially have an impact on a corporation both now and in the future is known as a PEST analysis. PEST Analysis is a systematic process for assessing important external factors that have an impact on a company's operations in order to improve the company's competitiveness in the market.

2.5.1. Political Analysis

- This multifunctional IoT-based smart battery management system for electric vehicle may be incorporated. Most people feel that electric vehicles are the future of transportation.
- There has been a tremendous increase in their adoption, and governments are beginning to enact measures to encourage their use. But they are a cop-out that allows governments to avoid making difficult decisions. Politically speaking, EVs are fairly simple to execute.
- They do not necessitate a cultural shift, involve relatively little investment from the central government, and utilize existing transportation infrastructure.
- Moreover, its acceptance makes governments appear ecologically conscious. Internet of Things-enabled energy systems can be used to gather information on how much energy each item consumes, resulting in energy conservation by lowering energy losses in customers and industrial settings in Bangladesh and throughout the world.

2.5.2. Economic Analysis

- This proposed method may result in a general cost reduction because it collects information from the user's location without requiring human intervention.
- In order to prevent pollution, the government heavily promotes the need for cleaner energy on the international market. The industry must transition from the classic internal combustion engine, whose primary energy sources are nonrenewable, to other processes and energy sources.
- The automotive industry is currently focusing on electric vehicles, and vehicle makers are conducting more research to discover solutions to challenges in the realm of electrification [28].

2.5.3. Social Analysis

- Smart battery management systems for electric vehicles have both beneficial and bad societal implications.
- Smart Electric Vehicles increase productivity and aid a business in becoming or retaining a competitive position by enabling faster product development and execution. Electric vehicles charge their batteries with electricity as opposed to fossil fuels such as gasoline or diesel.
- Electric vehicles are more efficient, and when paired with the cost of power, charging an electric vehicle is less expensive than refueling with gasoline or diesel. The results of the analysis indicate that the diesel- and electric-vehicle lifetime costs to society are roughly identical, while the electric car is somewhat less expensive to society [29].

2.5.4. Technological Analysis

- Electric vehicle technology has improved quickly, and there are now numerous plug-in hybrid and battery electric vehicle alternatives on the market.
- The Electric vehicle was the first EV to enter the market for contemporary vehicles. Because they utilize less fuel, HEVs like the Toyota Prius and Lexus CT-200-H are well-liked. These automobiles feature an electric motor, an internal combustion engine, and a tiny battery to store electricity.
- Any grid management system in this country should start with the IoT-based Smart battery management system for electric vehicles because it will change the current charging system and make it more trustworthy thanks to its Smart technology [30].

2.6. Professional Responsibilities

Electric Vehicle Provides lots of benefit for both Electricity supplier and customer in terms of economics, efficiency, and safety. The ecology is significantly impacted by the use of electric vehicles. the electric car may offer the best transportation service for private and public or individuals to establishing a dynamic to use the charging station, integrating solar and other renewable energy sources into the grid, and consuming.

2.6.1. Norms of Engineering Practice

It is argued that engineering ethics should be supplemented by a social ethics of technology paradigm. A social ethics perspective identifies as problematic the changing social frameworks for technological decision-making. Essentially, the NSPE code of ethics and the first IEEE code of ethics served as the basis for our proposed approach. By integrating the IoT, which will ensure the data's privacy, our proposed solution also protects the privacy of the users. The majority of parts are recyclable. In the end, the welfare, security, and health of the general populace were our highest priority [31].

2.6.2. Individual Responsibilities and Function as Effective Team Member

The tasks of Member (Insia, Khaleque):

- Preparing chapters 1,2,3,5
- Implementing the hardware of the project and worked with member 3 to complete Proteus Simulation.
- Preparing the project report & PowerPoint presentation slide
- Working on and prepare poster summary.

The tasks of Member (Ali, Imran):

- Preparing chapters 2 & 6
- Working with member 1 by assisting with coding in the Arduino IDE to prepare the software.
- Working with members 2 & 3 to help prepare poster design and presentation slide.
- Helping and collecting all the necessary hardware components for implementation.
-

The tasks of Member (Barua, Sreejon):

- Preparing chapters 5, & 6
- Working with 1 member to prepare the project report.
- Working with member 1 to complete Proteus Simulation.
- Working with members 2 & 3 to help prepare poster design and presentation slide.

The tasks of Member (Ahmad, Sharif):

- Preparing chapters 4 & 6
- Working with member 1 to implement the hardware of the project.
- Preparing the presentation slide.
- Working with member 1 to help prepare the poster summary

2.7. Management Principles and Economic Models

Management is the process of supervising an activity. In order to effectively manage our project and complete it on time. Used the Gantt charts we were completed all the task. The primary objective of this project is to efficiently and cost-effectively eradicate disability in society as a whole. In this project, S.W.O.T. and P.E.S.T. analyses were employed for managerial and financial purposes. The standard deviation has also been used in cost analysis. Cost analysis is a method for determining which solutions are the most cost-effective by weighing the benefits and drawbacks of each. As a result, the organizational and economic models were completed. These inquiries also reduce the project's overall cost.

2.8. Summary

This chapter delves deeply into all of the analytical aspects of the project, including cost analysis, S.W.O.T. analysis, and P.E.S.T. analysis. In addition to measuring, monitoring, and limiting the user's energy consumption, it is essential to create an IoT-based platform with proper analysis and discussion of specific words such as the battery's strengths, weaknesses, opportunities, and disadvantages. One of the most significant aspects of any project is the cost analysis; in all engineering and non-engineering work, there must be a cost meter that indicates how cost-effective the project is. This chapter contains an in-depth cost analysis with appropriate pricing. Additionally, this chapter defines the independence of standard deviation. In addition, this chapter illustrates analytical challenges, such as political, economic, and social issues, etc. Individual responsibilities relate to the collaborative spirit of the members of this project group in order to execute this undertaking.

Chapter 3

METHODOLOGY AND MODELING

3.1. Introduction

The user interface and the monitoring device are the two main components of the proposed Internet of Things-based battery monitoring system. According to test results, the system is able to recognize diminished battery performance and notifies the user for further action. By obtaining precise state of charge readings, it enables operating systems to carry out power management actions via a smart battery charger depending on remaining anticipated run periods. IoT can assist in resolving issues with traffic, energy management, trash management, and public safety by using data from a variety of sources. Moreover, the implementation of IoT in the energy business is essential for its sustainability and profitability for both utility companies and consumers. An IoT-based smart Battery Management System for Electric Vehicles is a similarly innovative, environmentally-friendly, and futuristic choice for clients.

This chapter will cover the project's technique and design. Using a block diagram, a flowchart, and a hardware configuration, the systemic operation of the project is detailed. The block diagram explains the operation flow of the hole system employing the net-meter concept accurately. From the PV panel to the grid, the grid to the consumers, and also the distributors' activities. Displays the Charging station. The flowchart depicts the sequential process flow that is the key operational component of the state of charge Battery management system. In order to comprehend the software component of this project, the EV State app works in a certain way that has also been briefly explained. After studying this chapter, a clearer comprehension will be obtained.

3.2. Block Diagram and Working Principle

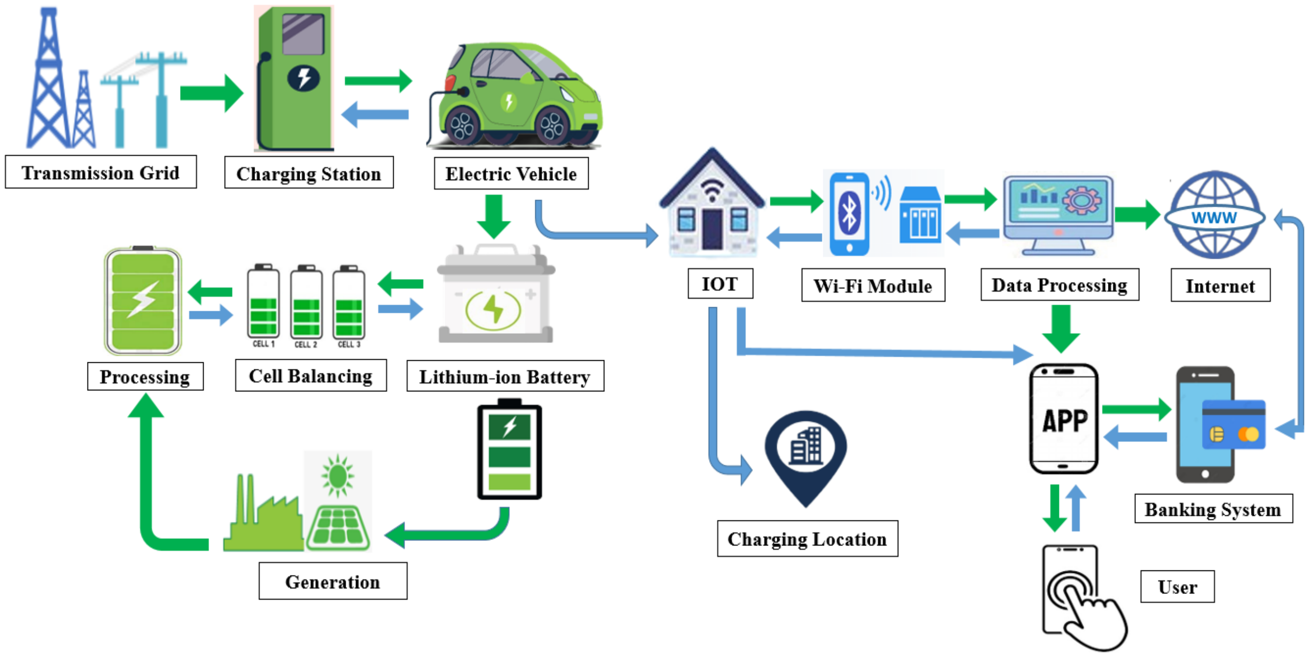


Figure 3.1: Block Diagram of IoT Based Smart Battery Management System for Electric Vehicle.

In Figure 3.1, the PV panel generates DC voltages in the presence of sunlight and transmits energy to the grid. The vehicle's Lithium-ion battery is charged by an Electric Vehicle charging station and controller. In this project, a microcontroller Arduino Uno reads data from the sensors. This project is a bidirectional smart battery management system that can monitor battery health and notify the user of the battery's health condition from any location. Battery management systems (BMS) are electronic control circuits that regulate and monitor the charging and discharging of batteries. In electric vehicles, the primary function of the battery management system is to detect the battery type, voltage, temperature, capacity, state of charge, power consumption, remaining operational time, and charging cycles. The ESP8266 module is used to transmit data to the specialized server for this IoT. This server stores all of the data. This electric car features a specialized Android app that allows the user to monitor everything. Through this application, a user can view all battery data, as well as the battery's general status and percentage of charge. And most importantly, the system always alerts the user to use the battery charge to determine how many kilometers the vehicle can travel, and when the battery is fully charged, the app displays the position of the nearest charging station and a map.

3.3. Modeling

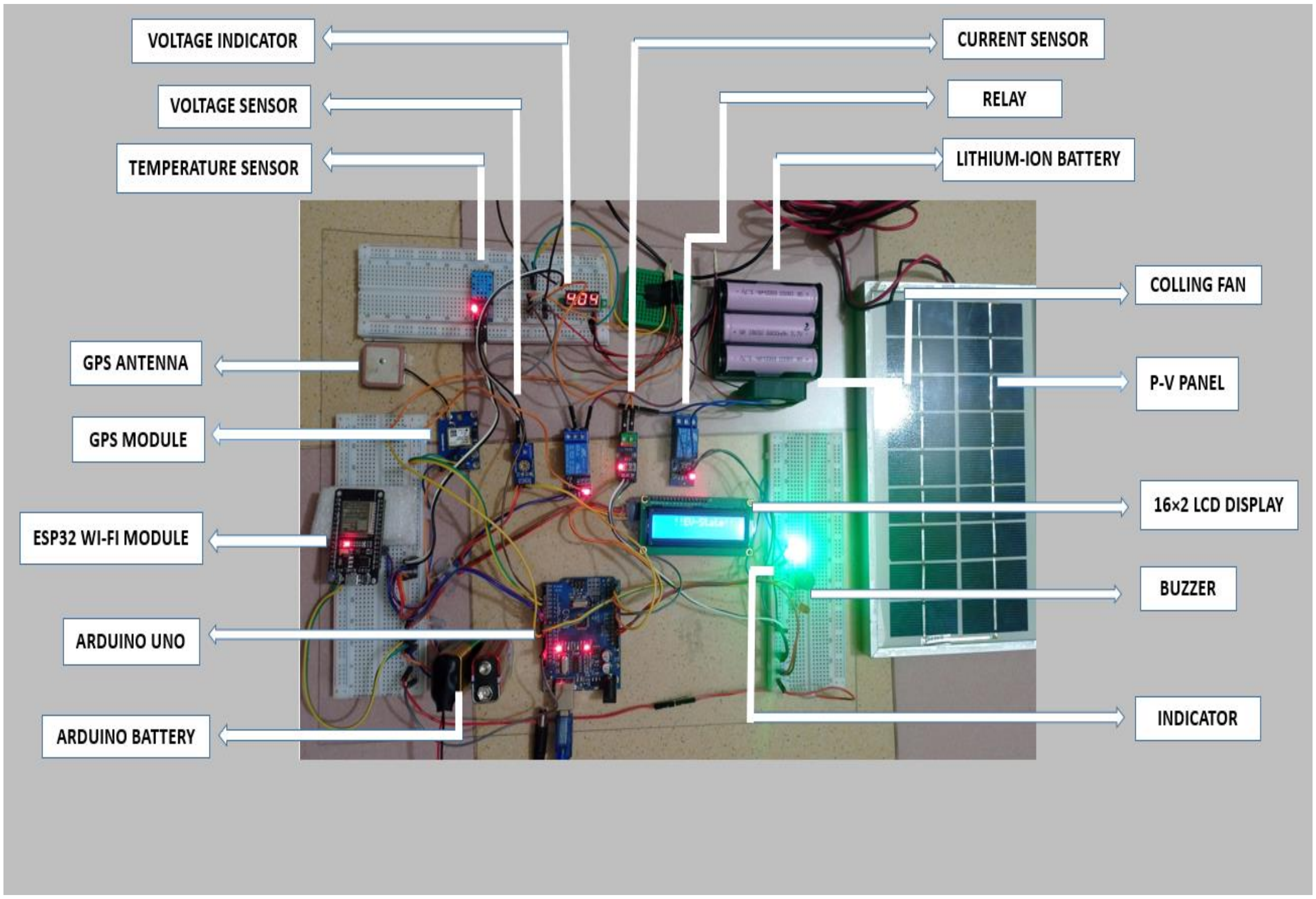


Figure 3.2: Top View of hardware setup

This figure 3.2 depicts a top view of the hardware component of the project. All the components, including Arduino Uno, Lithium-ion battery, ESP3266 (NodeMCU), PV panel, Wi-Fi module sensors, relay, and a few loads, are integrated into one system. According to the battery charge, the energy extracted from the PV panel is stored in the battery. The Voltage sensor and Current sensor measure the battery's voltage and current. Alternatively, the temperature sensor functions as an indicator and protects the battery from overheating issues. The primary function of this sensor is to notify the user when the temperature exceeds 35 degrees Celsius by activating a siren and turning on the cooling system. When the vehicle's battery dies, the GPS Module determines the nearest location and notifies the ESP3266 to transfer data to the IoT server through serial connection system.

3.3.1. Initializing Process and IoT

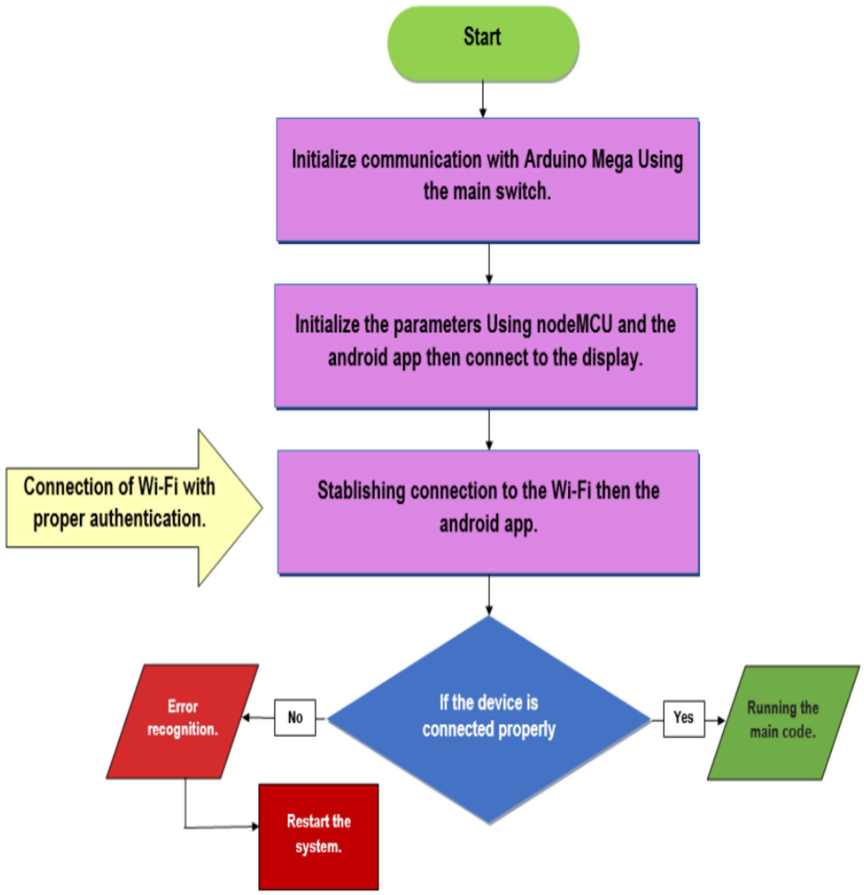


Figure 3.3: Initialization of Components and IoT Flowchart

Figure 3.3 is a flowchart depicting all the operations sequentially. After starting the main system, an initial switch will be used to establish communication between Arduino Mega and the main system. Then, the NodeMCU (wi-fi module) will initialize several parameters that will be shown in both the android application and the meter display. To establish a connection with the Android app, a stable Wi-Fi connection is required. If this system is successful, the device's main code will execute correctly. If not, the system will automatically recognize the fault and reset the system from the beginning.

3.3.2. Battery Management System in Electric Vehicle Flowchart

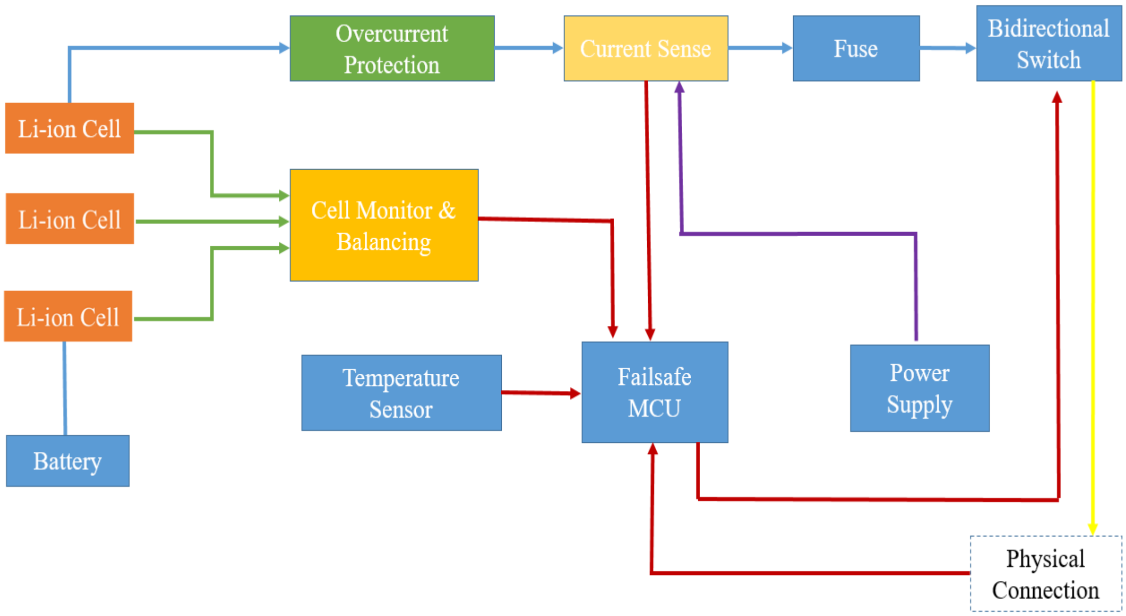


Figure 3.4: The main functions of Battery Management System Flowchart

Electric vehicles are powered by high-voltage batteries. Consequently, we must guarantee the safe operation of these batteries. To ensure the safe operation of the battery, the BMS monitors factors such as temperature, input and output current, and voltage across the battery packs. Monitoring the current flowing towards the battery pack prevents overcharging. The Battery management system is also responsible for calculating the State of Health (SoH), which displays the battery's remaining capacity. BMS continuously monitors temperature and conducts thermal management duties. It measures characteristics such as average temperature, intake temperature, output temperature, and individual cell temperatures. In Battery Management System activates cooling system to the devices when the battery becomes overheated. BMS can connect with the vehicle's Electronic Control Units. The central controller of the BMS connects with the cell well's internal hardware or with external hardware. It transmits information about the battery parameters to the motor controller so that the vehicle can operate efficiently.

3.3.3. Battery State of Charge estimation flowchart

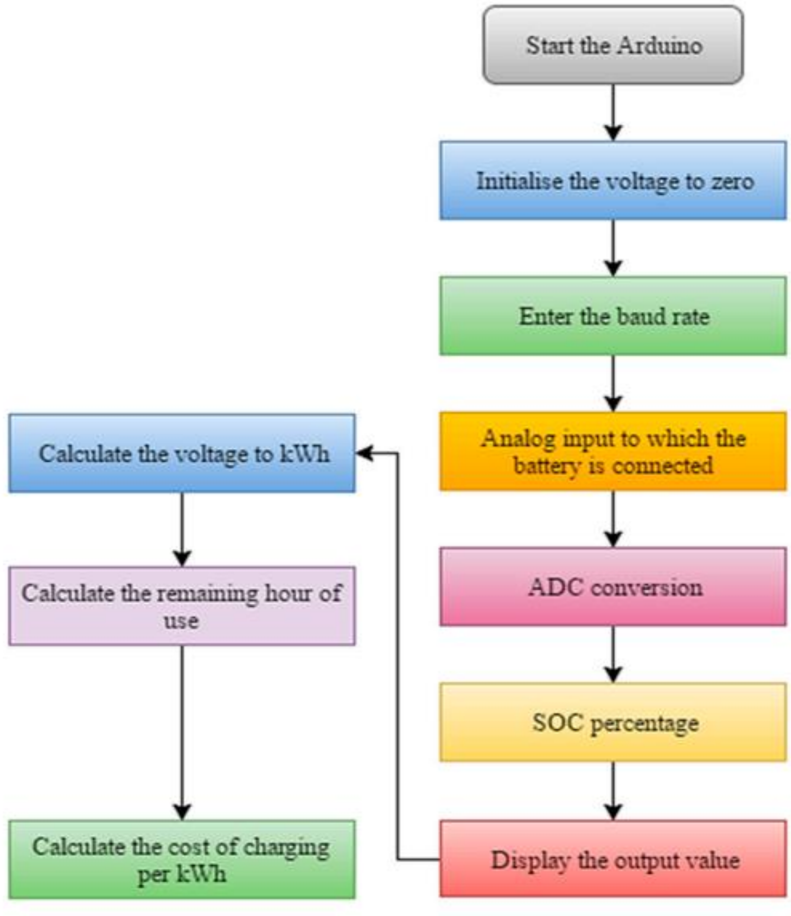


Figure 3.5: Battery State of Charge estimation flowchart

At first Initialize and set the voltage value on the Arduino. Then Configure the baud rate to enable communication between the Arduino and the computer. After establishing the Amp hour of the Li-ion battery that will be connected to the analog pin of the Arduino, the corresponding digital value (ADC Value) is recorded in the analog-to-digital converter (ADC). On the basis of the updated battery status, the remaining battery usage hours will be determined. The cost of charging will vary based on charging distance and duration.

3.3.4. Flowchart of app application

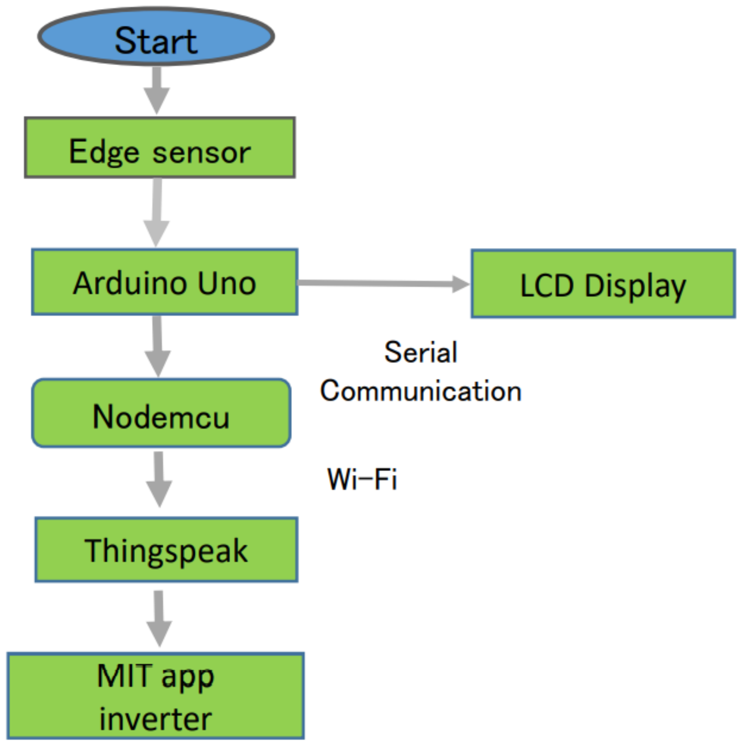


Figure 3.6: Flowchart of app application.

This chart in Figure 3.6 illustrates the application's systematic execution. After running the application, the edge sensor provides data to the microcontroller, and then two-way communication begins, with one direction going to the hardware's display and the other to the NodeMCU. NodeMCU is a wireless module that processes all data over time and sends them to the ThingSpeak server. The server then transmits all the information to the application.

3.3.5. 2D design using AutoCAD

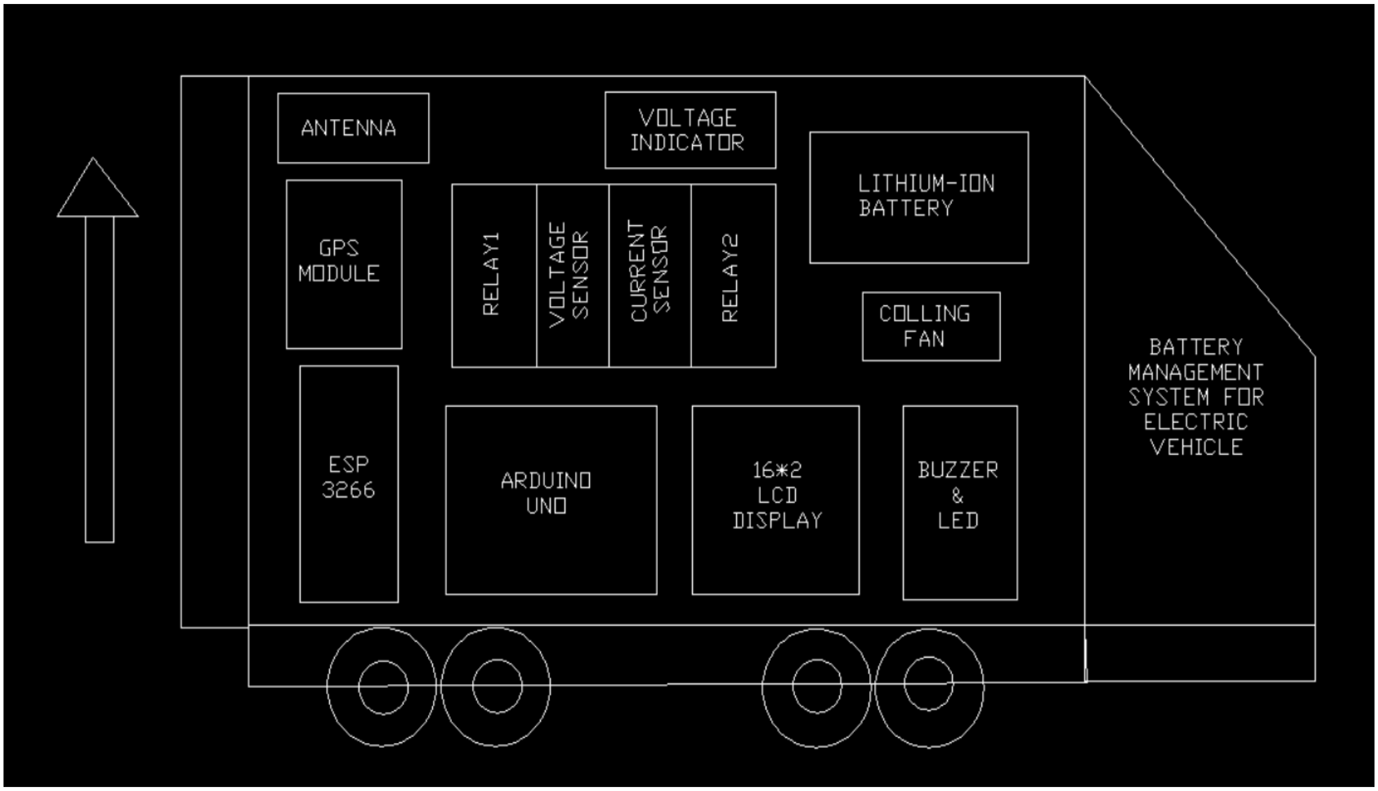


Figure 3.7: 2D design using AutoCAD

This figure 3.7 depicts the Smart Battery Management System for Electric Vehicle's two-dimensional representation. Using AutoCAD 2007, the meter's implemented dimensions are 24cm in height and 16cm in length. Arduino Uno 10/5cm, LCD Display 10/4cm, esp3266 approximately 6.5/4cm, relay1, Voltage sensor, Current sensor, and relay 2 are 6/5cm, buzzer and LED 4/2cm radius, and other sensors are added progressively. After incorporating all of the separate components, the meter's core design is now suitable for use in any industrial production.

3.4. Summary

In summary, the important components of the project are the block diagram, the hardware modeling (5W, 220-240V), as well as the GPS Module NEO-M8N and ESP-3266 modules. Due to the fact that they are microcontrollers, considerable attention was paid to the most crucial components. And specify the components, IoT process flowchart, battery management system flowchart, battery charging station process flowchart, and app application flowchart. Designed a 2D model using AutoCAD and systematically positioned all the components. After completing the hardware design, we systematically implemented our project.

Chapter 4

PROJECT IMPLEMENTATION

4.1. Introduction

To manage future energy demands and compete with the energy problem, electric vehicle batteries must be designed to resemble fossil fuel. Future batteries for electric vehicles must have a high energy density, a high current density, and a broad temperature range, as well as a lower price. For communication between vehicles and users, the app is the most effective medium. Due of its extensive network coverage and low cost, an SMS message can be a useful and practical tool. As an example of an Arduino-based Smart Battery Management system, the smartphone acts as the principal data server for smart automobiles, which send their data to it over Bluetooth. All of the parameters that will be transmitted by the new smart car system, including battery charge percentage, voltage, current, temperature, and location of the closest charging station. To resolve these issues, it is necessary to develop or optimize a new energy source to replace the current energy source, which is fossil fuel. A clean and sustainable energy Therefore, it is essential to ensure that the battery utilized is as dependable as fossil fuel. Thus, the design of the battery management system plays a significant role in preserving battery life and enhancing the performance of Electric Vehicles.

4.2. Required Tools and Components

In this section, we will discuss the required tools for system design, testing, and implementation.

4.2.1. Hardware Components

1. Arduino Uno
2. LCD Display 16×2
3. Current Sensor
4. Voltage Sensor
5. Temperature Sensor
6. GPS Module
7. Relay
8. Lithium-ion Battery

9. Buzzer
10. Wi-Fi ESP 3266
11. LED Light
12. Resistor
13. DC Brushless
14. PV Panel

4.2.2. Hardware Requirements

4.2.2.1. Arduino Uno

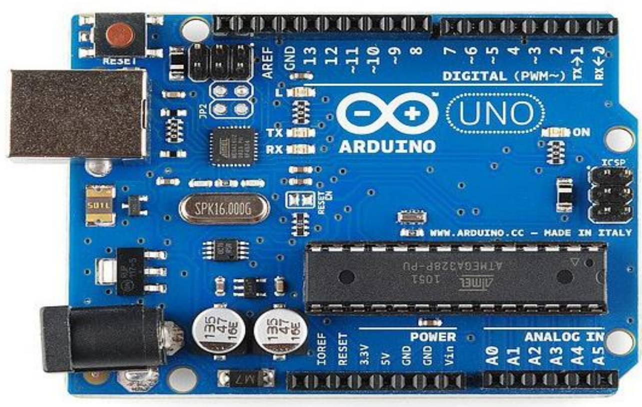


Figure 4.1: Arduino UNO R3 [32].

The Arduino UNO R3 board is used as the controller, as it is the most popular version of Arduino controllers. ATmega328 microcontroller-based Arduino UNO R3 features 14 digital I/O ports (6 of which support 8-bit PWM modulation mode), 6 analog inputs, 16 MHz clock frequency, USB port, power connector, in-circuit programming connector, and reset button. Each of the fourteen digital outputs can be utilized as either an output or an input. The terminals have a voltage of 5 V. It is advised that the output and input current of each output be limited to 20 mA.

The Arduino Uno R3 can be powered through USB or an additional power supply. The power source is automatically selected. The GND and Vin pin headers of the POWER connection are designed to accept battery leads. The board can function with an external power supply between 6 and 20 volts. However, if less than 7V is given, the 5V pin may provide less than five volts and the board may become unstable. If more than 12V is used, the voltage regulator may overheat and cause board damage. The suggested voltage range is 7 to 12 volts [33].

4.2.2.2. LCD Display 16×2

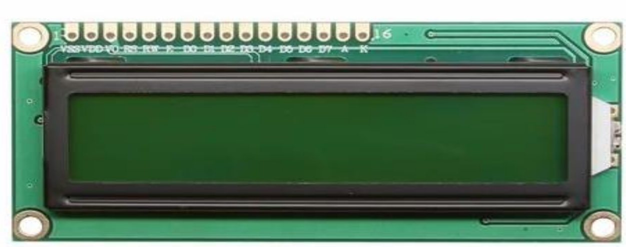


Figure 4.2: Liquid Crystal Display 16×2 [34].

LCD (Liquid Crystal Display) displays are the norm for handheld embedded systems. Color TFT (Thin-Film Transistor) LCDs are becoming prevalent, even in inexpensive devices. The components of an LCD display system are an LCD panel, a frame buffer memory, an LCD and frame buffer controller, and a backlight inverter and lamp. This LCD1602 Parallel LCD Display is an easy and cost-effective way to add a 162 White on RGB Liquid Crystal Display to your project. The display is a 16-character by 2-line display with white text on a blue background/backlight that has a very high contrast. It’s is an excellent LCD monitor with a blue backlight. It's excellent for Arduino-based projects. This LCD1602 Parallel LCD Display with Yellow Backlight interfaces easily with Arduino and Other Microcontrollers [35].

4.2.2.3. Current Sensor

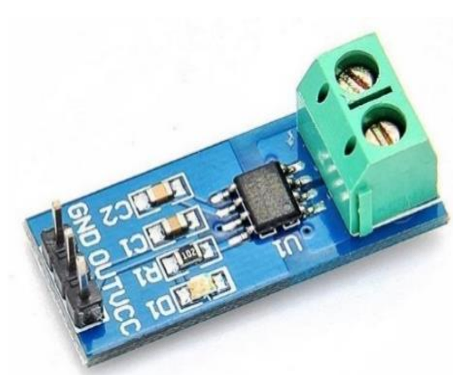


Figure 4.3: Current Sensor [36]

Multiple manufacturers have developed ASC712 Current Sensor Module boards that can be easily interfaced to a microcontroller such as The 30A range of Current Sensor Module ACS712 consists of a precise, low-offset, linear Hall Circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field in which the Hall IC converts into a proportional voltage.

4.2.2.4. Voltage Sensor

Figure 4.4: Voltage Sensor [37].

A compact single-phase AC voltage sensor module called the ZMPT101B was developed by Qingxian Zeming Langxi Electronic. It is based on the similarly produced by ZMPT101B tiny 2mA/2mA precision voltage transformer. The analog inputs of the Arduino Uno enable precise voltage measurement.

By default, an analog input pin will convert analog input voltages of 0 to 5 volts into integer values of 0 to 1023 with an accuracy of 4.9 millivolts per unit (5.00 volts per 1023 units). 5.00V/1023 units will be the resolution used for this mapping [37].

4.2.2.5. Temperature Sensor

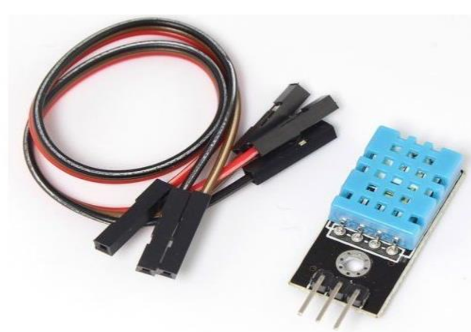


Figure 4.5: Temperature Sensor [38].

The DHT11 Humidity & Temperature Sensor Module is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and outputs a digital signal on the data pin (no analog input pins needed). This DHT11 Humidity & Temperature Sensor Module makes is easy to connect to an Arduino or microcontroller as it includes the pull-up resistor required to use the sensor. Only three connections are required to be made to use the sensor – Vcc, Gnd, and Output. We have also included the cables required to connect the DHT11 to a microcontroller.

4.2.2.6. GPS Module

Figure 4.6: GPS Module [39].

The use of a GPS tracking device to provide real-time vehicle location data for fleet planning is prevalent. Goo-Tracking is a GPS tracking system comprised of commodity hardware, open source software, and an easy-to-manage user interface via a Web server using Google Map or Google Earth software.

This is an all-inclusive GPS module based on the NEO 6M GPS. This device uses cutting-edge technology to provide the most accurate positional data possible and features a 25 x 25mm active GPS antenna with a UART TTL connection. A battery is also included so that a GPS lock can be obtained more quickly. This is a revised GPS module compatible with ardupilot mega v2. This GPS module provides the most accurate position data available, hence enhancing the performance of your Ardupilot or other Multirotor control platform. It has four pins: TX, RX, VCC, and GND. You can download the u-center software to configure the GPS and change settings, among other things [39].

4.2.2.7. Relay

Figure 4.7: Relay [40].

This 5V relay module enables your Arduino projects to control real-world devices. It is capable of switching 10A per channel. Includes back-EMF protection and LEDs so that you can quickly monitor the state of the outputs, as well as optical isolation to safeguard your development board. A relay is a switch that is electrically regulated. In this project, the relay is controlled by Arduino. The relay's purpose is to trip the load (operating at 220-240 volts) if it exceeds the limit or if the meter is tampered with. It is powered by 5V, which is provided by the Arduino 5V pin.

4.2.2.8. Lithium-ion Battery

Figure 4.8: Lithium-ion Battery [41].

The lithium-ion batteries have revolutionized portable gadgets and are the preferred technology for electric vehicles. In addition, they serve a crucial role in facilitating the further incorporation of intermittent renewable energy sources into power networks for a more sustainable future. This 18650 Li-ion Rechargeable Battery Lithium-Ion Battery offers excellent value. It is a single-cell, compact, and powerful battery cell with a true capacity of 2400-2600 mAh. It is quite simple to install in your project to fulfill a 3.7-volt, high-capacity demand. The battery terminals are compatible with any battery converter or holder, or they can be permanently soldered to the power supply wires of our application [41].

4.2.2.9. Buzzer

Figure 4.9: Buzzer [42].

The piezoelectric material physically deforms when a voltage is placed between the two electrodes as a result of the applied voltage. The buzzer's piezo disk rotates to make the same sound that a magnetic buzzer's ferromagnetic disk or an overhead speaker cone would produce. Passive Buzzer Module is an integrated construction of digital transducers, DC power supplies, and is widely used in computers, printers, copiers, alarms, digital toys, automobile digital equipment, phones, timers, and other digital electronics projects for Alert sound.

4.2.2.10. Wi-Fi ESP 3266

Figure 4.10: WI- Fi ESP 3266 [43].

ESP-WROOM-32 Dual-Core 2.4GHz Dual-Mode WiFi + Bluetooth Development Board for ESP32 ESP-32S. The ESP32 is combined with Antenna switches, RF Balun, power amplifiers, low-noise amplifiers, filters, and management modules, and the entire solution occupies the smallest amount of PCB real estate. 2.4 GHz Wi-Fi plus Bluetooth dual-mode chip, using TSMC Ultra-low power consumption 40nm technology, has the best power dissipation performance and RF performance, is safe and dependable, and is simple to adapt to a variety of applications. ESP3266's inbuilt RF components, such as the Power Amplifier, Low-Noise Receive Amplifier, Antenna Switch, Filters, and RF Balun, are a plus. This makes developing hardware around the ESP8266 relatively simple, as just a few external components are required.

4.2.2.11. LED Light

Figure 4.11: LED Light [44].

In many gadgets, LEDs serve as indicator lights, and they are increasingly used for additional illumination applications. The series is intended specifically for applications that require greater brightness. The led lamps are offered in a variety of hues and intensities. In terms of overall color look, LED-based light sources were favoured above halogen and incandescent light sources [44].

4.2.2.12. DC Brushless

Figure 4.12: DC Brushless [45].

A 5V 0.2A 3007 Cooling Fan for 3D Printer is a little but effective fan. The cooling fan serves as an exhaust fan on both the Raspberry Pi casing and 3D printers. It maintains the extruder's temperature, allowing for smooth printing. The cooling fan is powered by a 0.2A 5V DC power source, which is easily supplied by the RPI board. It features a two-pin JST connector for simple connection to the printer controller system and effortless operation. Plastic is used to construct the lightweight fan.

4.2.2.13. Resistor

Figure 4.13: Resistor [46]

The resistance of a certain length and thickness of iron wire is 1 ohm. One Ohm The color code for resistors is brown, black, gold, and gold. Resistance: 1 Ohm, Power Rating: 1 Watt, and Approximately Maximum Current: 1 Amps. One ohm is equal to one-kilogram meter squared per second cubed per ampere squared when converted to SI base units (1 kg m 2 s -3 A -2). The ohm also corresponds to one volt per ampere (V/A). One ohm is equal to the resistance of a conductor through which one ampere of current flows when one volt of potential difference is applied.

4.2.2.14. PV Panel

Figure 4.14: PV Panel [47]

The solar panels on the roof of the Sunlight is a free and environmentally beneficial renewable energy source that doesn't run out. The amount of solar energy that enters the earth every hour is sufficient to supply all of the energy needed for a year. In the modern period, we required electricity constantly. This solar energy is produced for use in commercial, industrial, and residential settings. It is simple to collect energy from direct sunshine. As a result, it is incredibly effective and does not pollute the environment. In this post, we analyzed solar energy derived from sunlight and talked about its potential and current trends. The page also aims to discuss how solar panels function, different types of solar panels, and different uses and strategies for promoting solar energy's advantages [48].

4.2.3. Software Requirements

4.2.3.1. Proteus

Proteus is an experimental library system that will aid in the collection of such data. Typically, reuse library systems are bound to a single method Proteus supports numerous techniques. Lab Center Electronics Ltd developed Proteus, a design and simulation application used by the electrical engineering community. Proteus includes a vast selection of component models for constructing or executing nearly any circuit and simulating it. Additionally, Proteus allows you to create PCB boards based on your models. In this project, Proteus version 8.10 was used to simulate the entire system to guarantee that it would function properly following the addition of hardware.

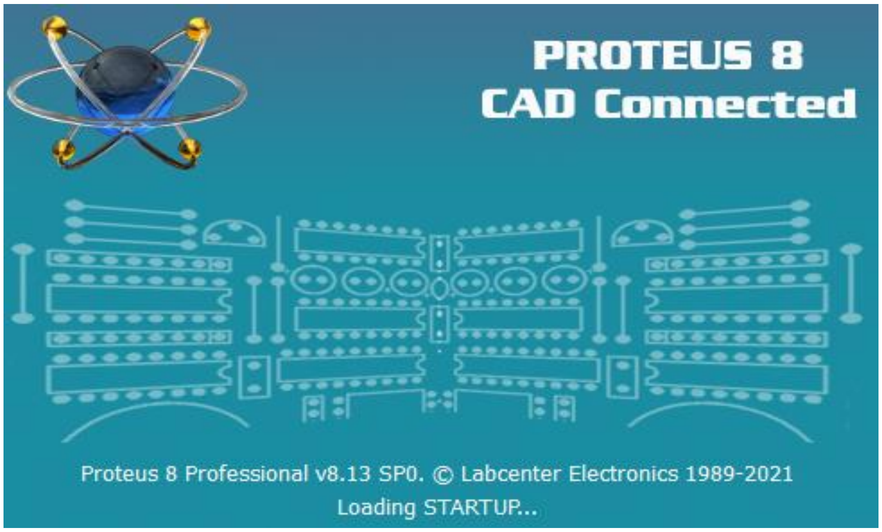


Figure 4.15: GUI of Proteus Software [49].

4.2.3.2. Arduino IDE

The Integrated Development Environment, or IDE, is software used for programming Arduino-branded boards. The Arduino IDE is also known as a cross-platform software. This application uses a special programming language that blends C, C++, and Java. The Arduino IDE enables programmers to generate code, upload it, and track its progress using a serial monitor. This program offers a comprehensive library and supports multiple boards, including a number of third-party boards.

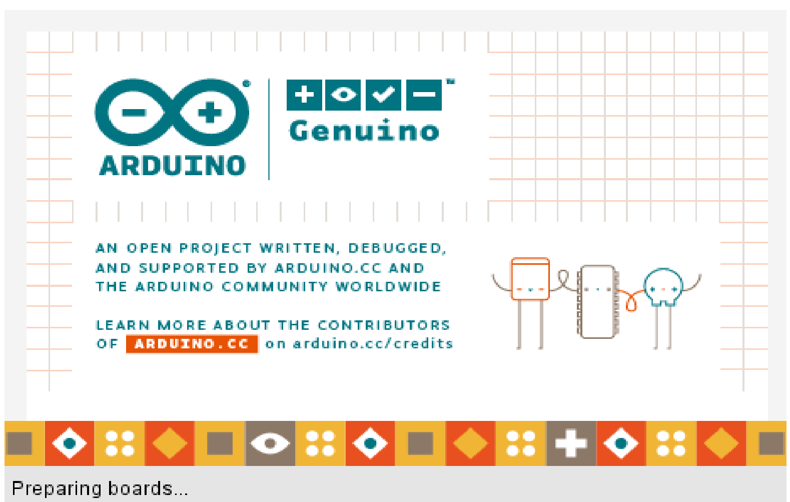


Figure 4.16: GUI of Arduino IDE software [50].

4.2.3.3. MIT App Inventor

MIT App Inventor is a user-friendly, graphical programming environment that allows anyone to create fully-functional apps for smartphones and tablets. Traditional programming environments require substantially more time to develop complicated, high-impact applications than the block-based approach. The MIT App Inventor initiative aims to democratize software development by enabling all individuals, particularly youth, to transition from technology consumption to production. Block-based coding methods benefit students intellectually and creatively. MIT App Inventor goes beyond this to deliver actual empowerment to make a difference a means to accomplish demonstrable social impact in their communities. In fact, App Inventors within and outside of conventional educational institutions have united.

Figure 4.17: GUI of MIT APP Inventor software [51].

4.3. Implemented Models

4.3.1. Simulation Model

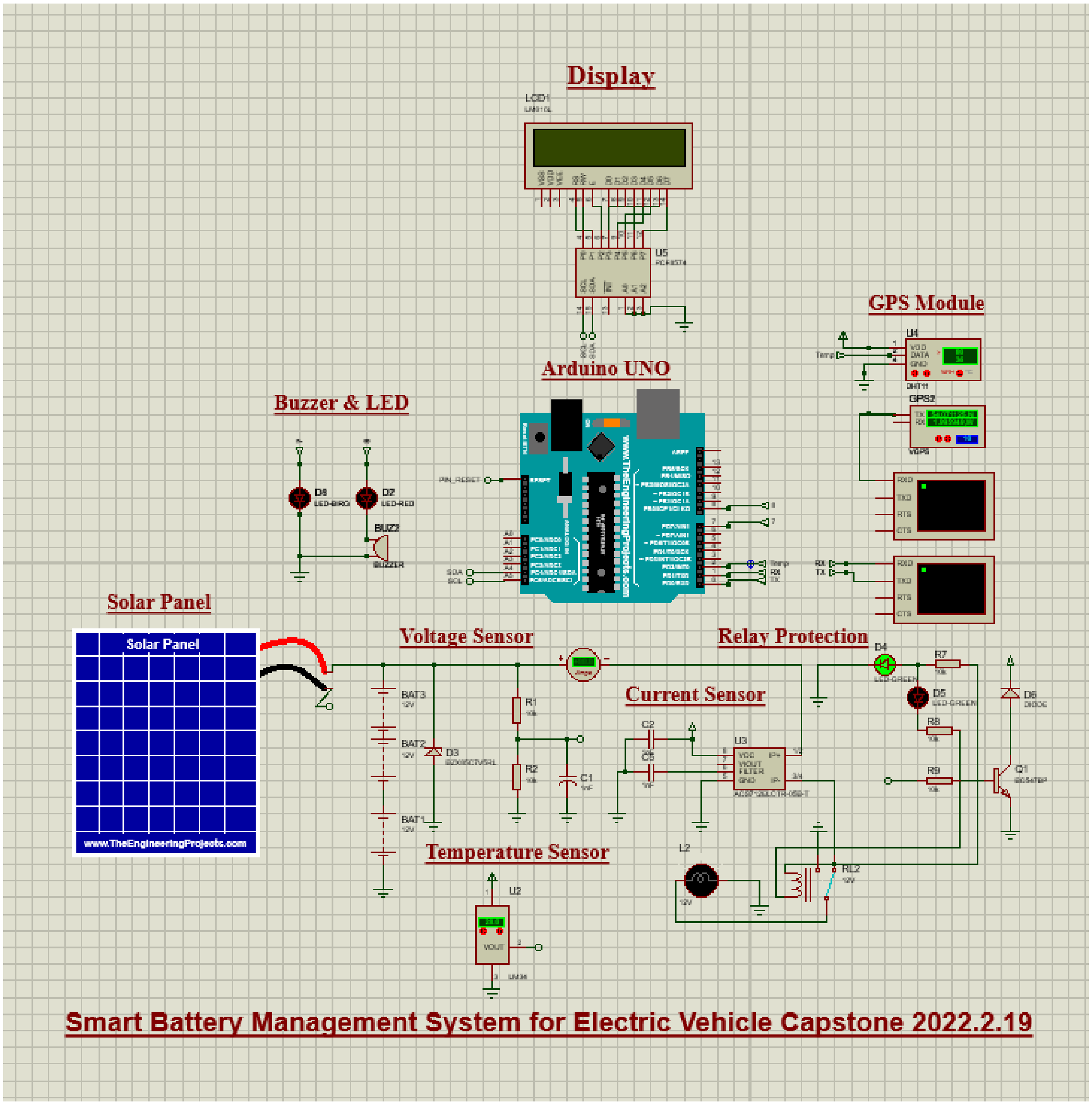


Figure 4.18: Simulated Model Designed in Proteus 8.13 Version

In Fig. 4.14, the simulation model incorporates all the electronic components, including a voltage and current sensor, a temperature sensor, a gas sensor, and a relay protection, to detect the battery's health state. However, the IoT integration was implemented independently in this hardware.

In order to combine the Internet of Things (IoT) and establish contact with the mobile application, we utilized a number of sensors and components for which separate coding was performed while matching our simulated model; and the code was transmitted directly to the microcontroller. In this project, the solar system was manually programmed into the software, and the DC supply of the system was changed to an AC source. the Solar System followed. Voltage sensors are handcrafted, and three current sensors (ACS712 30A models) are utilized to indicate or display the voltage and current whenever a failure of any type occurs. They are linked in parallel way. To utilize these Sensors, we implement Cell Balancing, a technique that extends the battery's life, creates an equal voltage and current level, and maximizes the battery pack's capacity. The temperature sensor fulfills the role of thermal management by continuously monitoring the temperature. It measures parameters such as the mean temperature. When a heating problem develops and the average temperature limit is exceeded, an alarm will sound to reduce the temperature. To reduce the temperature, connect the 5V colling fan to the battery and activate the relay to turn it on automatically. When the temperature is normal or average, the fan will turn off automatically. Utilize the 16x2 LCD display that indicates the percentage of charge in the battery and the maximum range that can be achieved with this charge. And also display the actual voltage and charging station location when charging is requiredAll of the Sensors collect data and transmit it to the Arduino Uno. Using serial connection, this Arduino UNO transmits System Data to ESP3266 via the Wi-Fi module. In this project, the syste, utilize ESP8266 and Arduino IoT Cloud to create a Battery Status Monitoring System. utilizing the Internet of Things, this project able to directly notify people. The user can also remotely check the battery status of their smartphone or computer. And this Arduino Uno serves as the project's brain. With a pin that is explained in the coding section. In the simulation phase, the entire operation will run by uploading the hex file to the mega.

4.3.2. Hardware Model

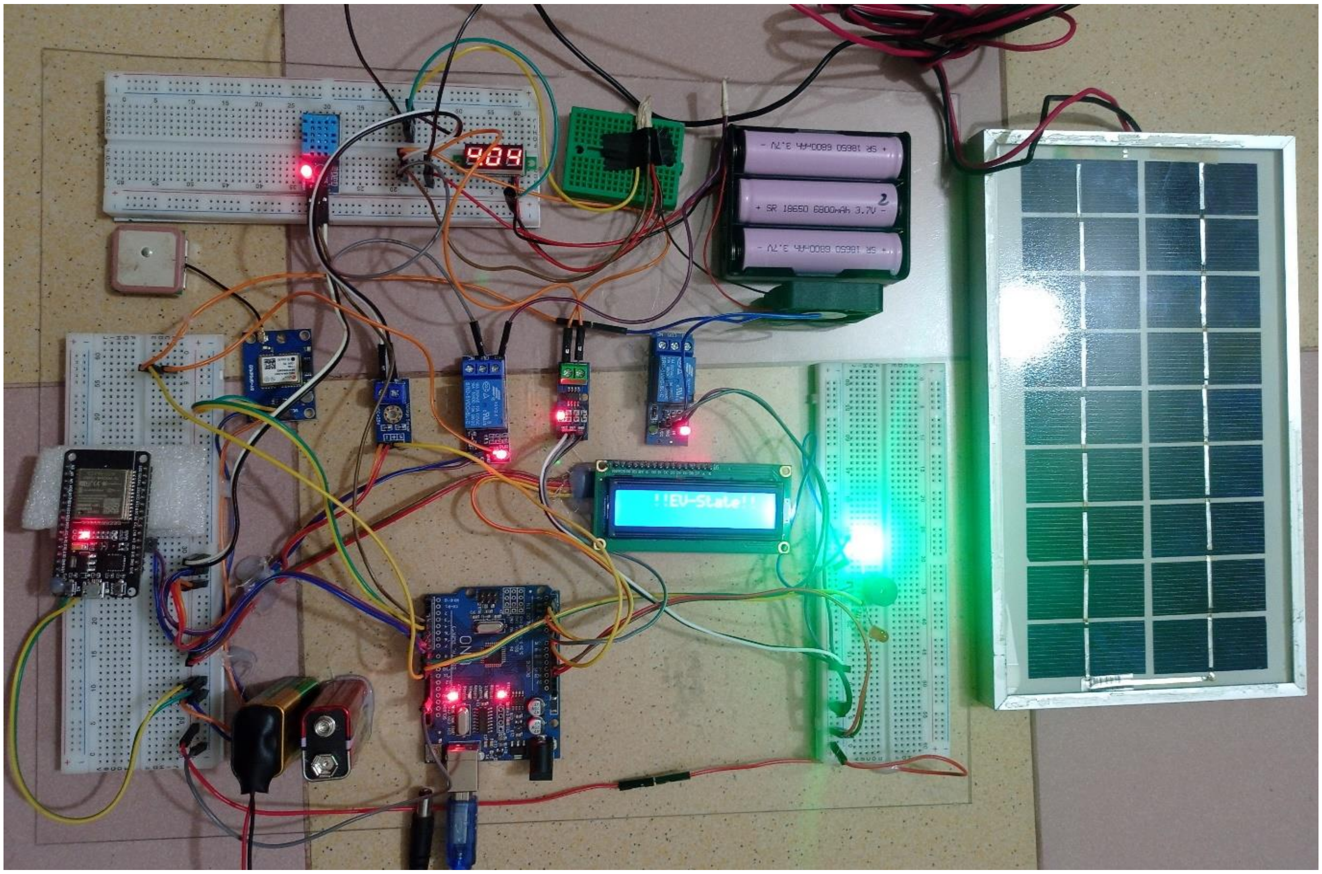


Figure 4.19: Implemented Testing Hardware

This equipment and instruments substantially on hardware components to function. Before final implementation, the microcontrollers and sensors were tested by constructing a test board, installing all sensors and modules based on the simulation model, and operating the system. The sensor data were reviewed in depth. Further testing of the IoT integration involved comparing the data displayed on the LCD display to the data displayed on Thingspeak and the app. However, the hardware implementation of a system is distinct from its simulation.

4.4. Engineering Solution in accordance with professional practices

The proposed system satisfies the requirements for a professional engineering solution because it aims to address an existing problem while building on previous work and adding new ideas. The creation of the smart energy net meter prototype involved the construction of a block diagram, the testing of a simulation model, and the implementation of a real hardware model. Comparing the results from the hardware and simulation model ensures that the system is running properly. A variety of technical domains, including electronics, microcontrollers, and programming, are required for the implementation of the entire system. The IoT component is implemented using the MIT app inventor platform. This app hosts all server and data transfer, enabling improved and more stable IoT connectivity as well as a server that is available 24/7. IoT connectivity enables users to remotely manage and monitor the device from any location with only an internet connection.

4.5. Summary

In this project, we attempted to develop an IoT-based smart battery management and monitoring system for electric vehicles. Arduino Uno served as the microcontroller for the hardware implementation. Wi-Fi-Module ESP-3266 was used to create the connection between the system and the user via SMS and mobile applications, respectively. The results of the hardware prototype and simulation will be discussed in the following chapter. Designed simulation component with all required components, added in the correct manner, and meeting all connection criteria. A critical design evaluation will also be included in the subsequent stages. In the software section, the exact software tools utilized for this project are described in detail. The ESP3266 will transmit all data to the MIT app inventor server, and the app will display all hardware operations and data.

Chapter 5

RESULTS ANALYSIS & CRITICAL DESIGN REVIEW

5.1. Introduction

In this chapter, both the hardware model and the simulation model results will be carefully examined. The last chapter displayed both the complete hardware model and the simulation model.
In this chapter, the simulation and its results will be addressed before the hardware model and its results. The system's efficiency will next be examined, and its viability in contrast to alternative scenarios will be assessed, through comparison of the results.

5.2. Results Analysis

In this simulation, the LCD displayed many metrics on its screen, including the battery's percentage of charge, the vehicle's mileage, the battery voltage, battery current, temperature, and the position of the charging station that is the closest to the user's location. Additionally, the app delivers warnings when the battery charge is below 30%, when the battery has been tampered with, or when another accident-related concern has arisen.

5.2.1. Simulated Results

5.2.1.1. When Load is turn on

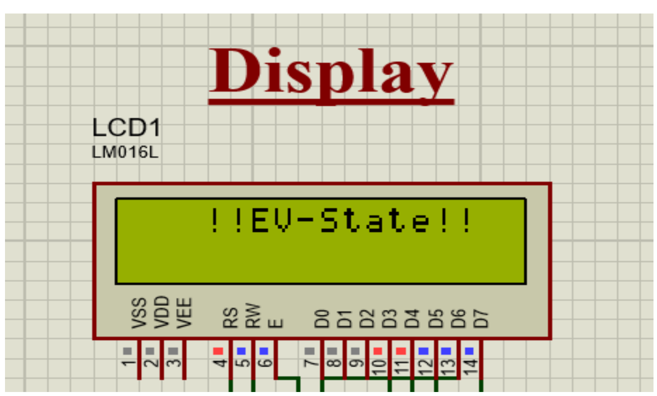


Figure 5. 1: Readings from Electric Vehicle System when Load is ON

5.2.1.2. When the Battery Voltage and Current detected

When the battery safety sensors like voltage sensor, current sensor are detected any type of overvoltage or overcurrent flow in battery as shown in the figure

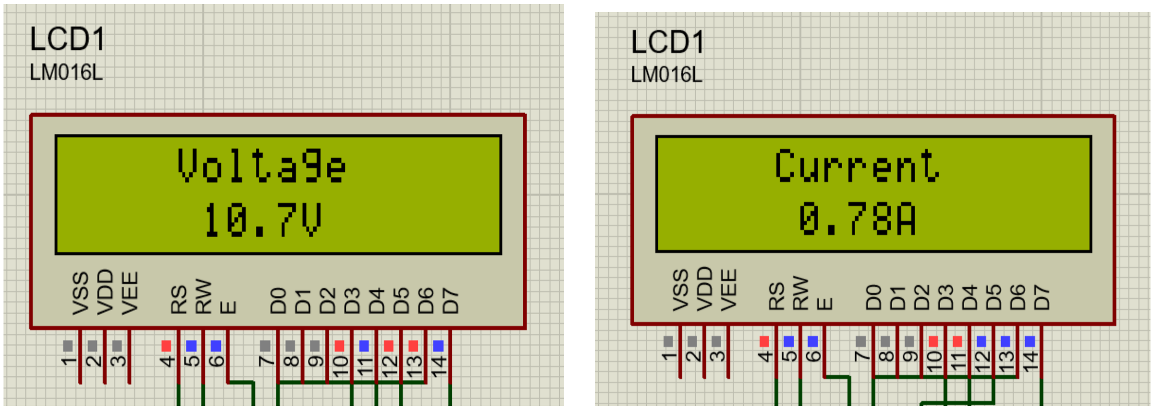


Figure 5.2: When the voltage sensor and current sensor is detected

5.2.1.3. When the battery percentage of Charge, Mileage detected

When the Battery Percentage represent that to use this charge how much kilometer go in destination as shown in the figure:

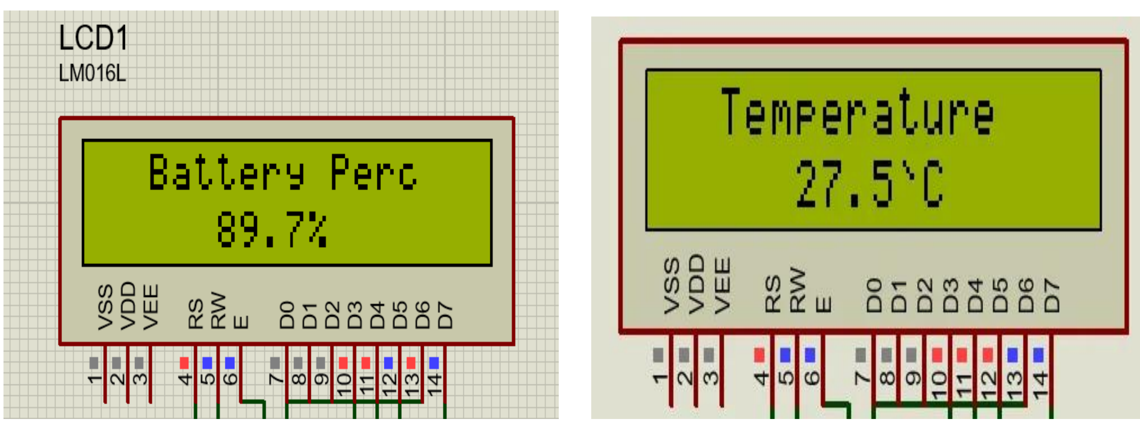


Figure 5.3: When Battery Charge and Mileage is detected

When the Virtual terminal show the distance and longitude of nearest charging station. GPS show the actual graph of this station shown in below the figure:

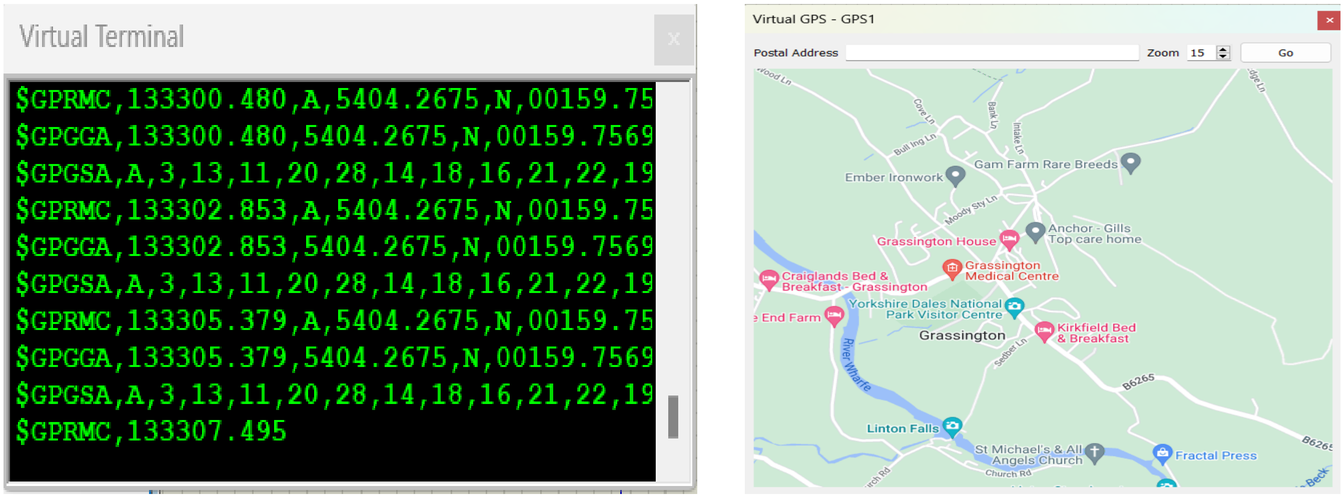


Figure 5.4: When the GPS Show the Map of charging station

Therefore, in simulation, the output value and actual result of our hardware system are shown by these figures. The purpose of simulation is to develop a battery management system in lithium ion battery for electric vehicle cell balancing, protecting the battery pack from overcurrent, overvoltage, and under voltage conditions, monitoring the temperature, and isolating the battery management system when the temperature exceeds and remains above a specified limit. Monitoring current, voltage, battery condition, as well as system health Find the location of the nearest charging station to charge the vehicle.

These two voltage and current sensors, ZMPT101-b and ACS-712 - 30A, display the battery's voltage and current. Figure 5.4 shows the actual distance and longitude of the nearest charging station between the user and the charging station for a 12V lithium-ion battery. The percentage of charge and vehicle mileage depend on the battery charge.

5.2.2. Hardware Results

5.2.2.1. Test Model

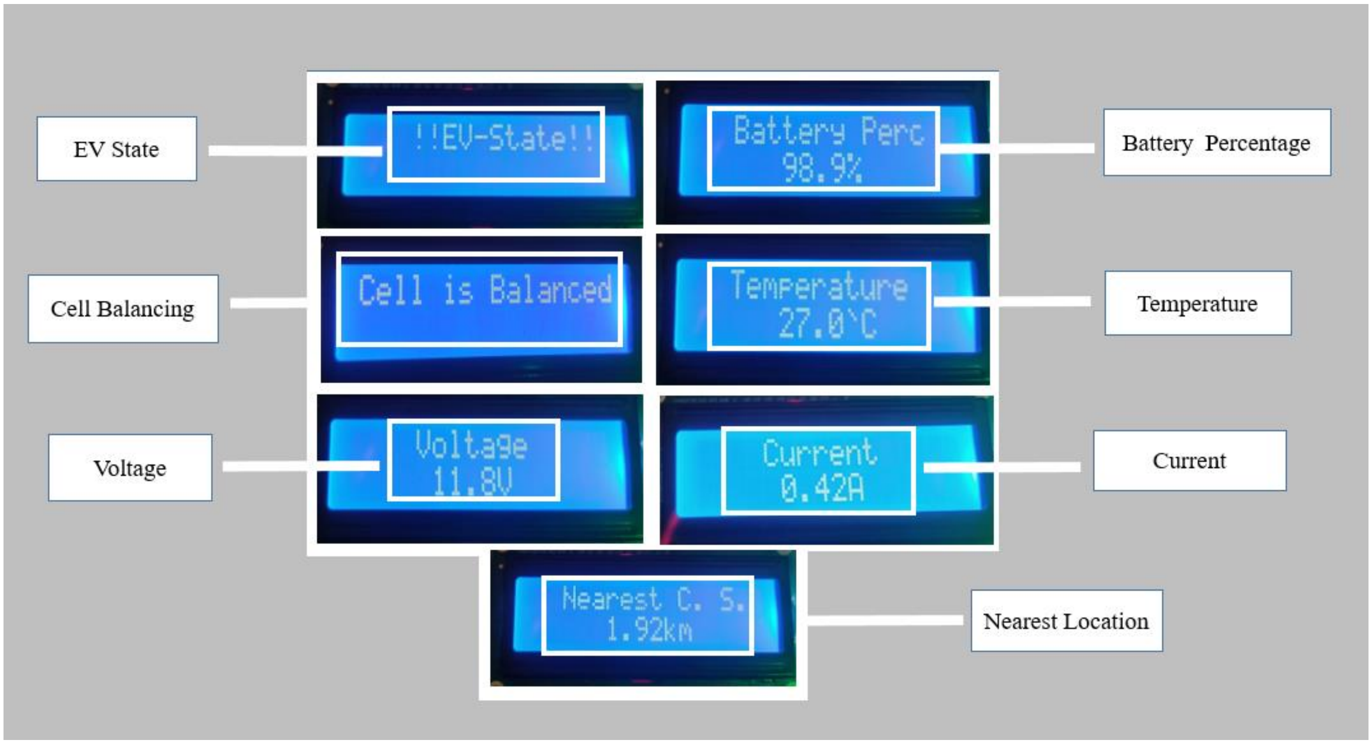


Figure 5.5: Modeling of electric vehicle display output

Figure 5.5 shows a comprehensive overview of the battery management system for electric vehicles. Where each data element has its own significance, such as battery information, PV information, and the exporting of solar energy to the grid. When the system is operating, each parameter displays its accurate and true value. From the starting stage to the final stage, all outputs, such as battery charge percentage, battery voltage, current, and temperature, change according to the user. In the final section of the nearest location, there is an alert message that will help in finding the nearest charging station in the case of an emergency.

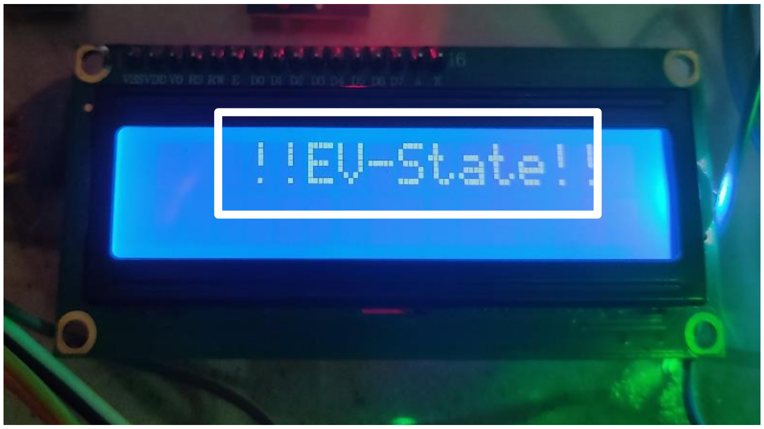


Figure 5.6: The initial stage

Initialization of the electric vehicle is shown in Figure 5.6. The process of initiating the system when the EV State are displayed on the display, as well as other values. There will be no warning on the notice site when the Arduino Uno is powered on, but it will be displayed on the LCD display.

Figure 5.7: Percentage of charge of battery

After the system has been installed and connected to the battery and solar panel, the battery's charge percentage will be displayed on the LCD display among the entire system. Which is shown in Figure 5.7.

By increasing the capacity of a battery pack with several cells connected in series and making sure that all of its energy is available for use, the technique of "cell balancing" increases the life of the battery.

Figure 5.8: Battery Cell Balancing

These continuous charge/discharge processes in this proposed system degrade the balances between the battery cells. This causes the cells to drift apart. Cells with a lower total capacity than the system's highest cells can experience overcharging and undercharging, which accelerates the aging process of those cells.

Figure 5.9: Battery Voltage

The actual voltage supply of the vehicle can be determined by connecting the voltage sensor to the battery. The voltage sensor synchronizes the voltage in each battery cell and measures the transmission voltage. These Sensor will always show or display the voltage and protect the battery from any type of overvoltage, and calculate the amount of voltage, which will be displayed on the battery LCD display.

Figure 5.10: Battery Current

When the current sensor is connected to the battery, the actual current flow of the battery can be measured. The current sensor measures the current flow and balances the current in each battery cell. which shown in figure 5.10.

when the temperature sensor was connected with the battery. This temperature sensor monitors the temperature continuously and performs the function of thermal management.

Figure 5.11: Battery temperature

This measures and displays the temperature on an LCD display. When the battery overheats and exceeds the average temperature limit, a buzzer will sound to lower the temperature. which temperature is shown in figure 5.11.

Figure 5.12: Nearest location of charging station

When the battery charge is critically low, the system will inform the user and display the nearby location on the LCD display as shown in figure 5.12. The distance between the user and the nearest charging station, in how much kilometers, will be automatically calculated and displayed on the LCD screen of the vehicle.

5.2.2.2. In IoT mode

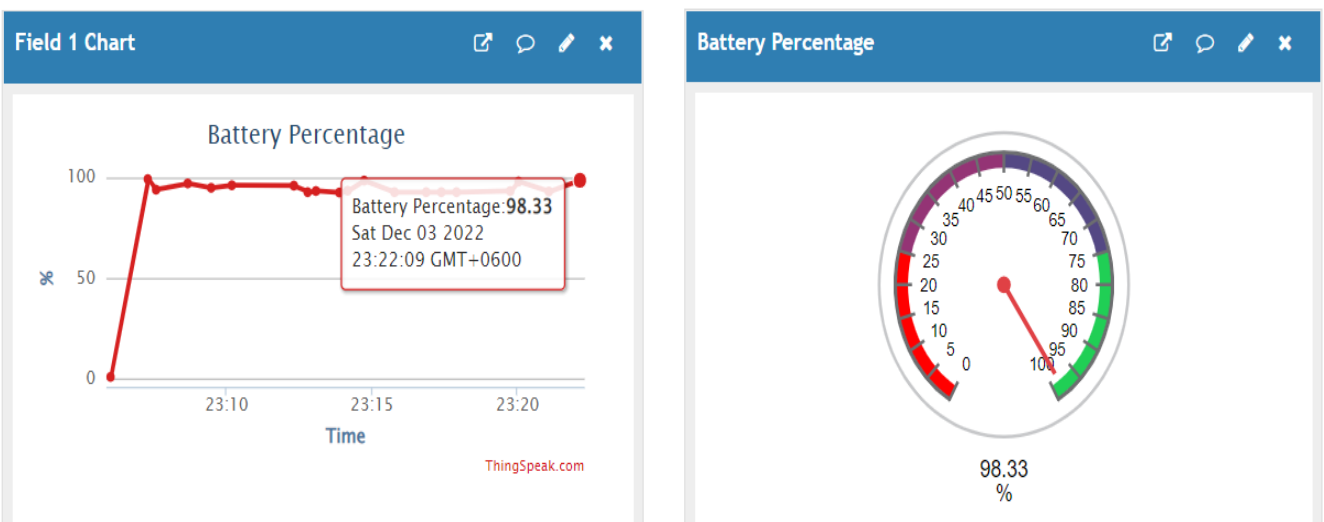


Figure 5.13: Battery Charge percentage in IoT system

This system can monitor the battery condition, such as the percentage of charge, through the Internet of Things using an Android smartphone.

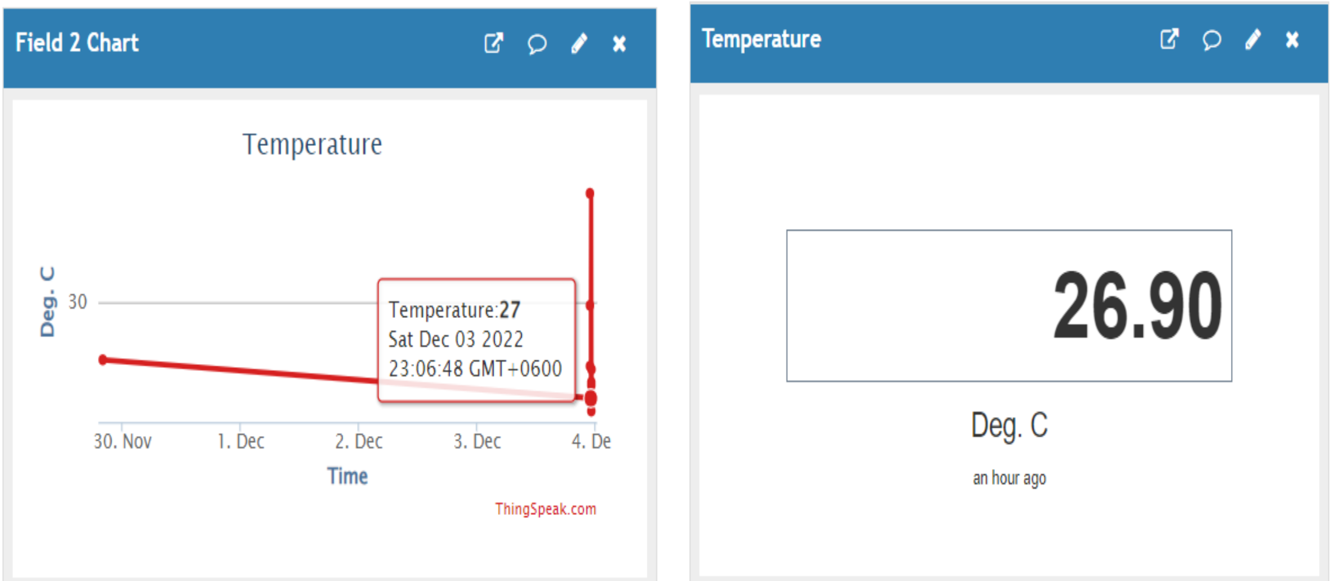


Figure 5.14: Battery Temperature in IoT system

This is an effective system for measuring and controlling the temperature through the Internet of Things and an Android smartphone when the temperature will exceed the limit.

There are further advantages as well. For example, the lower current produced by the higher voltage results in less heat, which is always advantageous for EV batteries as battery cooling devices may consume a significant amount of electricity.

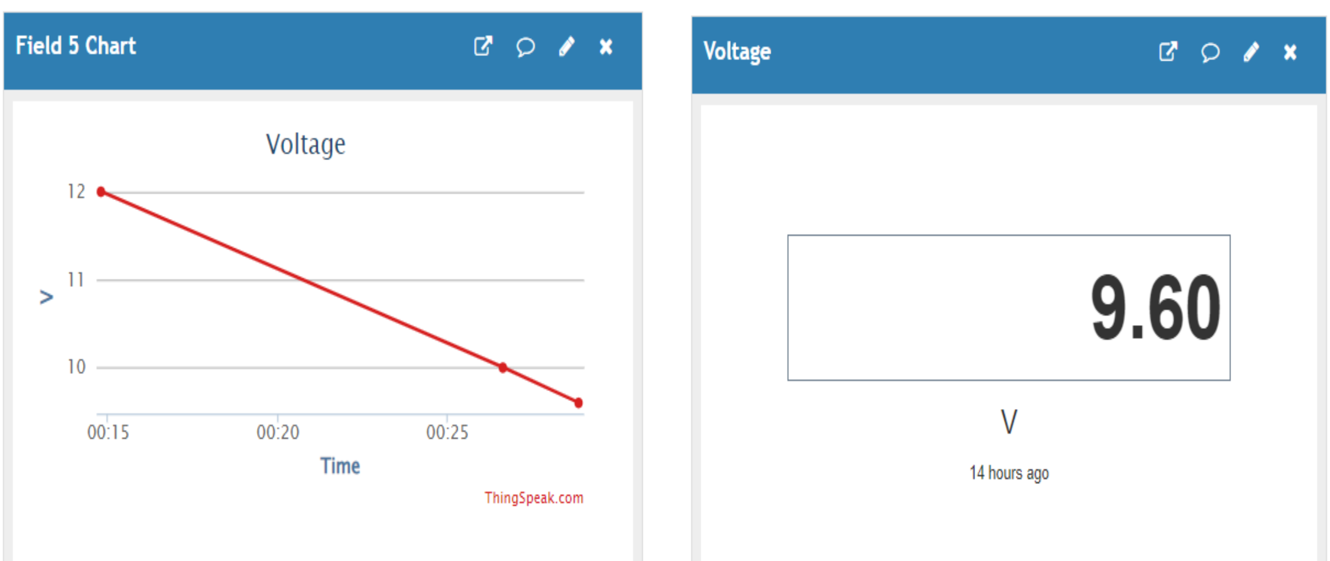


Figure 5.15: Battery Voltage in IoT System

The voltage of the cell can be measured and controlled with this system. It continuously monitors the battery cells to prevent the error or explosion.

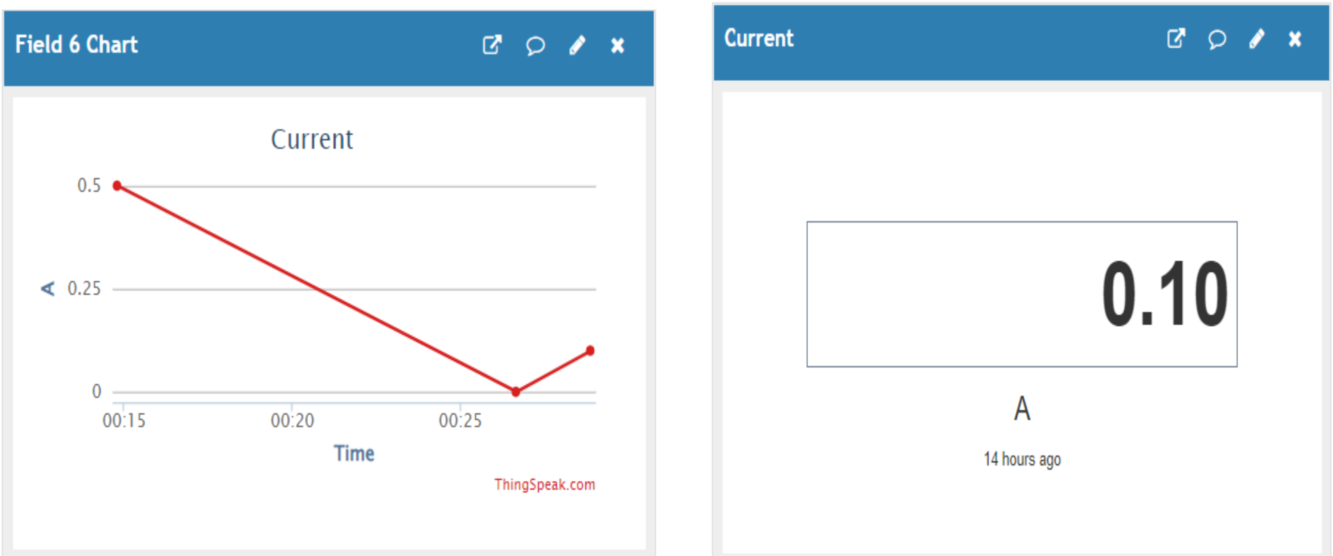


Figure 5.16: Battery Current in IoT System

The current of the battery can be monitored and determine with this system. It continuously monitors the lithium batteries current to prevent failure or detonation.

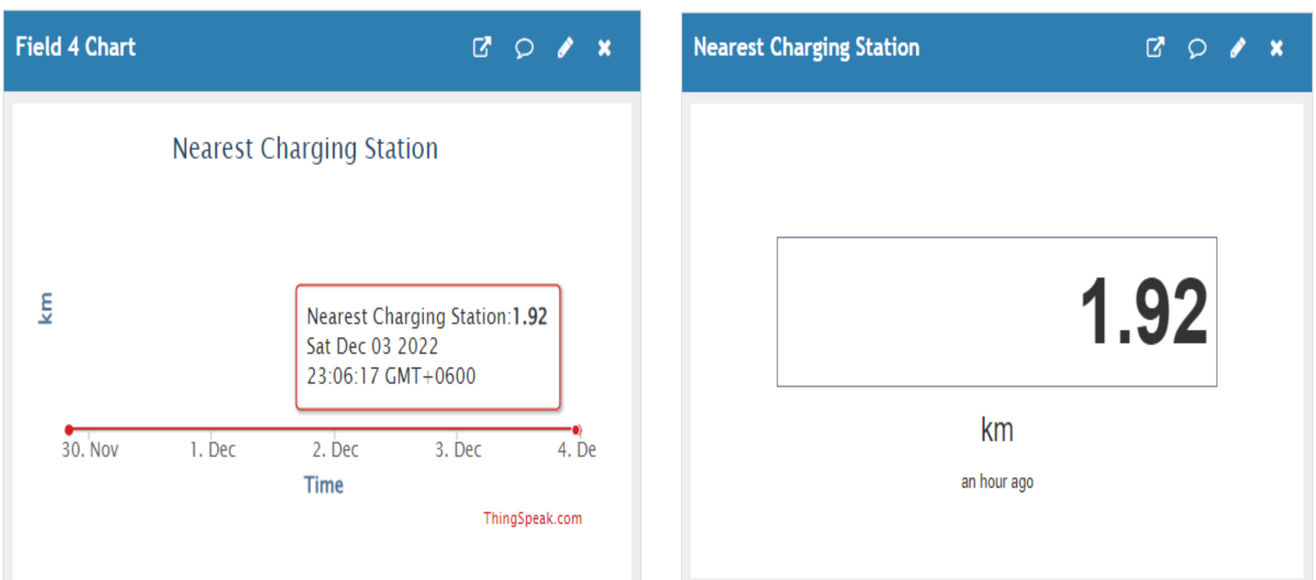
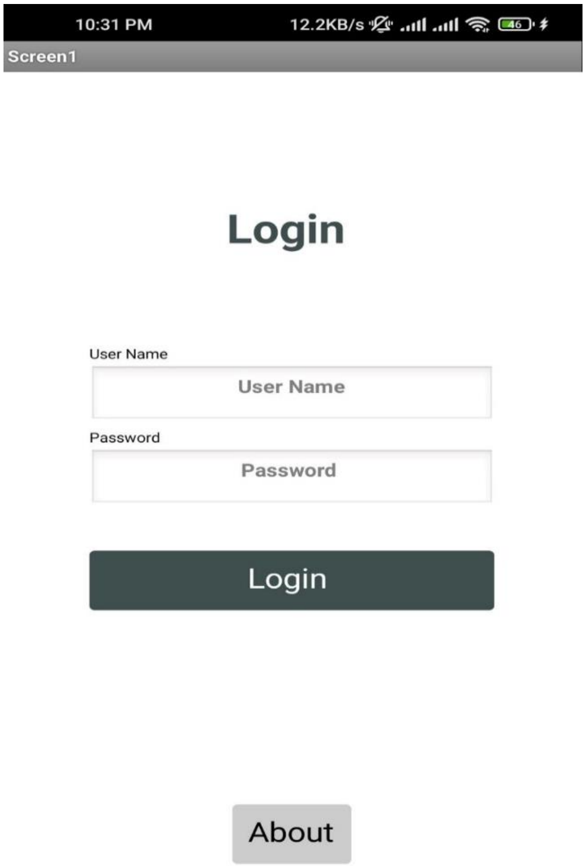


Figure 5.17: Nearest Charging Station location in IoT system

When the vehicle's battery is depleted, the system automatically calculates and checks the location of the nearest charging station. Using the Internet of Things using an Android mobile device.

5.2.2.3. In App Mode



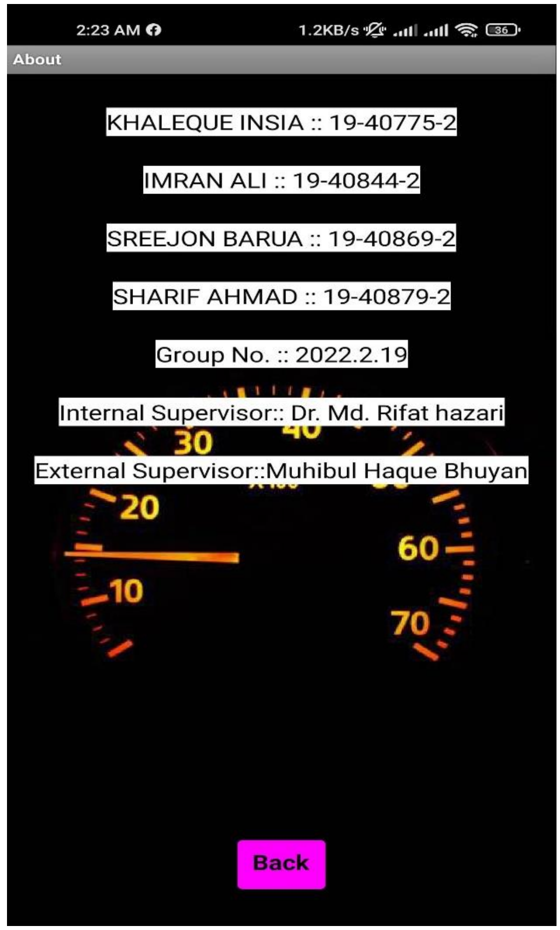


Figure 5.18: Login interface and about of the Apps

The login page of the mobile applications allows users to access the applications by entering their username and password or by authenticating with a social login. In addition, the apps allow us to enter both authorized users and a login function that may be used to create content exclusivity. Thus improves its worth and gives modern users a stronger sense of sercurity. The second figure shown the about page, which contains and represents both esteemed external and internal supervisors as well as our other group members.

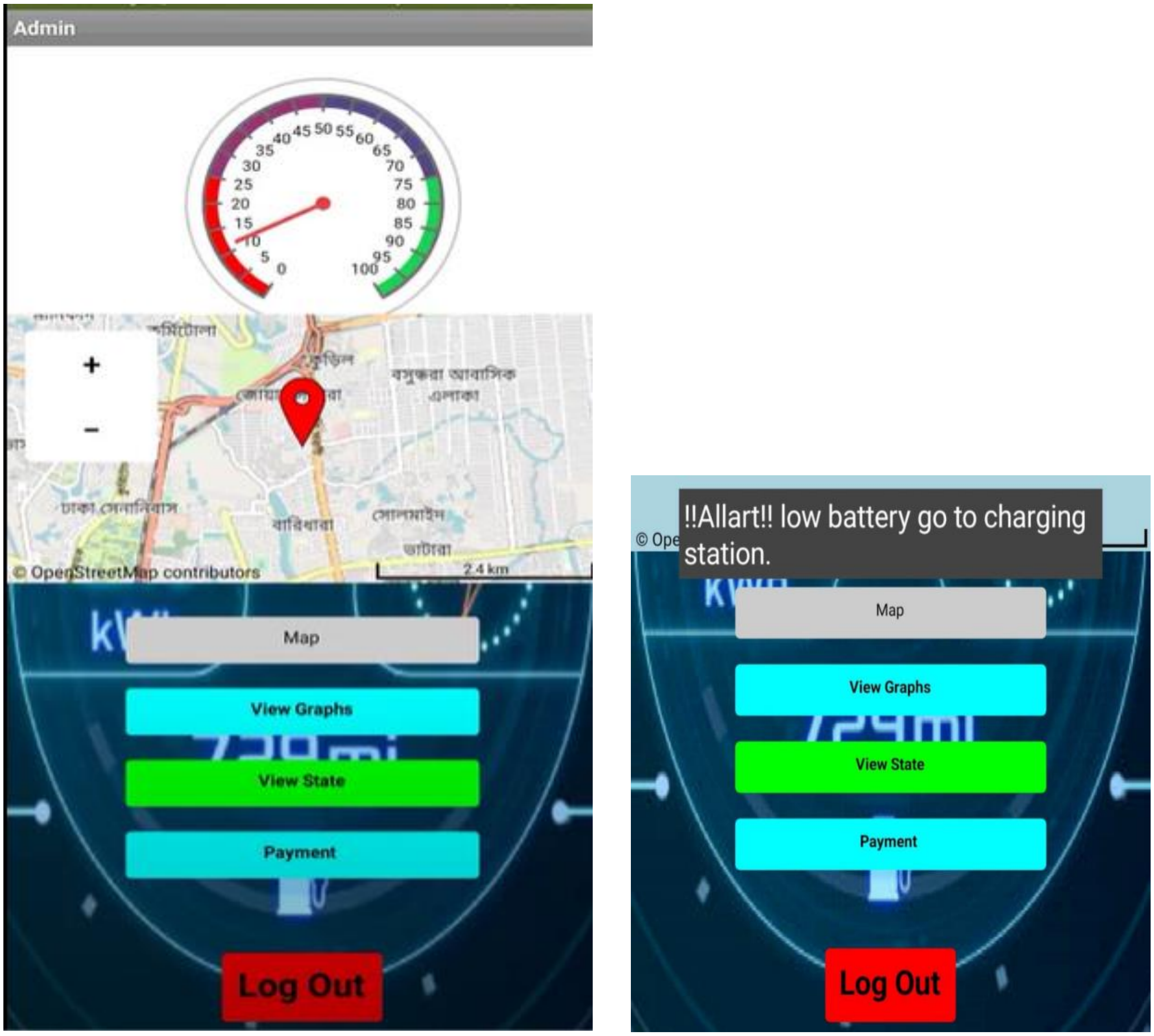


Figure 5.19: App Home page and low battery charge alert message

Figure 5.19 shown the home page of the app. The home screen of an app contains a search field or button so that users may quickly locate the desired material. In addition, because the home screen is the beginning of the user's journey, it frequently incorporates navigation elements that provide access to the various content sections, such as the charging station map and the battery performance by graphical, along with their respective values. After charging the vehicle, the user can click the payment method within the app to pay the bill. On the other hand, the second figure shown When the battery charge falls below thirty percent of the vehicle's capacity, the system will notify the user automatically.

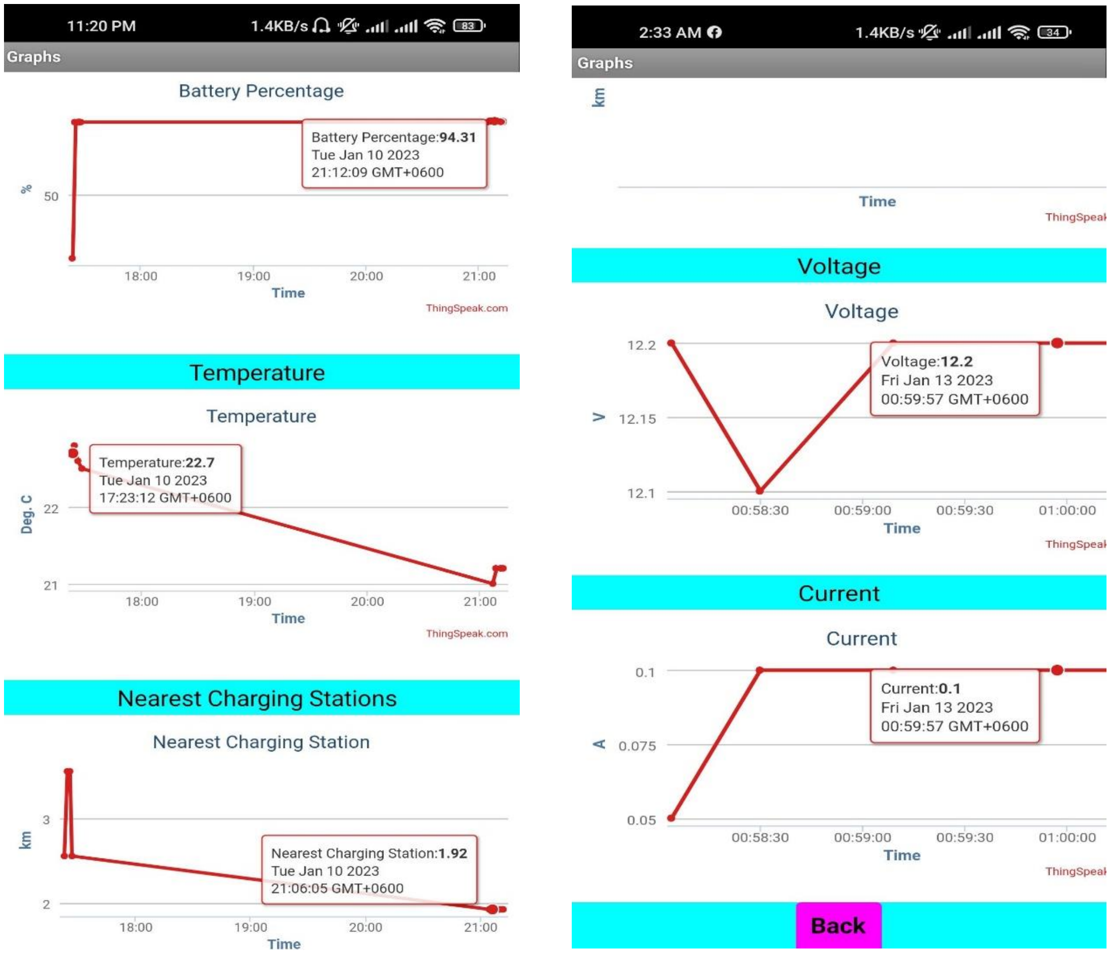


Figure 5.20: Graphical statistics of battery condition

The graphical data of battery status and performance are shown in Figure 5.20. The first graph displays the percentage of battery charge. The value and shape of the graph will fluctuate depending on the battery charge. The temperature will be displayed as 27 degrees. In Li-ion batteries, charge extraction due to current, battery capacity, the impact of internal resistance, and thermal effects beyond the rise in temperature caused by the battery condition are all included. The remaining temperature will fluctuate depending on the temperature of the battery. The range of an electric vehicle is dependent on the battery' capacity and charge. The estimated range of a fully charged battery is 160-170 kilometers. In addition, side the system will notify the user when the battery needs to be charged, then the user can check the nearest location through the mobile application.

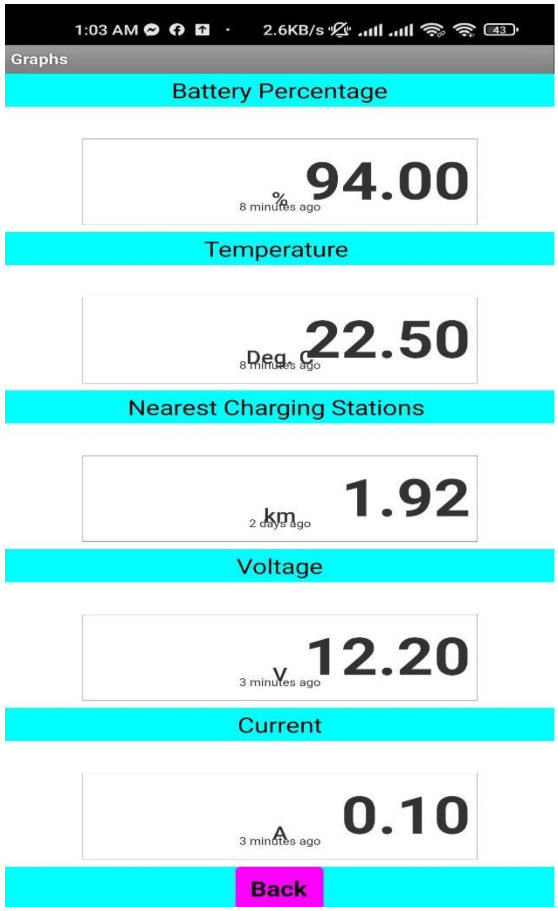


Figure 5.21: Numerical values of battery condition via App

This figure 5.21. shows the lithium-ion battery's performance in a mobile application for electric vehicles. The percentage of charge and the maximum number of kilometers the car can travel may both be easily checked by the user. The program specifically displays the battery's voltage, current, and temperature. When a charge is required if the battery charge is low, then the smart electric vehicle will provide the approximate location of any charging stations.

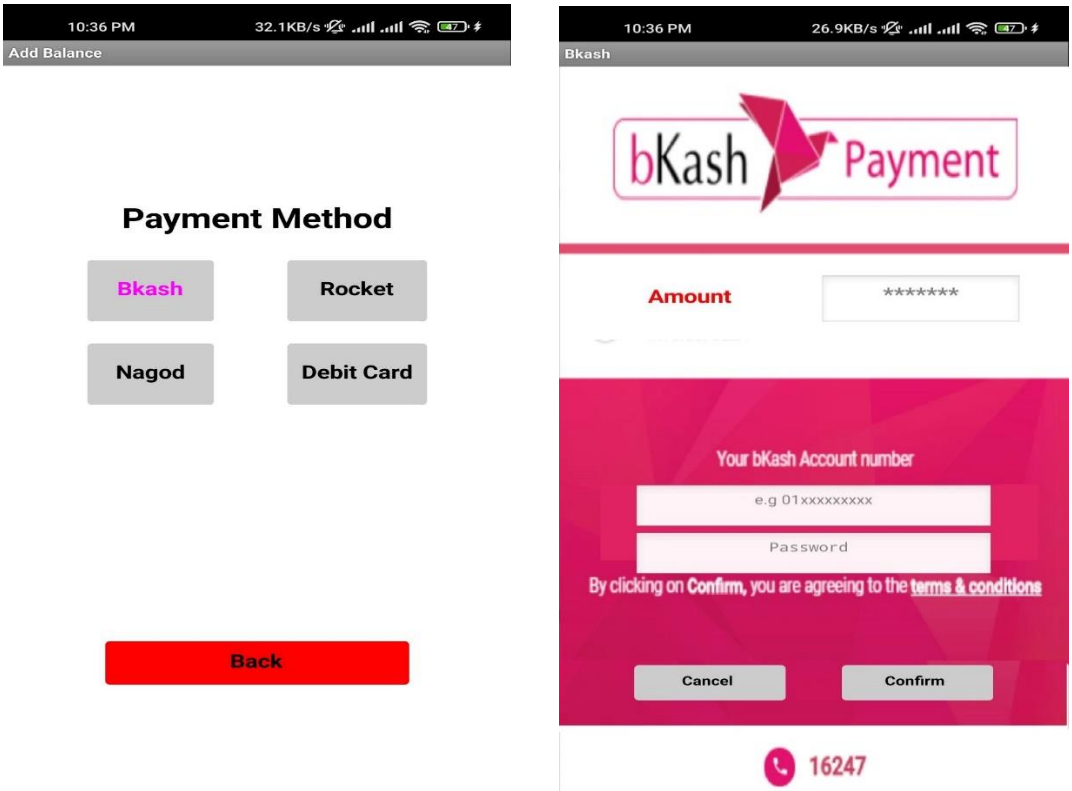


Figure 5.22: Mobile App Payment System

This system can be payment in many ways for battery charging cost through mobile banking system using their user ID on the gateway, and they also have the option to use a debit or credit cards.

5.3. Comparison of Results

The project simulation and hardware were completed, and both scenarios were successful. In the simulation, humans demonstrated the safety aspect of the proposed battery management system for electric vehicles, which displays an alarm message when a malfunction arises in the battery and measures current and voltage. As for the implementation of hardware, overall system architecture is a little unique. However, users have added the prepaid mode and IoT component battery safety and health status monitoring, respectively, in addition to the extra features; approximating the model simulation. In the past few years, there has been a significant difference between conventional electric vehicles and newer models. The electric vehicle system has just been improved from conventional to modern. Digital allows users to see the results via means of smartphone application. In this project, we give an Android application for monitoring the percentage of charge and battery status of electric vehicles, as well as a few alarms and a graph of consumed units. Since this intelligent electric car is directional, the meter can monitor both PV and grid voltage, as well as consumed and exported units. Therefore, IoT features were applied to improve this project.

Table 5.1: Comparison of result between traditional system and proposed system

Traditional System	Proposed System
[1] To improve the life of the battery cells and minimize costs, it is essential to monitor and regulate a variety of battery characteristics. Consequently, a battery management system is required for battery management to assure the safe, sustainable, and dependable operation of electric vehicles	[1] Design and development of an IoT-based battery and management and monitoring system for electric vehicles to ensure online monitoring of battery degradation..
[2] To provide a dynamic solution that takes into account the age and operational states of the batteries, the BMS should attempt to use one of the two cell equalization methods to balance the cells and prevent them from being overstressed.	[2] Implementing of cell-balancing system for protection battery each cell to increase the battery health condition.
[3] Another essential purpose of BMS is to maintain the battery pack within specified temperature limits. The performance, capacity, dependability, and security of batteries, etc., are affected by both high and low temperatures.	[3] Ensure maximum battery temperature limit. If the system cross the limit the system will notified or alert send to the user
[4] When GPS monitoring is synchronized with mobile devices, it gives crucial, real-time information such as position, emissions, distance, and speed.	[4] Through implementing a GPS system to detect the coordinate and display it on the Google Maps application, the system may display information such as position, battery condition, via the internet.

5.4. Summary

Analyzing the results of a project is essential. We must optimize the system's parameters in order to produce the most efficient design. We believe that this versatile smart Battery Management System would be advantageous to the energy, industrial, and residential sectors of society. This chapter is concluded with a summary of all the results, analytical information, and conclusions. A thorough analysis including both intended and unintended outcomes, design standards, and a description of the specific application we created have also been covered. It has to do with the energy transfer dashboard, price, and payment options. Finally, a comparison of our meter to conventional meters was made to make it clearer how much more effective our approach is from the standpoint of consumers and distributors.

Chapter 6

CONCLUSION

6.1. Summary of Findings

Battery Management System in Electric Vehicle, which manages the electronics of a rechargeable battery, whether a cell or a battery pack, is thus a critical element in assuring the safety of electric vehicles. It protects the user as well as the battery by ensuring that the cell runs within its safe operating boundaries. It monitors the temperatures throughout the pack and opens and closes numerous valves to maintain the temperature of the entire battery within a small temperature range for maximum battery performance. The electricity used to charge and fuel battery electric and plug-in hybrid vehicles is sourced from power grids that utilize a variety of energy sources, ranging from fossil fuels to clean renewable energy. Energy grids differ from state to state, therefore the carbon footprint of driving an electric vehicle varies based on its electrical source. m These sections will discuss several limits, potential ranges, and implications of the project. In addition, this chapter describes the originality of the project and how it conforms to the relevant technical criteria.

6.2. Novelty of the work

Every project possesses a unique combination of factors that influence its effectiveness and profitability. Having a blend of various abilities and characteristics is highly desired today. This project's primary objective was to design a battery management system for electric vehicles, transmit data to the utility via an app, and monitor battery health condition via the Internet of Things. Our project's primary objective. Battery management systems (BMS) are electronic control circuits that regulate and monitor the charging and discharging of batteries. In electric vehicles, the primary function of the battery management system is to detect the battery type, voltage, temperature, capacity, state of charge, power consumption, remaining operational time, and charging cycles. Electric vehicles are powered by high-voltage batteries. Consequently, we must guarantee the safe operation of these batteries. To ensure the safe operation of the battery, the BMS monitors factors such as temperature, input and output current, and voltage across the battery packs. Monitoring the current flowing towards the battery pack prevents overcharging. When the battery is depleted, the mobile application enables the user to quickly identify any battery-related issue, check the battery's remaining charge percentage, and locate the nearest charging station. The revolutionary aspect of this idea is the PV system computation based on IoT

.

6.3. Cultural and Societal Factors and Impacts

6.3.1. Cultural and Societal Factors Considered in Design

The primary purpose of this system was to improve the intelligent Battery Management system and properly monitor the Battery's health state. Our IoT-based smart Battery management and Monitoring solution for Electric Vehicles was designed and made available in mind of Bangladesh's global environmental and energy circumstances. In addition, the intelligent Battery Management systems that are currently available for purchase in Bangladesh and around the world may be replaced with our electrical technology at a lesser cost, hence reducing environmental damage. We believe that incorporating technology such as IoT will inspire everyone to engage in energy-efficient practices. In order to take sociological and cultural factors into account, we have compiled responses to surveys and comments regarding our project in the figure below.

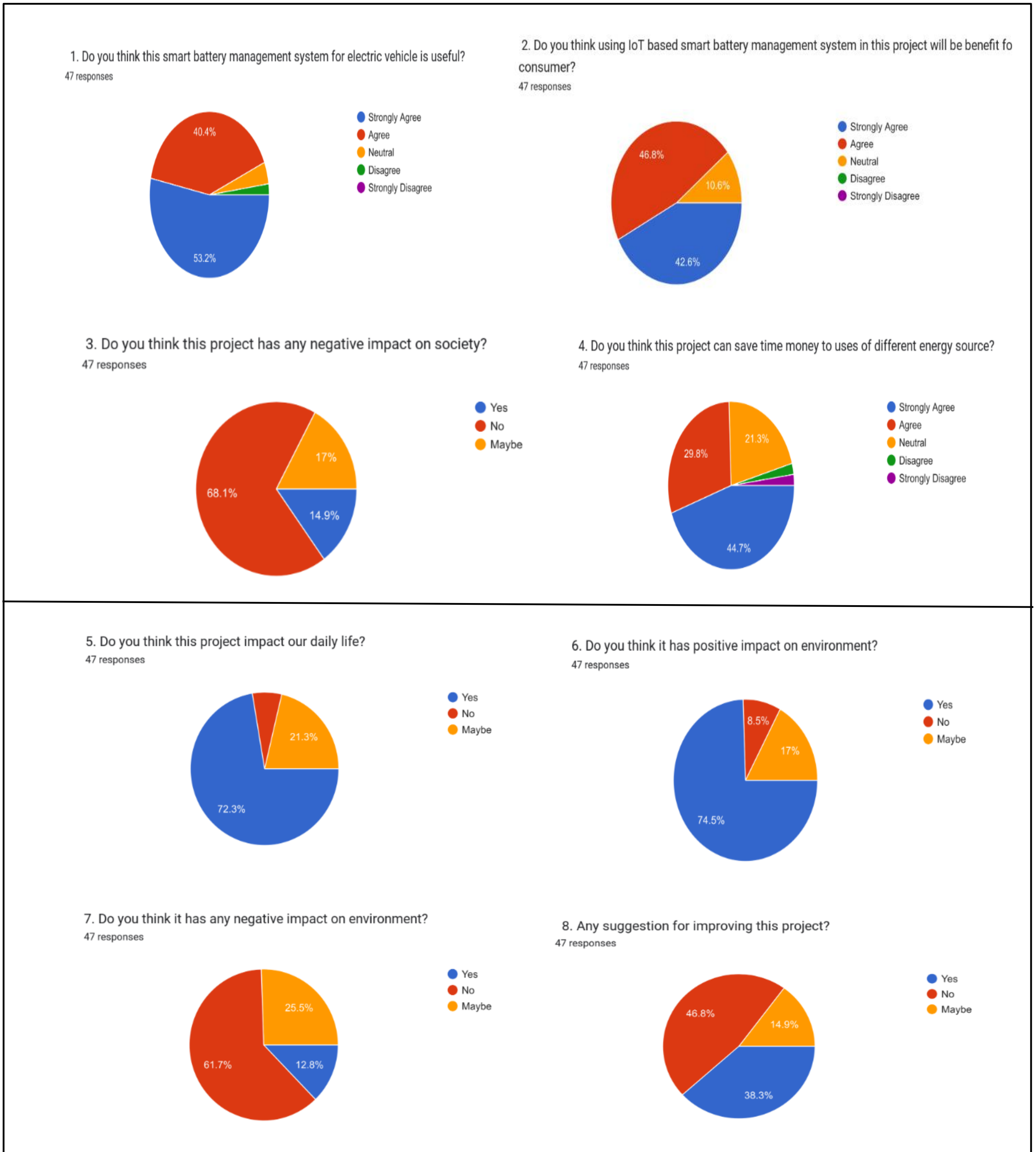


Figure 6.1: Survey Data Table

6.3.2. Cultural and Societal Impacts of the Proposed Design

This system performed precisely as expected. Such aspects like smart electric car battery parameters utilization were measured. The IoT connection also operated as predicted, allowing the observed data to be transmitted to the smartphone app. This improved version of the vehicle will have a significant impact on society.

- Demand response programs provide consumers with prices or other incentives to reduce their electricity consumption, allowing them to save money.
- New products and services that can create opportunities to use electricity more efficiently and effectively.

Therefore, our technology has the ability to offer a cost-effective and dependable monitoring solution.

6.4. Limitations of the Work

Although the designed system functioned successfully and the results were promising, the system has the following limitations:

- The app is not available for download from app stores.
- Additionally, the delay during the transfer from solar to the battery could be reduced.
- This system can be costly to purchase.
- The hardware prototype needs additional promise.

A suitable GSM module model can be implemented.

6.5. Future Scopes

Despite the fact that the system is operating as intended, there are areas where it can be enhanced in the future. These scopes are described in detail below:

- The Battery management System manages and commands the battery pack of any EV or E-bike to ensure its longevity and operating safety.
- Real-time data collecting helps in modeling a battery model as close to reality as possible for analysis, development, and performance enhancement.
- An improved version of Network communication can be utilized to more precisely receive the data.

6.6. Social, Economic, Cultural and Environmental Aspects

These processes and processes influence the distribution of resources, money, and authority in a community and on a global scale. This distribution, known as the socio - economic environment, determines how individuals and groups acquire the resources necessary to meet their basic human requirements.

6.6.1. Social Aspects

This method charges its batteries with electricity as opposed to fossil fuels such as gasoline or diesel. Electric vehicles are more efficient, and when paired with the cost of power, charging an electric vehicle is less expensive than refueling with gasoline or diesel. The social and environmental repercussions of electric and hybrid vehicles include effects on mobility and travel, operation of the energy supply system, consumption of petroleum and other fuels, air pollution, and traffic noise.

6.6.2. Economical Aspects

The designed system is economically feasible due to the fact that it offers flexibility at a competitive price relative to alternative options. The system has no negative environmental consequences. No component of this system degrades into e-waste, as none of the components have an expiration date. Since the system is modular, any malfunctioning sensor may be readily replaced without affecting the operation of the other sensors.

6.6.3. Health and Safety

The majority of the organization believes that protecting the health and safety of the general public and its own members is the most essential ethical principle. To protect the health and safety of the public, ethical design and sustainable development principles must be observed. Additionally, the privacy of others must be protected, Furthermore, any aspects that could jeopardize the public or the environment must be made as transparent as feasible.

6.6.4. Cultural and Environmental Factors

Electric vehicles have come to represent the fight against global warming. However, the commercial development of EVs is sluggish in many countries, and global adoption rates vary widely. The results of linear regression studies indicate that uncertainty avoidance, individualism, masculinity, and indulgence have a substantial negative effect on the sales of battery electric automobiles, whereas long-term orientation effects their market share positively. Results reveal that national culture is a significant international element that determines the rate and direction of electric car adoption. The analysis also highlights how cultural values translate into the purchase of EVs and offers marketers and regulators insight on how to expand the use of alternative-fuel vehicles

6.7. Conclusion

The proposed method has the capacity to reduce user discomfort and increase user awareness of inefficient energy usage and environmental degradation. Reduced pollution may result from the utilization of electrical energy sources, so improving the environment. In addition, Electric Vehicle offer substantial benefits in terms of energy conservation and environmental protection. Eco Motors is a company that manufactures electric vehicles in the country to reduce the need for imports. The company has already produced a variety of battery-powered vehicles, including solar cars, motorcycles, vans, and eco-taxis, among others. In Bangladesh, there is an eco-friendly electric vehicle. Palki Motors Limited manufactures electric vehicles in Bangladesh to help commercial vehicle owners reach breakeven more quickly. Tesla, the leading provider of electric vehicles, is constructing a world powered by solar energy, running on batteries, and utilizing electric vehicles for transportation. Examine the most recent effects of our products, employees, and supply chain. This knowledge may therefore contribute in the distribution of the load at a given site. Within chapter provides a comprehensive summary of the project. Unique characteristics, social elements, weaknesses, and the future Scopes are also covered within this chapter. Several matters regarding to health and safety, the economy, and the environment demonstrate that the model of this net-meter can have a significant effect on the current situation in Bangladesh and the rest of the world.

REFERENCES

[1] Rezvanizaniani, S. M., Liu, Z., Chen, Y., & Lee, J. (2014). Review and recent advances in battery health monitoring and prognostics technologies for electric vehicle (EV) safety and mobility. *Journal of power sources*, *256*, 110-124.

[2] Lam, A. Y., Leung, Y. W., & Chu, X. (2014). Electric vehicle charging station placement: Formulation, complexity, and solutions. *IEEE Transactions on Smart Grid*, *5*(6), 2846-2856.

[3] Hannan, M. A., Hoque, M. M., Hussain, A., Yusof, Y., & Ker, P. J. (2018). State-of-the-art and energy management system of lithium-ion batteries in electric vehicle applications: Issues and recommendations. *Ieee Access*, *6*, 19362-19378

[4] Hu, R. (2011). Battery management system for electric vehicle applications.

[5] Hariprasad, A., Priyanka, I., Sandeep, R., Ravi, V., & Shekar, O. (2020). Battery management system in electric vehicles. *International Journal of Engineering Research*, *9*(05).

[6] Rezvanizaniani, S. M., Liu, Z., Chen, Y., & Lee, J. (2014). Review and recent advances in battery health monitoring and prognostics technologies for electric vehicle (EV) safety and mobility. *Journal of power sources*, *256*, 110-124.

[7] Laadjal, K., & Cardoso, A. J. M. (2021). Estimation of lithium-ion batteries state-condition in electric vehicle applications: issues and state of the art. *Electronics*, *10*(13), 1588.

[8] Pelegov, D. V., & Pontes, J. (2018). Main drivers of battery industry changes: Electric vehicles—A market overview. *Batteries*, *4*(4), 65.

[9] Kirsch, D. A. (2000). The electric vehicle and the burden of history.

[10] Bowkett, M., Thanapalan, K., Stockley, T., Hathway, M., & Williams, J. (2013, September). Design and implementation of an optimal battery management system for hybrid electric vehicles. In *2013 19th International Conference on Automation and Computing* (pp. 1-5). IEEE.

[11] Karmawijaya, M. I., Haq, I. N., Leksono, E., & Widyotriatmo, A. (2019, November). Development of big data analytics platform for electric vehicle battery management system. In *2019 6th international conference on electric vehicular technology (ICEVT)* (pp. 151-155). IEEE.

[12] Chatzakis, J., Kalaitzakis, K., Voulgaris, N. C., & Manias, S. N. (2003). Designing a new generalized battery management system. *IEEE transactions on Industrial Electronics*, *50*(5), 990-999.

[13] Liu, K., Li, K., Peng, Q., & Zhang, C. (2019). A brief review on key technologies in the battery management system of electric vehicles. *Frontiers of mechanical engineering*, *14*(1), 47-64.

[14] Zhu, C., Li, X., Song, L., & Xiang, L. (2013). Development of a theoretically based thermal model for lithium ion battery pack. *Journal of Power Sources*, *223*, 155-164.

[15] Ali, M. U., Zafar, A., Nengroo, S. H., Hussain, S., Junaid Alvi, M., & Kim, H. J. (2019). Towards a smarter battery management system for electric vehicle applications: A critical review of lithium-ion battery state of charge estimation. *Energies*, *12*(3), 446.

[16] Abd Wahab, M. H., Anuar, N. I. M., Ambar, R., Baharum, A., Shanta, S., Sulaiman, M. S., ... & Hanafi, H. F. (2018). IoT-based battery monitoring system for electric vehicle. *International Journal of Engineering & Technology (IJET)*, *7*(4.31), 505-510.

[17] Tran, M. K., Panchal, S., Khang, T. D., Panchal, K., Fraser, R., & Fowler, M. (2022). Concept review of a cloud-based smart battery management system for lithium-ion batteries: Feasibility, logistics, and functionality. *Batteries*, *8*(2), 19.

[18]] Saqib, M., Hussain, M., Alam, M. S., Beg, M. M., & Sawant, A. (2017). Smart electric vehicle charging through cloud monitoring and management. *Technology and Economics of Smart Grids and Sustainable Energy*, *2*(1), 1-10.

[19] Ferreira, J. C., Monteiro, V., Afonso, J. L., & Silva, A. (2011, June). Smart electric vehicle charging system. In *2011 IEEE Intelligent Vehicles Symposium (IV)* (pp. 758-763). IEEE.

[20] Bakker, S., Maat, K., & van Wee, B. (2014). Stakeholders interests, expectations, and strategies regarding the development and implementation of electric vehicles: The case of the Netherlands. *Transportation Research Part A: Policy and Practice*, *66*, 52-64.

[21] Wolbertus, R., Jansen, S., & Kroesen, M. (2020). Stakeholders' perspectives on future electric vehicle charging infrastructure developments. *Futures*, *123*, 102610.

[22] Cao, J., Chen, X., Qiu, R., & Hou, S. (2021). Electric vehicle industry sustainable development with a stakeholder engagement system. *Technology in Society*, *67*, 101771.

[23] Han, B., Lu, S., Xue, F., Jiang, L., & Xu, X. (2017). Three-stage electric vehicle scheduling considering stakeholder's economic inconsistency and battery degradation. *IET Cyber-Physical Systems: Theory & Applications*, *2*(3), 102-110

[24] Clairand, J. M., García, J. R., Bel, C. A., & Sarmiento, P. P. (2017, September). A tariff system for electric vehicle smart charging to increase renewable energy sources use. In *2017 IEEE PES Innovative Smart Grid Technologies Conference-Latin America (ISGT Latin America)* (pp. 1-6). IEEE.

[25] Giosuè, C., Marchese, D., Cavalletti, M., Isidori, R., Conti, M., Orcioni, S., & Stipa, P. (2021). An Exploratory Study of the Policies and Legislative Perspectives on the End-of-Life of Lithium-Ion Batteries from the Perspective of Producer Obligation. *Sustainability*, *13*(20), 11154

[26] Jamal, H., Arshad, M. N., Butt, Y., Shafiq, H., Manan, A., Arif, A., & Janjua, M. K. (2020, September). Design of an economical and reliable net-metering device for residential consumption measurement using IoT. In 2020 59th Annual Conference of the Society of Instrument and Control Engineers of Japan (SICE) (pp. 1747-1752). IEEE.

[27] Ravi, R., Surendra, U., & Shreya, N. (2020). *Comparative analysis of various techniques of IOT in Electric vehicle* (No. 4500). EasyChair.

[28] Venugopal, P., Haes Alhelou, H., Al-Hinai, A., & Siano, P. (2022). Analysis of Electric Vehicles with an Economic Perspective for the Future Electric Market. *Future Internet*, *14*(6), 172.

[29] Christensen, A. S., Christensen, E. E., & Bentzen, J. B. (2011). A Social Cost-Benefit Analysis of an Electric Vehicle.

[30] Chan, C. C. (1993). An overview of electric vehicle technology. *Proceedings of the IEEE*, *81*(9), 1202-1213.

[31] Devon, R. (1999). Towards a social ethics of engineering: the norms of engagement. *Journal of Engineering Education*, *88*(1), 87-92

[32] Arrahman, R. (2022). Rancang Bangun Pintu Gerbang Otomatis Menggunakan Arduino Uno R3. *Jurnal Portal Data*, *2*(2).

[33] Zanofa, A. P., Arrahman, R., Bakri, M., & Budiman, A. (2020). Pintu Gerbang Otomatis Berbasis Mikrokontroler Arduino UNO R3. *Jurnal Teknik Dan Sistem Komputer*, *1*(1), 22-27.

[34] Smith, C. A. (2008). A review of liquid crystal display technologies, electronic interconnection and failure analysis. *Circuit World.*

[35] Choi, I., Shim, H., & Chang, N. (2002, August). Low-power color TFT LCD display for hand-held embedded systems. In *Proceedings of the 2002 international symposium on Low power electronics and design* (pp. 112-117).

[36] Zheng, J., Li, B., Zha, K., Guo, N. and Wang, L., 2020. Equipotential shielding voltage sensor for contact measurement of transient voltage in EHV/UHV power grids. High Voltage, 6(2), pp.291-301.

[37] Bezanilla, F. (2002). Voltage sensor movements. *The Journal of general physiology*, *120*(4), 465-473.

[38] Ukil, A., Braendle, H., & Krippner, P. (2011). Distributed temperature sensing: Review of technology and applications. *IEEE Sensors Journal*, *12*(5), 885-892.

[39] Chadil, N., Russameesawang, A., & Keeratiwintakorn, P. (2008, May). Real-time tracking management system using GPS, GPRS and Google earth. In *2008 5th International Conference on*

Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (Vol. 1, pp. 393-396). IEEE.

[40] Tjandi, Y. and Kasim, S., 2019. Electric Control Equipment Based on Arduino Relay. Journal of Physics: Conference Series, 1244(1), p.012028.

[41] Xie, J., & Lu, Y. C. (2020). A retrospective on lithium-ion batteries. *Nature communications*, *11*(1), 1-4.

[42] Kiran Dhumal, Tanuj Meshram, Atul Padol and Ganesh Yeole, 2022. Electrical Rain Detector Using Arduino Uno with LCD and Buzzer. International Journal of Advanced Research in Science, Communication and Technology, pp.444-447. 42.

[43] Ingole, M. and Rane, S., 2022. WIFI Module Based ESP 32. International Journal of Innovations in Engineering and Science, 7(5), p.39. 43.

[44] Narendran, N., & Deng, L. (2002, November). Color rendering properties of LED light sources. In *Solid State Lighting II* (Vol. 4776, pp. 61-67). SPIE. 44

[45] Xu, M., Teng, D., Wang, G., & Fei, Y. (2010, October). High Efficient BLDC Controller for Automobile Cooling Fan. In *2010 International Conference on Intelligent System Design and Engineering Application* (Vol. 1, pp. 809-812). IEEE.

[46] Bower, J. L., & Ordung, P. F. (1950). The synthesis of resistor-capacitor networks. *Proceedings of the IRE*, *38*(3), 263-269. 46

[47] Chathurangi, D., Jayatunga, U., Perera, S., Agalgaonkar, A. and Siyambalapitiya, T., 2021. Comparative evaluation of solar PV hosting capacity enhancement using Volt-VAr and Volt-Watt control strategies. Renewable Energy, 177, pp.1063-1075. 47

[48] Shaikh, M. R. S. (2017). A review paper on electricity generation from solar energy.

[49] Frakes, W. B., & Pole, T. P. (1990, November). Proteus: a software reuse library system. In *ACM SIGIR Forum* (Vol. 24, No. 3, pp. 43-55). New York, NY, USA: ACM.

[50] Arduino. (n.d.). Arduino IDE. Retrieved from Arduino.cc: https://www.arduino.cc/en/software 51

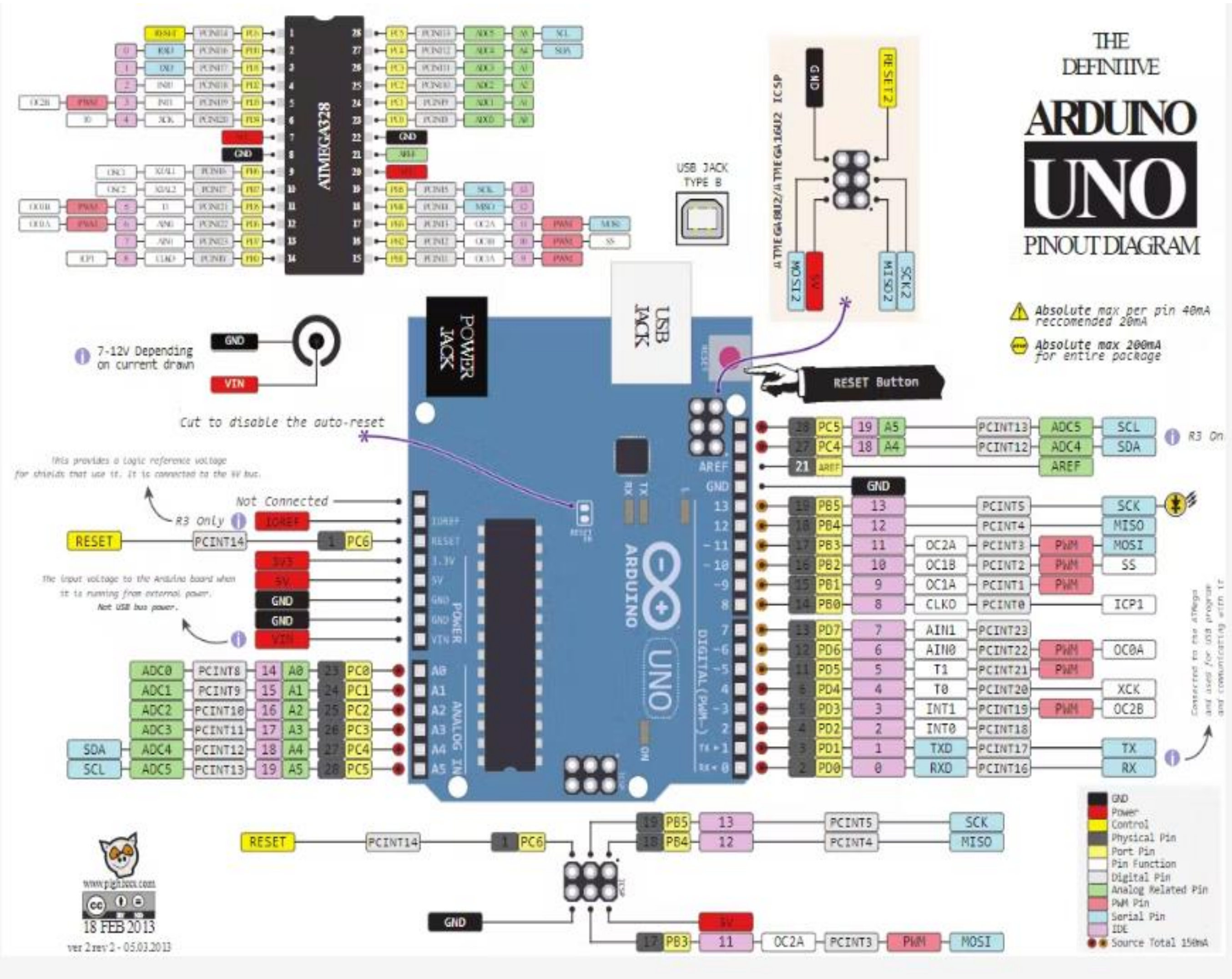
[51] Technology, M. I. (2012-2022, January). MIT App Inventor. Retrieved from mit.edu: https://appinventor.mit.edu/ 52

[52] P. Technology, M. I. (2012-2022, January). MIT App Inventor. Retrieved from mit.edu: https://appinventor.mit.edu

Appendix A

Datasheet of the ICs used

- **Arduino UNO**



Technical Specifications of Arduino Uno are given below

Microcontroller	ATmega328P – 8 bit AVR microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz
Power Jack	Yes
USB Connection	Yes

Arduino Uno Pinout Configuration table

Pin Category	Pin Name	Mapped Pin Details
Power	Vin	Vin: Input voltage to Arduino when using an external power source.
	5V	5V: Regulated power supply used to power microcontroller and other components on the board.
	3.3V	3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA.
	GND	GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V

Input/output Pins	Digital Pins 0 - 13	Used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

- **LCD 16*2" Display**

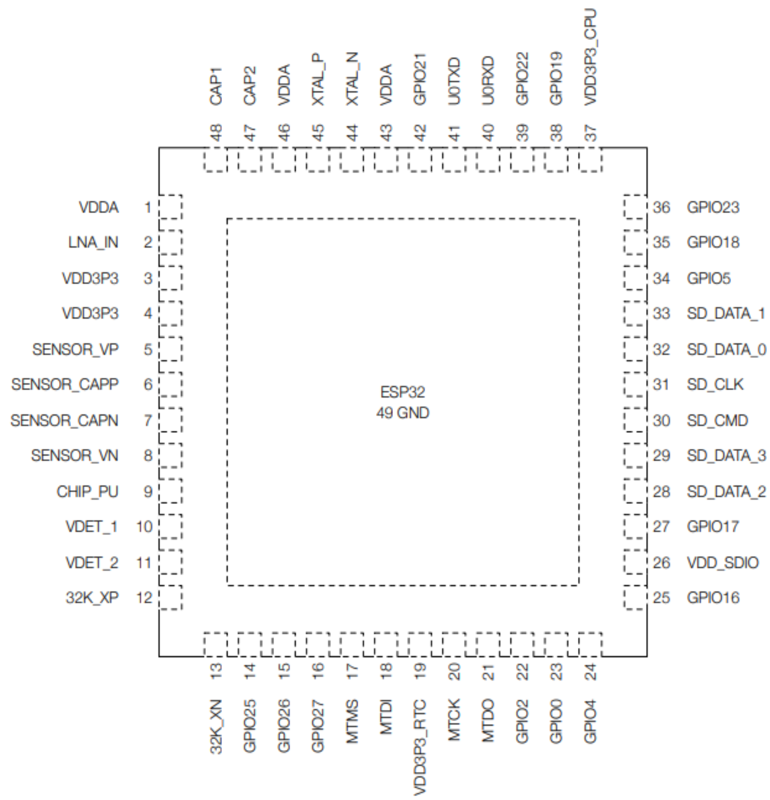
Dimensions

Item	**Dimensions**	**Unit**
LCD Size	80 x 36	mm
Viewing Area	64 x 16	mm
Dot Size	0.55 x 0.66	mm
Dot Pitch	0.60 x 0.70	mm
Character Size	2.96 x 5.56	mm
Character Pitch	3.55 x 5.94	mm
LCD Thickness	9.5	mm

LCD Display Pin Connections

Pin No	Symbol	Level	Function
1	Vss		GND(0V)
2	Vdd		Vcc(+5V±5%)
3	Vo		Contrast Adjust
4	RS	H/L	Register Select
5	R/W	H/L	Read/Write
6	E	H/L	Enable Signal
7	DB0	H/L	Data Bit 0
8	DB1	H/L	Data Bit 1
9	DB2	H/L	Data Bit 2
10	DB3	H/L	Data Bit 3
11	DB4	H/L	Data Bit 4
12	DB5	H/L	Data Bit 5
13	DB6	H/L	Data Bit 6
14	DB7	H/L	Data Bit 7
15	NC		Not Connected
16	NC		Not Connected

➢ ESP 3266 Wi-Fi Module



ESP 3266 Pinout Configuration

Name	ESP8266
Processor	Xtensa Dual-Core 32-bit LX6 with 600 DMIPS
GPIO pins	36
CPU speed	160 MHz
Analog In	12-bit
Bluetooth	Yes
CAN	Yes
SRAM	Yes
USB	Micro
SPI/I2C/I2S/UART	4/2/2/2

General Specifications

Pin Category	Name	Description
Power	Micro-USB, 3.3V, GND, Vin	Micro-USB: NodeMCU can be powered through the USB port 3.3V: Regulated 3.3V can be supplied to this pin to power the board GND: Ground pins Vin: External Power Supply
Control Pins	EN, RST	The pin and the button resets the microcontroller
Analog Pin	A0	Used to measure analog voltage in the range of 0-3.3V
GPIO Pins	GPIO1 to GPIO16	NodeMCU has 16 general purpose input-output pins on its board
SPI Pins	SD1, CMD, SD0, CLK	NodeMCU has four pins available for SPI communication.
UART Pins	TXD0, RXD0, TXD2, RXD2	NodeMCU has two UART interfaces, UART0 (RXD0 & TXD0) and UART1 (RXD1 & TXD1). UART1 is used to upload the firmware/program.
I2C Pins		NodeMCU has I2C functionality support but due to the internal functionality of these pins, you have to find which pin is I2C.

- **Voltage Sensor**

Voltage Sensor Module Pinout Configuration

Pin Name	Description
VCC	Positive terminal of the External voltage source (0-25V)
GND	Negative terminal of the External voltage source
S	Analog pin connected to Analog pin of Arduino
+	Not Connected
-	Ground Pin connected to GND of Arduino

- **Current Sensor**

Current Sensor Module Pinout Configuration

Pin Number	Pin Name	Description
1	Vcc	Input voltage is +5V for typical applications
2	Output	Outputs Analog voltage proportional to current
3	Ground	Connected to ground of circuit
T1	Wire In	The wire through current has to be measured is connected here
T2	Wire Out	

General Specifications

5A Module	20A Module	30A Module
185mV/Amp	100mV/Amp	66mV per Amp

- **Temperature Sensor**

Temperature Sensor Pinout Configuration

No.	Pin Name	**Description**
1	Vcc	Power supply 3.5V to 5.5V
2	Data	Outputs both Temperature and Humidity through serial Data
3	Ground	Connected to the ground of the circuit

- **Relay**

Relay Module Pin Description

Pin Number	Pin Name	Description
1	Relay Trigger	Input to activate the relay
2	Ground	0V reference
3	VCC	Supply input for powering the relay coil
4	Normally Open	Normally open terminal of the relay
5	Common	Common terminal of the relay
6	Normally Closed	Normally closed contact of the relay

General Specifications

Supply voltage	3.75V to 6V
Quiescent current	2mA
Current when the relay is active	70mA
Relay maximum contact voltage	250VAC or 30VDC
Relay maximum curren	10A

- **GPS Module**

GPS Module Pin Configuration

Pin Name	Description
VCC	Positive power pin
RX	UART receive pin
TX	UART transmit pin
GND	Ground

- **PV Panel**

PV Panel Configuration

MODULE TYPE: FY-36-20P
Peak Power(Pmax) (W): 9,
Production Tolerance (%): 0~+3,
Maximum Power Current(Imp) (A): 1.08,
Maximum Power Voltage(Vmp) (V):18.5,
Short Circuit Current(Isc) (A): 1.16,
Open Circuit Voltage(Voc) (V): 22.14,
Weight,(Kg): 0.5,
Dimensions (mm): 500*360*25,
Maximum System Voltage,(VDC): 1000,
Application class: A,

Appendix B

iThenticate Plagiarism Report

IOT-BASED SMART BATTERY MANAGEMENT AND MONITORING SYSTEM FOR ELECTRIC VEHICLE

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23 Rizwan A. Farade, Mirza Talha, Ismail Taha, Harshal Waghambre, Shaikh Afaan, Ansari Zaki. "Battery Charger for E-Scooter with Flexible Output and Billing Service", 2022 Third International Conference on Intelligent Computing Instrumentation and Control Technologies (ICICICT), 2022
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67	Kailong Liu, Kang Li, Qiao Peng, Cheng Zhang. "A brief review on key technologies in the battery management system of electric vehicles", Frontiers of Mechanical Engineering, 2018 Crossref	7 words — < 1%
68	Wang Haiying, , Wu Feng, Fu Ying, Li Ran, and Zhang Qian. "Study on key technologies of lithium battery for electric vehicle", Proceedings of 2011 6th International Forum on Strategic Technology, 2011. Crossref	7 words — < 1%
69	Koji Kitada, Haruno Murayama, Katsutoshi Fukuda, Hajime Arai, Yoshiharu Uchimoto, Zempachi Ogumi. "Effect of Potential Profile on Battery Capacity Decrease during Continuous Cycling", The Journal of Physical Chemistry C, 2017 Crossref	6 words — < 1%

70 Muhammad Umair Ali, Amad Zafar, Sarvar Hussain Nengroo, Sadam Hussain, Muhammad Junaid Alvi, Hee-Je Kim. "Towards a Smarter Battery Management System for Electric Vehicle Applications: A Critical Review of Lithium-Ion Battery State of Charge Estimation", Energies, 2019 — 6 words — < 1%
Crossref

71 Shunli Wang, Carlos Fernandez, Yongcun Fan, Juqiang Feng, Chunmei Yu, Kaifeng Huang, Wei Xie. "A novel safety assurance method based on the compound equivalent modeling and iterate reduce particle‐adaptive Kalman filtering for the unmanned aerial vehicle lithium ion batteries", Energy Science & Engineering, 2020 — 6 words — < 1%
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