DESIGNING AND DEVELOPMENT OF A SUSTAINABLE CHARGING STATION FOR ELECTRIC CARS

An Undergraduate CAPSTONE Project
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Faculty of Engineering
American International University - Bangladesh

Designing and Development of a Sustainable Charging Station for Electric Cars

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

This is to certify that this project is our original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

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APPROVAL

The CAPSTONE Project titled **DESIGNING AND DEVELOPMENT OF A SUSTAINABLE CHARGING STATION FOR ELECTRIC CARS** 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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ABSTRACT

In Bangladesh, especially in Dhaka, air pollution is an alarming problem and vehicle emission is a great part of it. To solve this problem, Bangladesh is steadily moving towards electric vehicles, which needs enough charging infrastructures to actually implement the idea. It will require a huge amount of extra electricity which cannot be afforded due to the shortage of electricity production. This research is motivated by the desire to help the country execute the move to electric cars more reliably and decrease the dependency on national grid to charge the electric cars by using renewable energy. Some of the advantages of this project over other solutions in existence are-

- This research works to improve the current difficulties the country is facing using alternative resources with better features.
- The proposed solution follows the Sustainable Development Goals (SDGs) properly and works towards a ‘Green’ future.
- This research plays a vital role to develop a charging infrastructure for the Electric Vehicle industry of Bangladesh.

Chapter 1

INTRODUCTION

1.1. Overture

In today's modern world, everything is moving towards the future and so is the car industry. The world is adapting, and the future holds great prospect for Electric Vehicle (EV), the latest technology amongst the car industry. The usage of electric cars is booming over the entire world because of its 'Zero Emission' tagline and cost effectiveness. The usages of EV in different countries of the whole world is shown in Figure 1.1 as represented by the static bar chart. This visual representation proves the requirement of the charging infrastructures worldwide.

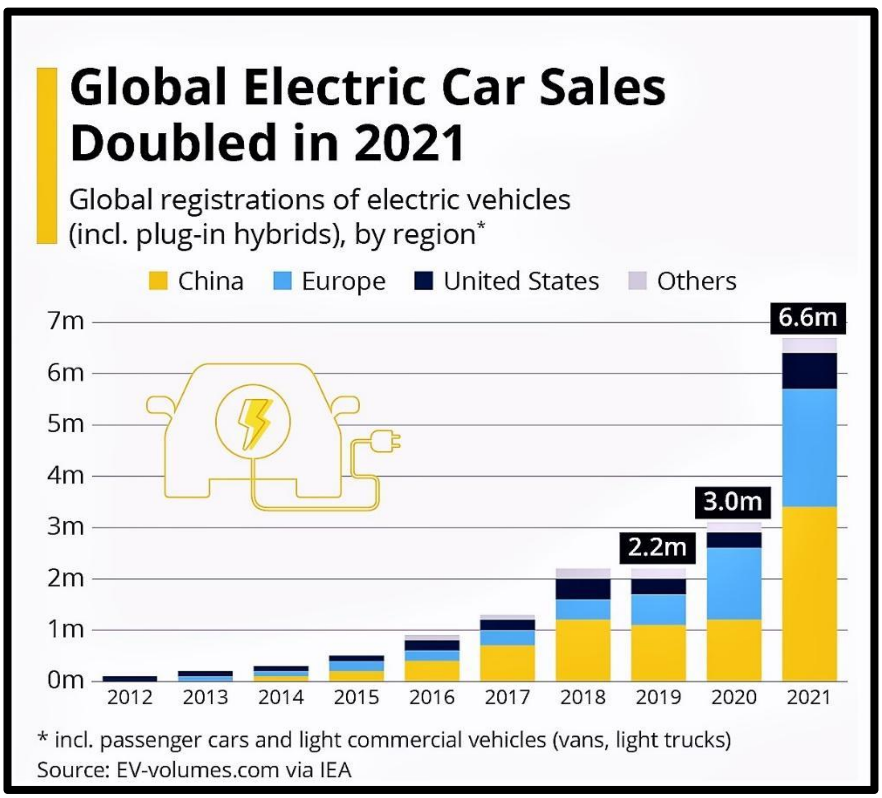

Figure 1.1 Bar chart representing the increase of EV usage [1].

Bangladesh is now nearer than ever to joining the global trend of switching to electric vehicles in the name of saving the environment and cutting down costs. In fact, it is remarkably close to manufacturing electric vehicles in its own territory. Bangladesh aims to adapt from fuel driven vehicles to the eco-friendly electric vehicles. Bangladesh Auto Industries Ltd (BAIL) has already made an initial investment of $200 million to make electric vehicles from June 2021 [2]. Bangladesh Government has also sanctioned the rules and guidance for producing electric vehicles and its charging infrastructure. Many private ventures such as- Nitol Motors and international investors for example- Omega Seiki, a member of the India-based Anglian Omega Network and A UK based energy and environmental consultancy firm, Ricardo-AEA plans to invest huge amount of money for setting up electric vehicle development projects in Bangladesh [3].

This project will help to build a sustainable infrastructure for electric vehicles with the help of clean renewable solar energy which is a cost-effective alternative and will reduce the pressure on national grid.

1.2. Engineering Problem Statement

This project is planned to be a prototype model of an electric vehicle charging infrastructure based on both solar power and national grid. This model will be mainly based on the renewable energy received by the solar panel along with the connection with national grid. This way, there will be less pollution and this process will reduce the overload on the national grid as the production of electricity is already not meeting the demand.

1.3. Related Research Works

1.3.1. Earlier Research

According to Ernest Henry Wakefield, in a well-researched history of the electric automobile, the first known battery-electric propulsion automobile was assembled in 1881 by electrical engineer Gustave Trouve of France. The tricycle configured vehicle used lead acid storage batteries for energy storage, which had been invented in 1859 by Gaston Plante, also of France [6].

In England, the second known electric automobile was constructed by Professors W. E. Ayrton and John Perry of London in the mid-1880's. The Ayrton and Perry tricycle used lead-acid batteries also, and incorporated several other automotive electrical features that would not appear again for decades: dual electric arc headlights, power and speed control via series battery. switching, a voltmeter, and an ammeter for estimation of battery charge remaining, friction brakes, and an allgear transmission. The first automotive World Land Speed Record competition was held between two electric vehicles in 1899. The winner was a bullet-shaped vehicle constructed by Janetzy Jamais Contente, with a record speed of 65 MPH. This vehicle also has the distinction of being the first automobile to include consideration of aerodynamics in its design, a concept not significantly incorporated again until at least thirty years later.

1.3.2. Recent Research

ChargePoint announced ChargePoint Express Plus, an ultra-fast DC charging solution that can deliver up to 400 kW. It supports charging voltages ranging from 200 V to 1000 V including today's 400 V cars and 750 V buses, and tomorrow's 800 V cars.

A modular platform designed for businesses and charging centers along major roadways or transit depots, Express Plus can charge today's newest electric vehicles, such as the Chevy Bolt EV, at their maximum rate; is equipped to charge upcoming EVs such as the Tesla Model 3; and is ready to deliver maximum charging speed to EVs coming to market in the years to come. Express Plus will be available in July 2017. ChargePoint up to now has offered 24 kW and 50 kW fast charging via its Express 100 and 200 platforms.

Complementing ChargePoint's existing products and services, ChargePoint Express Plus supports the creation of a network enabling the rapid refueling of EVs on long trips or to support the rigorous daily routines of electric buses and trucks.

With ChargePoint Express Plus, charging site operators can design for the long term and incrementally build out charging infrastructure to meet driver demand without any stranded investment along the way. The product intelligently allocates power among vehicles based on each battery's state of charge (SoC) and instantaneous maximum charge rate, so every car charges as fast as possible, getting drivers back on the road quickly while making efficient use of the power available at each site.

Power consumption is managed within a site's available capacity while minimizing the impact on vehicle charging rates. Power management and high-efficiency power conversion (more than 96% efficiency) reduce electricity costs and wasted energy. Fault-tolerant design, instrumentation for remote monitoring, intelligent diagnostics, and machine learning techniques work together predictively to prevent failures and ensure high availability.

The ChargePoint Express Plus architecture as shown in **Figure 1.2** consists of three modular building blocks that can be configured to meet the exact requirements at any site and scale incrementally as demand for charging increases.

Figure 1.2 Express Plus Station [7]

• Power Modules are a basic building block in the Express Plus architecture. Each module is a self-contained AC to DC power conversion system that operates between an output of 200 and

1000 V and delivers up to 31.25 kW at a max current of 78 A. Power Modules are sealed units, easily installed in Power Cubes or Express Plus Stations in the field without any special tools or technical expertise.

- Express Plus Stations dispense power to EVs and can support up to three flexible, lightweight cables compatible with all standard connector types. Each Express Plus Station houses two Power Modules and can connect with a Power Cube to deliver up to 400 kW to a single vehicle. There is a 10-inch LCD touchscreen for driver interaction, 20-inch wide-format LED display for notifications, cameras, area lighting, Wi-Fi, and Bluetooth connectivity and much more. Built-in cellular networking enables remote management through ChargePoint Cloud Services.

- Along with the Express Plus platform, ChargePoint Express 250, a standalone 50kW and 62.5kW DC fast charging station capable of adding 90 miles of range in 30 minutes, was introduced [6].

In **Figure 1.3**, the description of the distinct types of charging docks and the time duration to fully charge a tesla is given.

Level 1,2 and 3 Tesla Charger Explanation:

- Tesla owners can in fact charge via a standard 120V residential outlet with a trickle charging adapter. It is nicknamed “trickle” charging because it is really, really slow.

- A “Level 2” EV charger is simply any EV charger that can connect to a particular type of electrical circuit — 240-volt, split phase circuits (similar to what an electric dryer uses). But just like different clothes dryer models take different amounts of time to dry your clothes, different EV chargers take different amounts of time to charge your car.

Level 3 Superchargers can take a Tesla from 0-170 miles range in just 30 minutes. It can get to 80% full in just 40 minutes. At the 80%-point, charging slows to safeguard battery health. And there are lots of them.

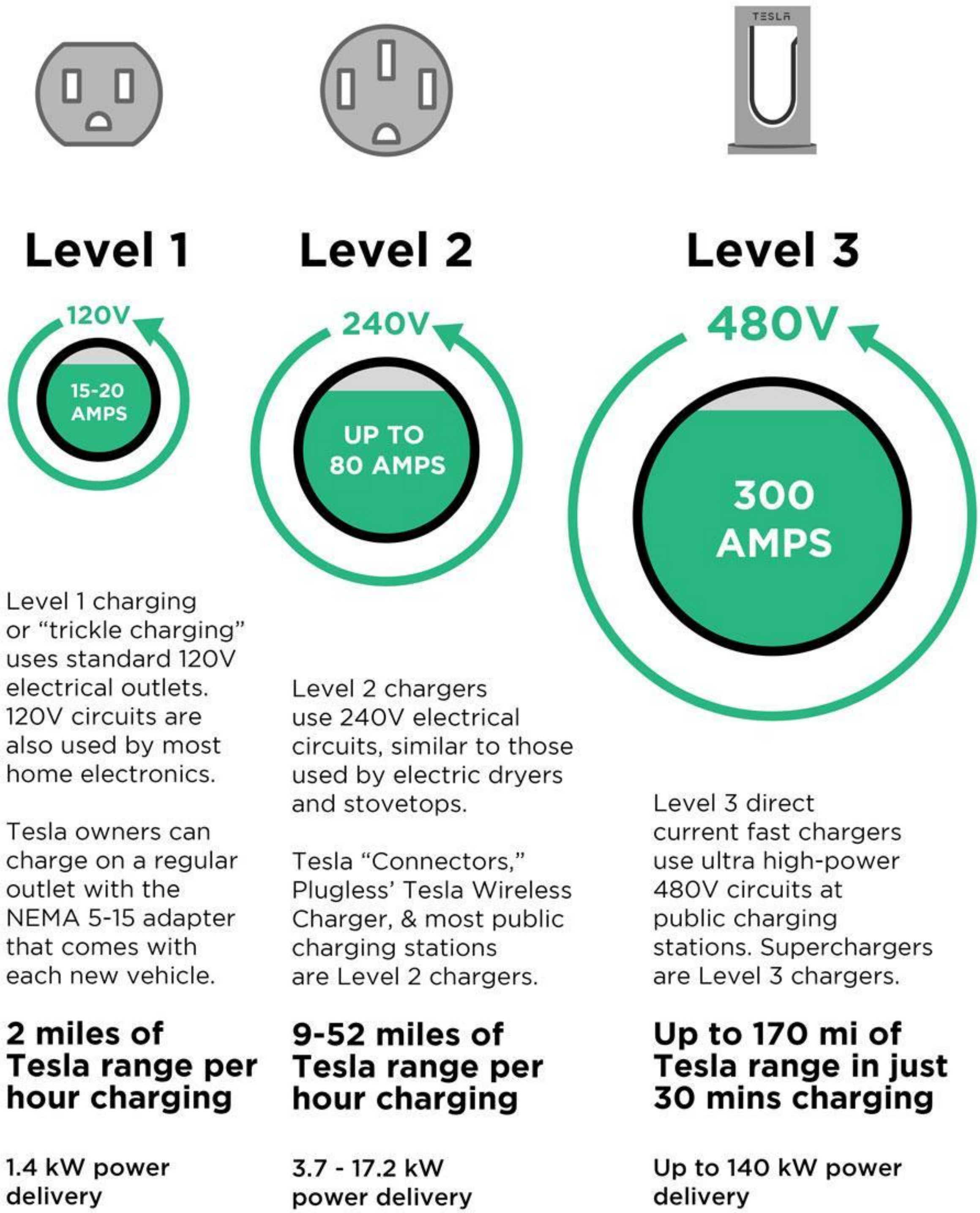

Figure 1.3 Tesla Charger classification with time duration [8]

Figure 1.4 shows the plot of Charging power VS state of charging of a Tesla model 3 LR AWD in case of DC fast charging.

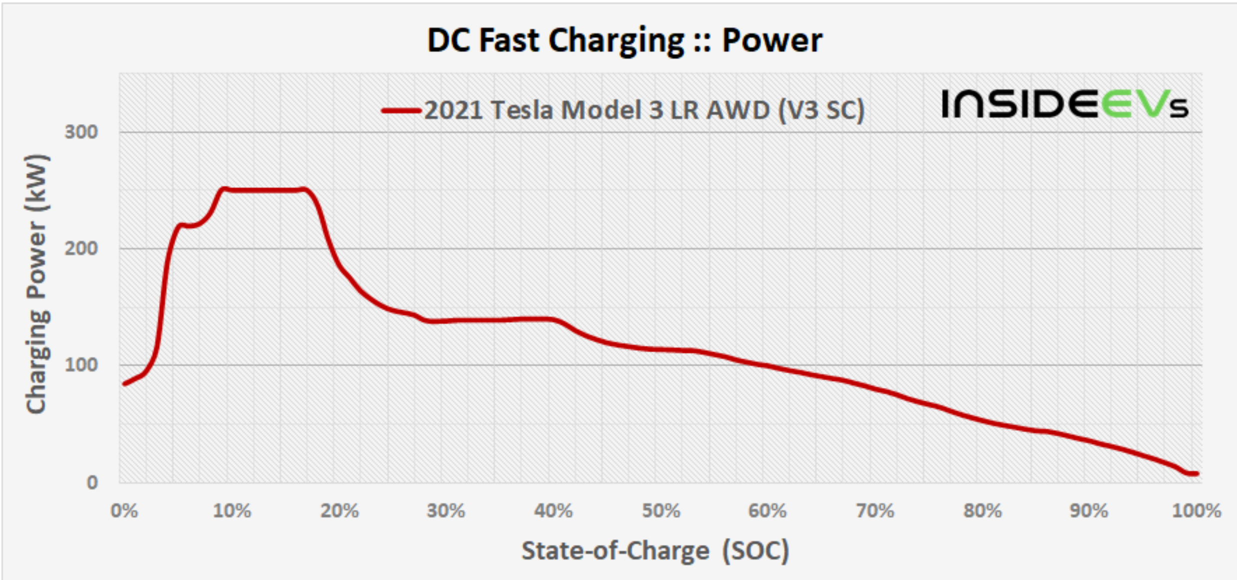

Figure 1.4 Charging power vs State of charging [9]

1.4. Critical Engineering Specialist Knowledge

This project requires in depth knowledge involving electric vehicles, the charging of electric vehicles and solar electricity. As Bangladesh is steadily moving towards electric vehicles, it needs enough charging infrastructures to actually implement the idea. It will require a huge amount of extra electricity which cannot be afforded due to the shortage of electricity production. This model will help the country to execute the move to electric cars more reliably and decrease the dependency on national grid to charge the electric cars.

To construct this proposed system, in-depth engineering knowledge is needed. The following list highlights some of the key areas where vital engineering knowledge is needed-

- **Solar Panel**: This project requires deep knowledge about the working principle of a solar panel and the process of producing electricity from it.

- **Electric Vehicle**: Extensive knowledge about charging an electric vehicle and the charging ports of EV is required.
- **Inverter**: Another requirement is to know about different kind of inverters.
- Battery: Knowledge on different types of batteries, the best material for batteries is needed.
- **Charging**: Classifications of EV charging and their working principles must be known.
- **Hybrid Charging**: Knowledge on fossil fuel & renewable energy and their combined use.

1.5. Stakeholders from Research Literatures

The availability of land and supply of power for EV charging, specification and installation of EV charging equipment, daily operation and maintenance of EV charging facilities, and services allowing EV owners to use charging facilities are all included in the EV charging ecosystem. In general, the ownership and use of EV charging infrastructure affect its governance. Public, semi-public, and private are the three broad categories that may be used to EV charging infrastructure. These are not rigid classifications, and some charging stations may exhibit hybrid traits. For example, charging infrastructure possessed by EV fleet owners and operators for captive use is regarded as private, but it can be made available to the public as a paid charging service while fleets are in operation. Depending on whether they are accessible to all EV users or just transit users, the EV charging infrastructure at bus depots or metro station parking may be semi-public or public. The management of EV charging is under the control of several central, state, and municipal government entities. These organizations' functions may be divided into two categories: executive or executing functions and policy-making and regulatory functions.

Widespread research on electric vehicle (EV) systems is driven by the current environmental problems of lowering greenhouse gases and the potential scarcity of fossil fuels. The public preference for EVs over conventional internal combustion engine vehicles, however, has a significant impact on EV research. The primary variable in predicting future demand for EVs is this willingness [26]. Renewable energy must be taken into account for electric vehicle charging as well because it is the future of energy production. Many nations are setting up EV charging stations powered by PV panels. Comprehending the EV-PV system that is now in use by companies or is being developed by a different academic institution is crucial for understanding the solar-powered EV charging infrastructure [27].

1.6. Objective of This Work

The main objective of this project is to design and develop a sustainable charging station for electric vehicles. The objectives are divided into two sections depending on the significance of the work. The two sections are mentioned below:

1.6.1. Primary Objectives

The primary objective of the work are as follows:

- To develop a charging infrastructure for the Electric Vehicle industry of Bangladesh.
- To produce clean renewable energy to charge the vehicles.
- To reduce the pressure on national grid.
- To build a prototype of our project to experience the real challenge and prospect.

1.6.2. Secondary Objectives

The secondary objective of the work are as follows:

- To build in house infrastructure in Bangladesh to make it cost-efficient**.**
- To reduce the high fuel cost for the general people of Bangladesh.

1.7. Organization of Book Chapters

A brief overview of the upcoming chapters with their title and a small description is given below:

Chapter-2: Project Management

- This chapter will mainly focus on the project timeline and different kind of analysis.

Chapter-3: Methodology and Modeling

- This chapter will go into great detail on the planning and execution process, the block model, and the simulation model.

Chapter-4: Implementation of Project

- As the title suggests, this chapter will solely cover the system that has been created and how everything will operate.

Chapter-5: Results Analysis & Critical Design Review

- This chapter will discuss all of the project's results and contrast them with the theoretical results that were predicted and the design review.

Chapter-6: Conclusion

- This thesis book's last chapter includes all the author's closing reflections, the project's limitations, suggestions for improvement, and an analysis of the environmental effect.

Chapter 2

PROJECT MANAGEMENT

2.1. Introduction

Effective engineering management involves a number of principles and practices that help ensure the success of a project. It is important to maintain them to obtain the ultimate goal. Firstly, the scope was defined. Clearly outlining the goals, objectives, and deliverables of the project helps to ensure that everyone is on the same page and that resources are allocated appropriately. Secondly, a timeline for the project was developed to ensure that milestones are met and that the project stays on track. Additionally, potential risks were identified and contingency plans were developed to mitigate any negative impacts on the project. Moreover, it was ensured that the right tools, and processes are in place to support the project is crucial for its success. The tasks were divided into all the project mates based on who was best as that specific task. Regular and effective communication between the groupmates were key to keep everyone informed and engaged in the project. Furthermore, regularly tracking progress against the project plan helped to identify any issues or deviations from the original plan and allowed for timely corrective action. By following these engineering principles, the project was effectively planed and managed to ensure the success of the project.

2.2. S.W.O.T. Analysis

SWOT analysis is a strategic planning tool used to evaluate the strengths, weaknesses, opportunities, and threats involved in a project or in a business venture. It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favorable and unfavorable to achieving that objective.

Figure 2.1 exhibits the explication of S.W.O.T. analysis.

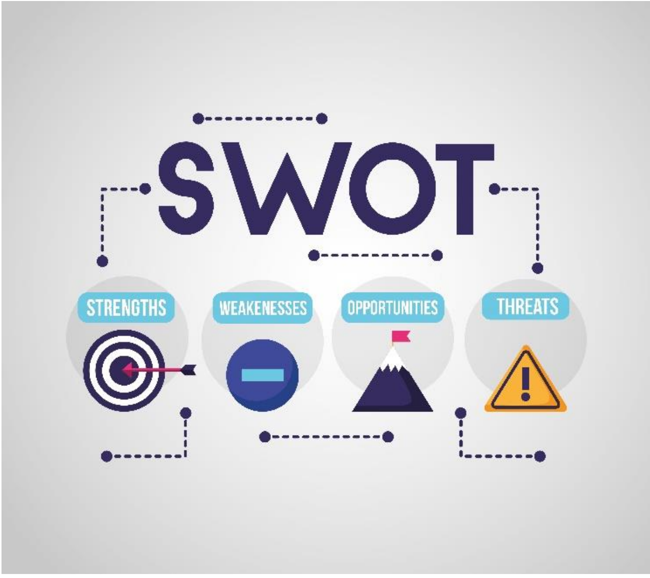

Figure 2.1 S.W.O.T. Analysis

Strengths: These are the characteristics of the project that give it an advantage over others. The strengths of this project are:

1. No fuel required and environment friendly
2. Low cost.
3. Locally manufacture possible
4. Alternative of fuel
5. Simulation able software is available.

Weaknesses: These are the characteristics that place the project at a disadvantage relative to others. The probable weaknesses of this project could be:

1. It is unable to charge high-voltage or high-current batteries.
2. Low quality voltage and current sensor are being used for cost-cutting purposes.

Opportunities: These are external factors that the project could take advantage of to improve its performance. The opportunities of this project are:

1. This product is in high demand both domestically and globally.
2. There is a chance to do multibillion dollar business opportunities.
3. The charging time can be reduced.

4. A lot of employment can be created.
5. Government is taking necessary steps to establish this project.

Threats: These are external factors that could negatively impact the business or project. The threat of this project can be:

1. Electric problems, such as short-circuits and current leaks, etc., can also cause failure. If the sensors are giving incorrect information, they have to be replaced right away.

By analyzing the strengths, weaknesses, opportunities, and threats, we can identify the internal and external factors of this project and develop strategies to address them. This helps the project to maximize its chances of success and achieve our objectives.

2.3. Schedule Management

Schedule management is the process of planning, coordinating, and controlling the activities and resources required to complete a project within a specific timeframe. It involves creating a schedule, monitoring progress, and making adjustments as necessary to ensure that the project is completed on time.

Schedule management is important because it helps to ensure that a project stays on track and is completed within the desired timeframe. It also helps to identify potential delays or obstacles, allowing project managers to take corrective action to keep the project moving forward. In addition, effective schedule management can help to improve resource utilization and reduce costs by ensuring that resources are used efficiently and effectively. By carefully planning and managing the schedule, project managers can help to ensure that projects are completed successfully and on time.

The Gantt table containing our schedule management of this project is shown in the **Figure 2.2** below:

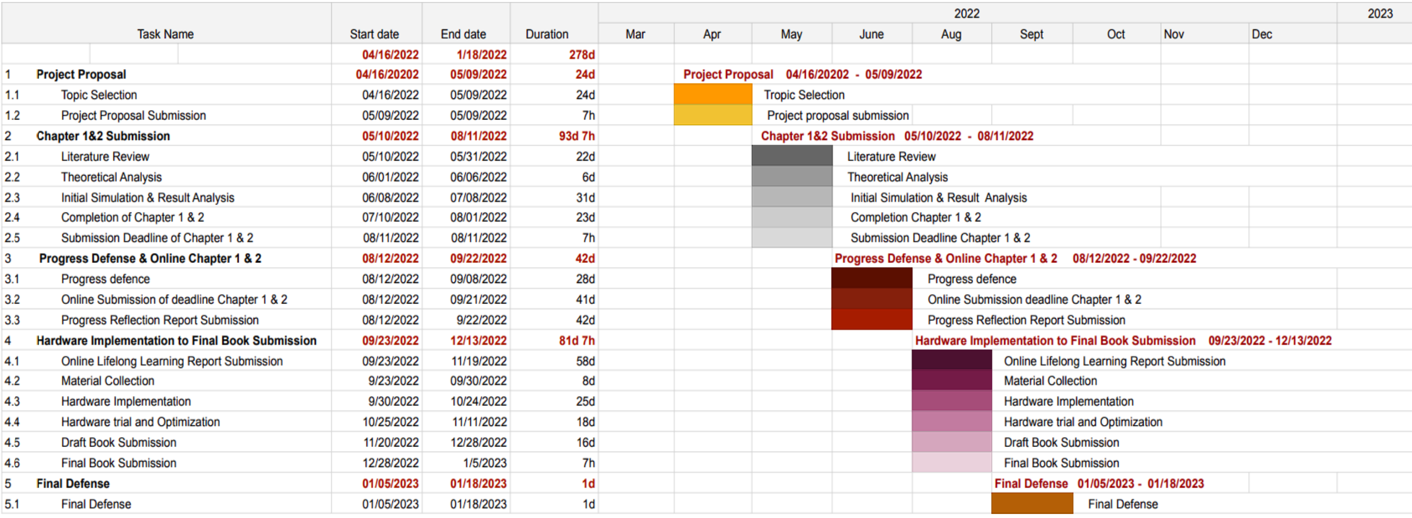

Figure 2.2 Gantt Chart

2.4. Cost Analysis

The cost analysis of this project is shown below:

No	Component	Quantity	Price
1	1sq.ft. 5mm Plywood Board	4	300.00 Tk
2	2 Pin Plug	1	25.00 Tk
3	2 Pin Tactile Switch Round	4	10.00 Tk
4	4 Inch Cable Tie 3 x 100 mm | 100 Pcs Per Package	1	30.00 Tk
5	4X4 Matrix Keypad Industrial	1	290.00 Tk
6	5V 4 Channel Relay Module	1	340.00 Tk
7	ACS712-30A Current Sensor Module	3	750.00 Tk
8	ALLPOWERS 20A Solar Charger	1	580.00 Tk

	Controller Solar Panel Battery Intelligent Regulator with USB Port Display 12V/24V		
9	Arduino Mega 2560	1	2,200.00 Tk
10	Arduino Uno R3	1	1,050.00 Tk
11	Best Soldering Wire (1 Meter)	6	160.00 Tk
12	Busbar (Alternative of Bread Board)	2	100.00 Tk
13	Connector for a certain type of lead-acid battery	10	50.00 Tk
14	Heat Shrink Tube 2mm - Red & Black 1 Meter	1	15.00 Tk
15	Hot Melt Glue Sticks 11.75mm	10	188.00 Tk
16	IIC I2C interface LCD Module	2	240.00 Tk
17	IMax B3 Pro Compact Charger 2-3S	1	450.00 Tk
18	LCD1602 16*2 With - Blue Backlight LCD	1	170.00 Tk
19	LCD2004 20*4 Character With - Blue Backlight	1	450.00 T
20	LM2596 DC-DC Adjustable Step-Down Module	2	160.00 Tk
22	Long 12V 7AH UPS Battery	3	4,500.00 Tk
23	Veroboard Dotted Best Quality 9*15 cm	1	90.00 Tk

24	Voltage Sensor Module DC 0-25V	5	600.00 Tk
25	Wire 1 Meter	6	90.00 Tk
26	Lithium battery	52	4000.00 Tk
27	Battery Management System (BMS)	1	550.00 Tk
28	Strip	5	400.00 Tk
29	Transformer	3	3000.00 Tk
30	Solar module	1	400.00 Tk
31	Resistor	20	40.00 Tk
32	Buck Converter	2	700.00 Tk
33	Diode	20	100.00 Tk
34	Capacitor	8	100.00Tk
35	Frame	1	1500.00Tk
36	Sheet acrylic	2	550
37	Paper Sheet	2	400
	Total Cost		**BDT 24,578.00**

Table 2.1 Cost Analysis

An important factor of this cost analysis is, in this project, due to limited budget, economical current & voltage sensors were used. To get more precise measurement values and overall better performance, much better current & voltage sensors are needed which will cost around 7-8 times more than that are used in this project.

2.5. P.E.S.T. Analysis

PEST analysis is a framework used to analyze the external factors that can impact a project. The acronym PEST stands for Political, Economic, Social, and Technological. These are the four main categories of external factors that can affect a project.

1. **Political:** This project involves building a facility in a certain location. The local government's zoning laws and building codes will need to be considered. Government is posing new laws in favor of this kind of projects, so that electric vehicles can be implemented easily in this fuel-driven vehicle-based country.

2. **Economical:** Government and non-government private companies can easily invest in this project. There are multibillion-dollar business opportunities. A few private companies have already stepped forward to run this system. The government of Bangladesh has made large number of investments in this sector. There are huge opportunities to export this product and earn foreign money.

3. **Social:** The adoption rate for new conceptions in our city is far too low. Some social trends, behaviors, or attitudes that may have an impact on our project and target market. Many jobs will be created because of this multibillion-dollar business opportunity. A significant number of designers, researchers, engineers, and so on will be required.

4. **Technological:** To protect itself from intellectual property theft, it must be trademarked. Because bigger corporations can take advantage of tiny investors and steal the big concept. Most of the company is struggling to reduce charging time. We have the opportunity to reduce the charging time by making a DC fast charger.

2.6. Professional Responsibilities

The professional responsibilities of members of a project can vary depending on their role and the specific project they are working on. However, some general responsibilities that may be expected of project team members include:

- Being familiar with the project plan and goals, and working towards achieving them within the specified timeframe.

- Providing input and expertise on the project, and contributing to the development of project deliverables.

- Communicating with other team members and stakeholders effectively, and keeping everyone informed of progress and issues.

- Managing one's own workload and priorities, and ensuring that tasks are completed on time and to a high standard.

- Providing support and assistance to other team members as needed.

- Participating in meetings and other team activities as required.

- Maintaining confidentiality and adhering to any legal or ethical obligations related to the project.

Ultimately, the professional responsibilities of project team members will depend on their role and the specific requirements of the project. It is important for team members to understand their responsibilities and be proactive in meeting them in order to ensure the success of the project.

2.6.1. Norms of Engineering Practice

Norms of engineering practice are the standards and guidelines that professionals in the engineering field are expected to follow in order to ensure that their work is safe, ethical, and of high quality. These norms are established by professional engineering societies and organizations, and they serve as a benchmark for acceptable behavior and practices in the engineering field.

In this project, the norms of engineering were practiced properly. All of the members adhered to codes of ethics and professional conduct that outline the principles and values that should guide our work. We tried our best to ensure that the products and systems they design and build are safe for use. Furthermore, we were keen on producing high-quality work that is accurate and reliable. All of us tried to do literature review and keep our knowledge which are necessary to this project updated to the current situation.

By following these norms of engineering practice, we can help to ensure that we are making a positive contribution to society and that our work meets the high standards expected of professionals in the field.

2.6.2. Individual Responsibilities and Function as Effective Team Member

In complete this project, each member was assigned with tasks they are best in. The team leader tried to understand who is better and interested in which task and divided the tasks to each individual. Then all members did their designated job while discussing with other members and updating the leader. In the end, all the work was incorporated and the whole project was completed successfully.

The responsibilities of each individual are described below:

Hardware & Simulation

Name	ID	Contribution
JAMI, SYED ASHFAQUL	19-40262-1	HARDWARE
HOSSAIN, MOHAMMED SHAHED	19-40299-1	HARDWARE
AKTER, ARIFA	19-39340-1	SIMULATION
ISLAM, MD. TOUHIDUL	19-40488-1	SIMULATION

Table 2.2 Hardware & Simulation Responsibilities

Book Writing

Name	ID	Contribution
JAMI, SYED ASHFAQUL	19-40262-1	CHAPTER 1,2,5
HOSSAIN, MOHAMMED SHAHED	19-40299-1	CHAPTER 1,3,5

AKTER, ARIFA	19-39340-1	CHAPTER 1,4,6
ISLAM, MD. TOUHIDUL	19-40488-1	CHAPTER 1,6

Table 2.3 Book Writing Responsibilities

2.7. Management Principles and Economic Models

Managerial economics is the application of economic principles and techniques to the management of businesses and other organizations. It involves the use of economic theory and quantitative methods to analyze business decisions and to assess the performance of firms and industries.

In managerial economics, managers and other decision-makers use economic concepts and tools to identify and solve problems, make informed decisions, and allocate resources effectively. This includes analyzing demand and supply, forecasting market trends, evaluating the cost and benefits of different options, and determining the optimal price and output level for a product or service.

EVs typically have lower operating costs than gasoline-powered vehicles because they require less maintenance and have lower fuel costs. The cost of electricity to power an EV is generally lower than the cost of gasoline, especially when gasoline prices are high. Furthermore, EVs do not rely on gasoline, which is often imported from other countries. By using EVs, countries can reduce their dependence on foreign oil and potentially save money on oil imports.

If the infrastructure is bought from foreign countries, it will cost our government a fortune. On the contrary, if we are able to construct this charging infrastructure in our country, it will be hugely cost-effective; let alone other advantages such as- creating employment opportunity, foreign reserve saving etc.

Based on these factors, it can be concluded that this project works towards creating a cost-effective and economical solution for EV industry in this country.

2.8. Summary

To manage this project systematically and effectively, it was important to follow a structured process and use appropriate tools and techniques. Some key steps in managing this project include:

- Defining the project: The project scope, objectives, and deliverables were clearly defined. This includes identifying the stakeholders, determining the budget and timeline, and developing a project plan.

- Planning the project: A detailed plan was developed that outlines the tasks and resources needed to complete the project. This includes creating a project schedule, identifying risks and developing contingency plans, and allocating resources.

- Executing the project: The project plan was implemented and managed the day-to-day activities of the project. This includes coordinating the work of team members, tracking progress, and making adjustments as needed.

- Monitoring and controlling the project: The progress of the project was regularly reviewed and any necessary changes were made to keep the project on track. This includes monitoring budgets, schedules, and quality, and taking corrective action as needed.

- Closing the project: Once the project was completed, a final review was conducted to assess the success of the project and identify any lessons learned. This includes documenting the results and delivering the final deliverables to the stakeholders.

By following these steps and using appropriate tools and techniques, it was possible to effectively manage the project and increase the likelihood of success.

Chapter 3

METHODOLOGY AND MODELING

3.1. Introduction

There are several basic engineering theories and methods that are used in the design and operation of electric vehicles (EVs) and electric vehicle charging systems. Some of these include:

- Electrical Circuit Theory: EVs and EV charging systems rely on electrical circuits to transfer and distribute electricity. Basic electrical circuit theory is used to understand how current flows through these circuits, and to design circuits that are efficient and safe.

- Battery Theory: Most EVs use lithium-ion batteries to store electricity and power the vehicle. Basic battery theory is used to understand how these batteries work, how they charge and discharge, and how to optimize their performance.

- Thermodynamics: The operation of EVs and EV charging systems involves the transfer of heat, which is governed by the laws of thermodynamics. Understanding these laws helps engineers design systems that are efficient and operate at the optimal temperature range.

- Control Systems: EV charging systems often use control systems to regulate the flow of electricity and optimize the charging process. Basic control system theory is used to design these systems and ensure they function correctly.

- Electromechanical Systems: Many EV charging systems use electromechanical components, such as motors and generators, to convert electricity into mechanical energy and vice versa. Understanding the principles of electromechanical systems is important for designing these components and ensuring they function correctly.

- ❖ Power Electronics: EV charging systems often use power electronic devices, such as inverters and converters, to control the flow of electricity. Basic knowledge of power electronics is essential for designing these systems and ensuring they are efficient and reliable.

Electric vehicles (EVs) and electric vehicle charging systems rely on a variety of basic engineering theories and methods to function properly. Understanding these theories and methods is essential for designing and operating EV and EV charging systems that are efficient, safe, and reliable.

3.2. Block Diagram and Working Principle

For better understanding purpose, the block diagram of the whole project has been divided into four steps. Each step is discussed in details with the engineering theories behind it & the interdependency of the equipment.

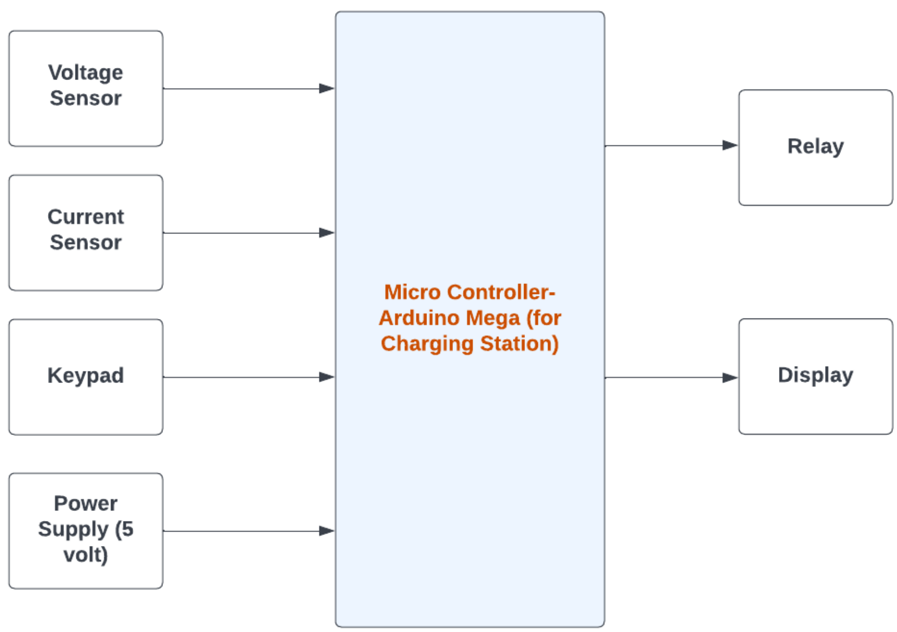

Figure 3.1 Inputs & Outputs of the Charging Station

The above **Figure 3.1** illustrates the inputs & outputs associated with the micro controller Arduino Mega which controls the charging station. The inputs are voltage & current sensors which measure the voltage & current of the lead acid battery and grid, the keypad which acts as the input of how much charge the car is requesting and the 5 Volt DC power supply to run the associated circuitry.

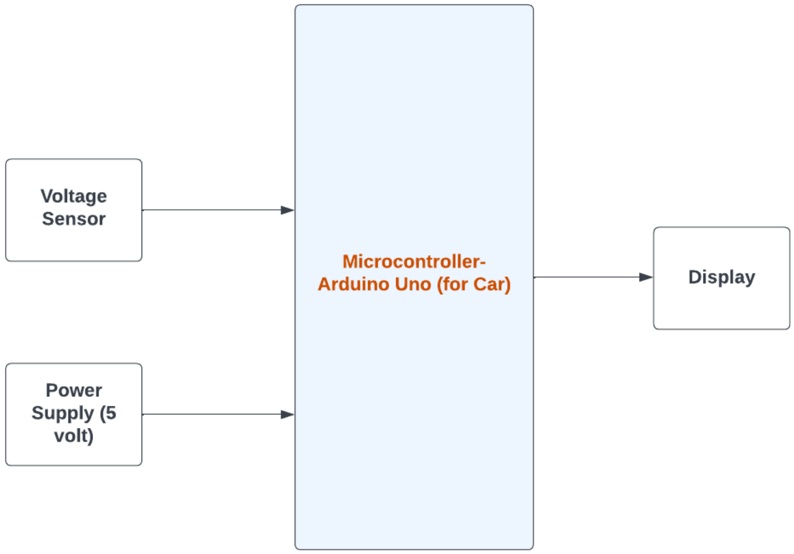

Figure 3.2 Inputs & Outputs of the Electric Vehicle

From **Figure 3.2**, the inputs & outputs of the Microcontroller Arduino Uno can be presented. The two inputs of the electric vehicle side are a voltage sensor which determines the voltage level of the lithium-ion battery that is the battery of the vehicle and the 5 Volt DC power supply which powers up the circuitry of the vehicle.

The below **Figure 3.3** demonstrates the block diagram of the whole project. There are three main parts of this diagram – the Solar part, the Grid part and the Vehicle part.

Solar is the main source of electricity in this model. The required solar panels produce direct current (DC) which is connected to the charge controller. The charge controller regulates the flow of electricity from the PV generator to the lead acid battery. The battery is connected with two components, one is a 5V buck converter which supplies the electricity necessary to run the circuitry through the microcontroller; the other one is a voltage sensor which measures the voltage of the lead acid battery. The voltage sensor connects to a 5 Volt relay which leads back to the Arduino Mega. This relay also takes input from another voltage sensor which comes from the grid section and gives decision from which source it will take the electricity.

Secondly, the alternative source in the absence of solar is a Grid connection. The grid is connected to a step-down transformer that steps down the voltage to 27.5 Volt. Then it is rectified with a full-bridge rectifier and to cancel the pulses of AC, a capacitor is connected which gives an output of 36.7 Volt. Furthermore, the received output is fed into a buck converter which steps down the voltage to 26 Volt. A current & voltage sensor is added to measure the current & voltage respectively of the grid side which is then fed into the micro-controller. The voltage is also fed into the relay as mentioned previously.

The micro-controller Arduino Mega also receives input from a keypad which inputs the percentage of charge requested by the customer. A 20*4 LCD display shows all the outputs of the Arduino Mega.

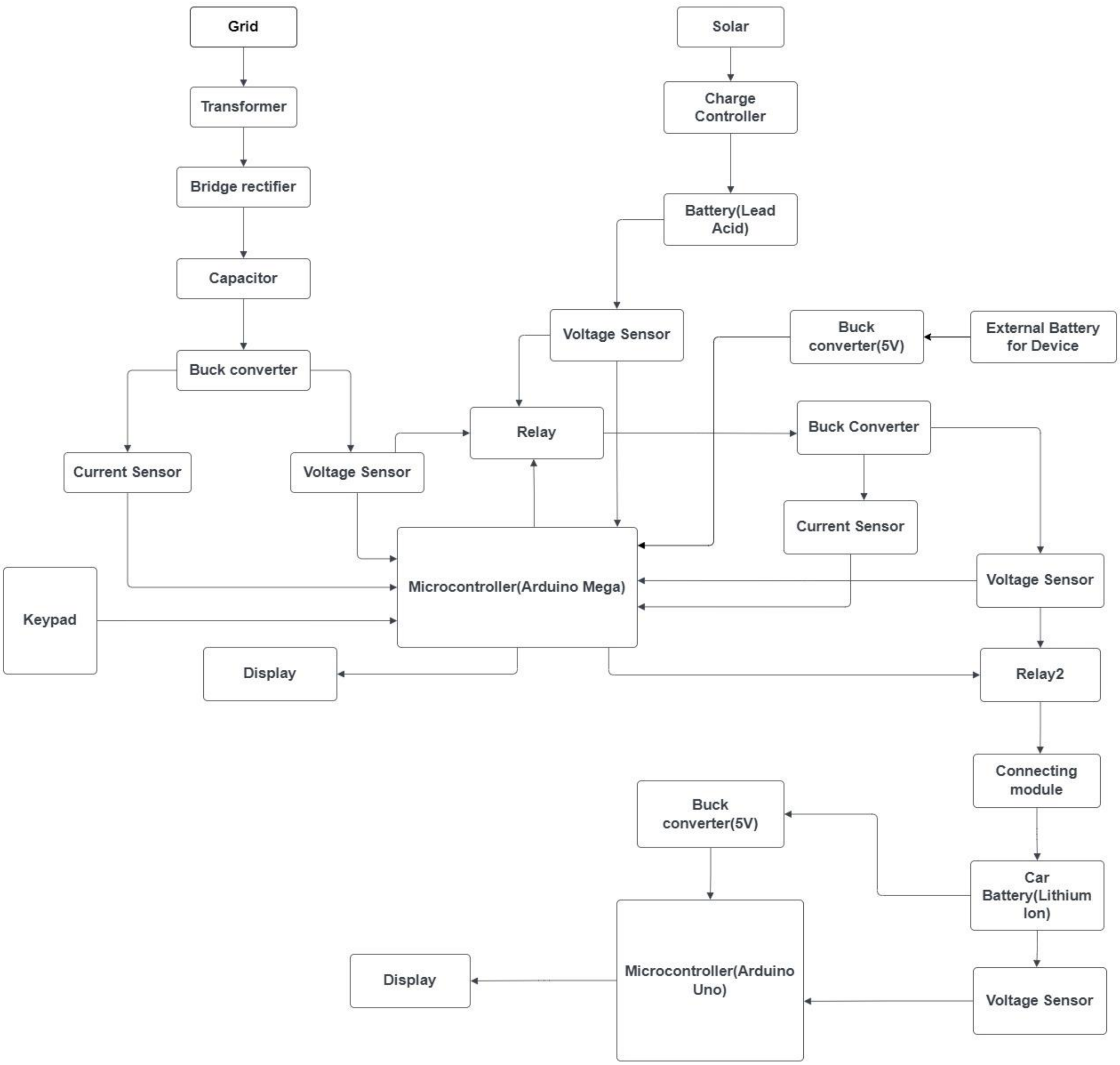

Figure 3.3 The Complete Block Diagram of the Project

A buck converter receives the decision of the first relay and upholds the output the another set of voltage & current sensor. Both of them connect back to Arduino Mega. Another relay is taken to control the cut-off of the charging after the required charging is completed. This relay gets a connection from the voltage sensor; other connection from the micro-controller. This relay is the connector between the voltage sensor and connection module that charges the Lithium-ion battery.

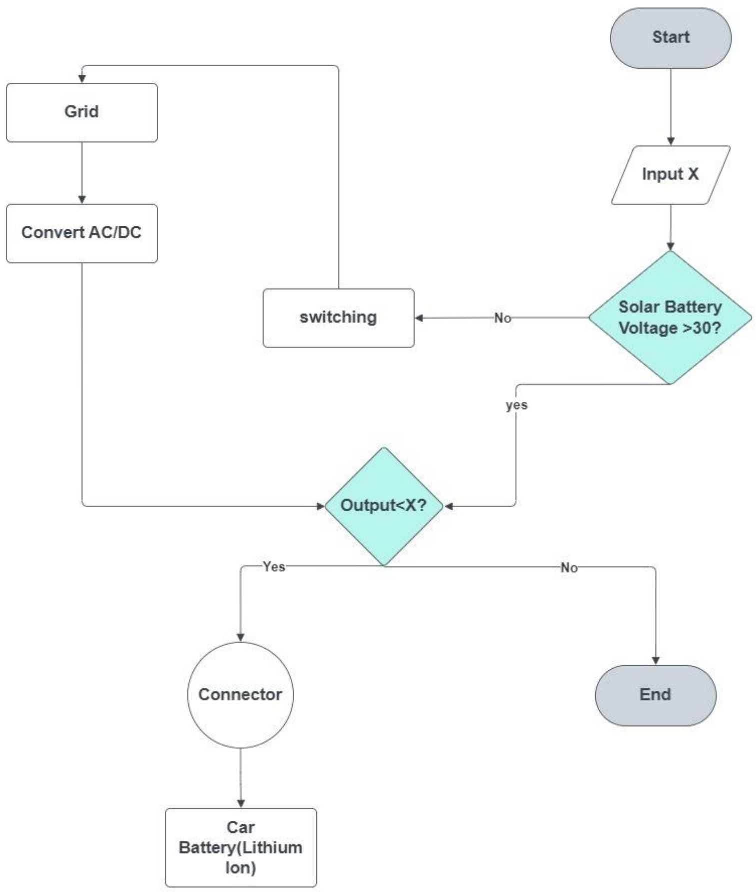

Figure 3.4 Logical Block Diagram

The functional block diagram of this project is shown in **Figure3.4**. The condition of our project is if the voltage level of the battery goes below 30 Volt, the relay will cut the output of solar and it will shift to the grid connection. After the first loop, input will go to the second loop, and then output will be checked to see if it is greater than x. If output is less than X, the system will run until output is greater than X.

3.3. Modeling

The 3D modeling of our project is displayed below:

Figure 3.5 Left-Side View

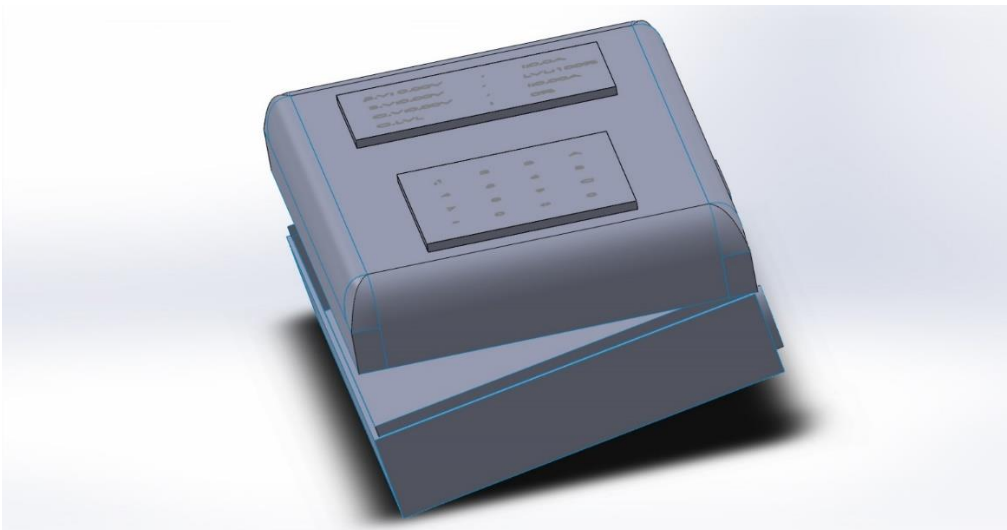

Figure 3.6 Right-Side View

Figure 3.7 Angular 3D View

Figure 3.8 Top-Side View

3.4. Summary

This design is done in solid work. First, it is done in a schematic, or 2D. After that, the 2D is extruded and modified into 3D. Since our hardwire design looks like a box, the 3D design is done like that. There will be two visible parts above the box. One is the keypad, and the other is the display. First, there is a keypad on the top. It has an input option, and the amount of current and voltage flowing from the grid and battery is displayed on the display. And on the side, there is an option to take it out.

Chapter 4

PROJECT IMPLEMENTATION

4.1. Introduction

This project aims to develop a charging solution for electric vehicles based on clean renewable energy, more specifically solar energy. To implement this project, first the components were bought from different places. Then they were assembled. After assembling the components first time, there were some problems which needed to be sorted out. After changing a few transformers, the problems were fixed. After that, we implemented the vehicle circuitry and developed the code behind it. Additionally, we connected it to the main charging side. All of these implementations were done keeping the safety & engineering ethics in mind.

4.2. Required Tools and Components

Resistor:

Figure 4.1 Resistor

A resistor is a two-terminal passive electrical component that uses electrical resistance as a circuit element. Resistors are used in electronic circuits to limit current flow, alter signal levels, divide voltages, bias active parts, and terminate transmission lines, among other things. High-power resistors, which can dissipate many watts of electrical power as heat, can be employed in motor controllers, power distribution systems, or as generator test loads. The resistances of fixed resistors vary only slightly with temperature, time, or operating voltage.

Capacitor:

A capacitor is a type of electronic component that stores electricity. The capacitor is constructed from two close conductors (typically plates) separated by a dielectric substance. When the plates are linked to a power source, they build an electric charge. The positive plate accumulates charge, while the negative plate accumulates charge. Capacitors can also remove AC pulse from DC power.

Figure 4.2 Capacitor

Diode:

Figure 4.3 Diode

A diode is a semiconductor device that functions as a one-way current switch. It permits current to flow freely in one direction while drastically limiting current flow in the opposing direction. Diodes are also referred to as rectifiers since they convert alternating current (ac) to pulsing direct current (dc) (dc). Diodes are classified based on their kind, voltage, and current capability.

Buck Converter:

A buck converter, also known as a step-down converter, is a DC-to-DC converter that reduces voltage while increasing current from its input (supply) to its output (load). It belongs to the switched-mode power supply family. As DC-to-DC converters, switching converters (such as buck converters) have substantially higher power efficiency than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat but do not step-up output current.

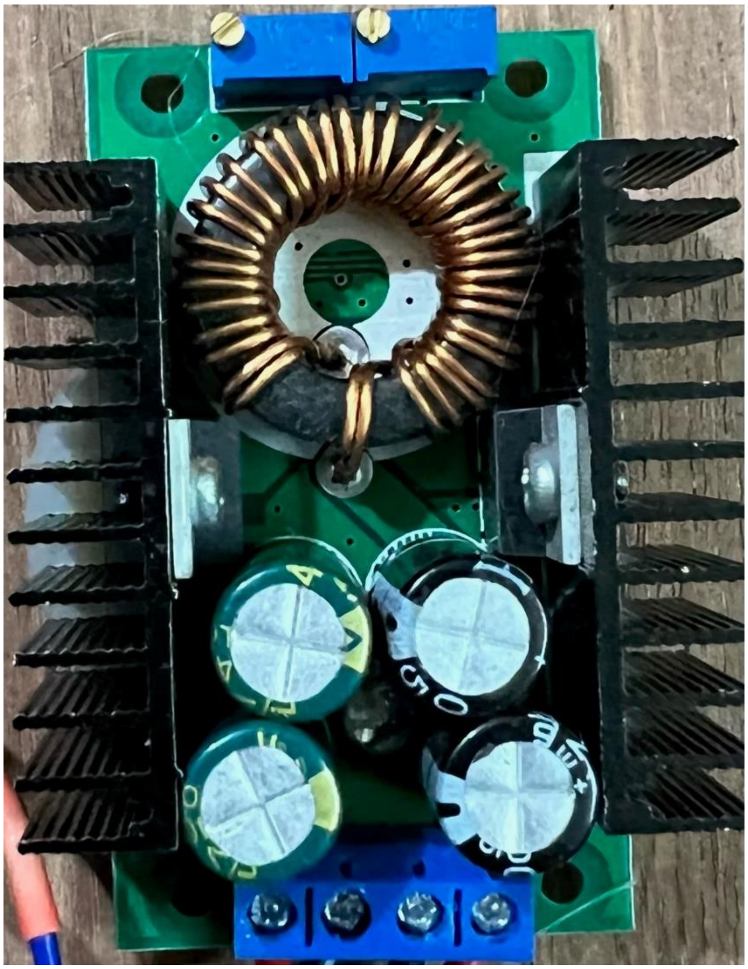

Figure 4.4 Buck Converter

Step – Down Transformer:

A step-down transformer is a type of transformer that converts high voltage (HV) and low current values from the transformer's primary side to low voltage (L) and high current values on the transformer's secondary side. A step-up transformer is the inverse of this.

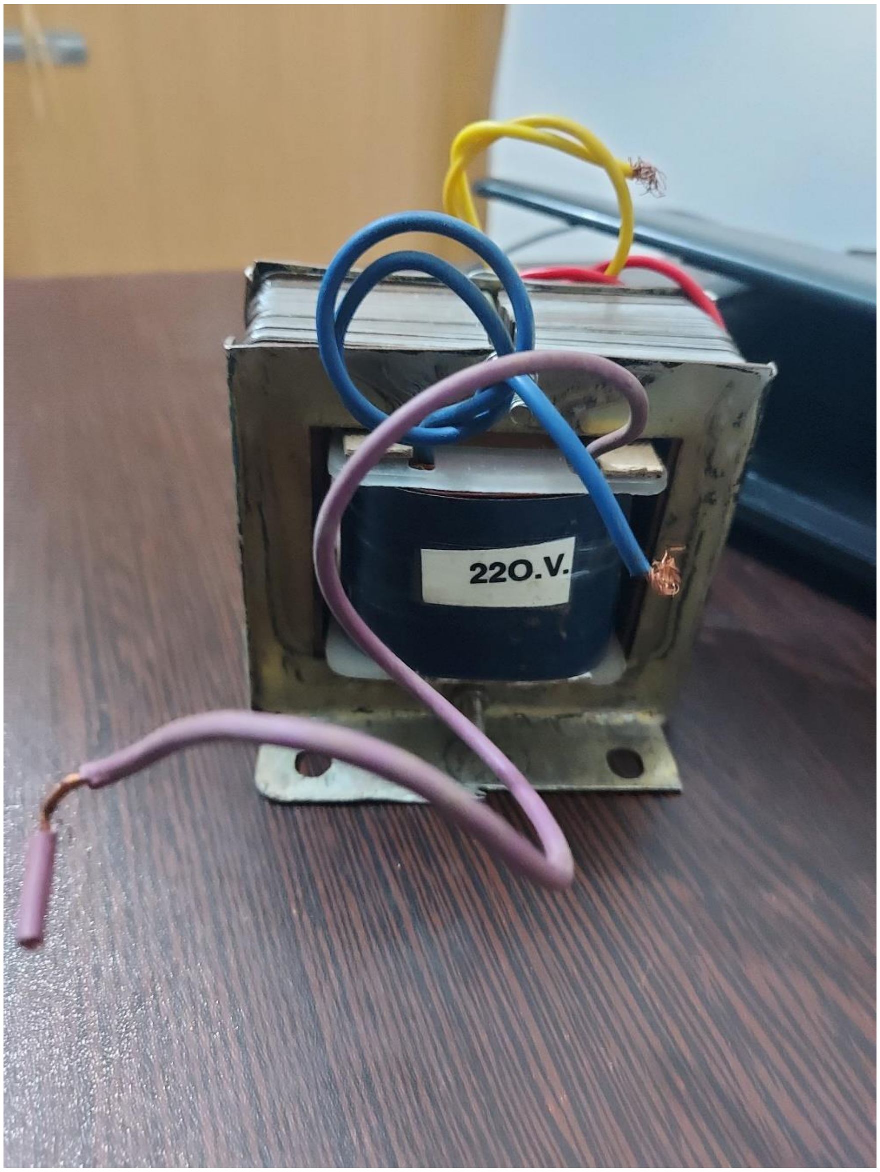

Figure 4.5 Step – Down Transformer

A transformer is a static electrical device that converts electrical energy (from the primary side windings) to magnetic energy (in the transformer magnetic core) and back again (on the secondary side of the transformer). A step-down transformer is used in a wide range of electrical systems and transmission lines.

Strip:

This component is used for to make lithium-ion battery pack. By using this component, we can connect series and parallel battery connection.

Figure 4.6 Strip

This component is used for to make lithium-ion battery pack. By using this component, we can connect series and parallel battery connection.

Battery Management System (BMS):

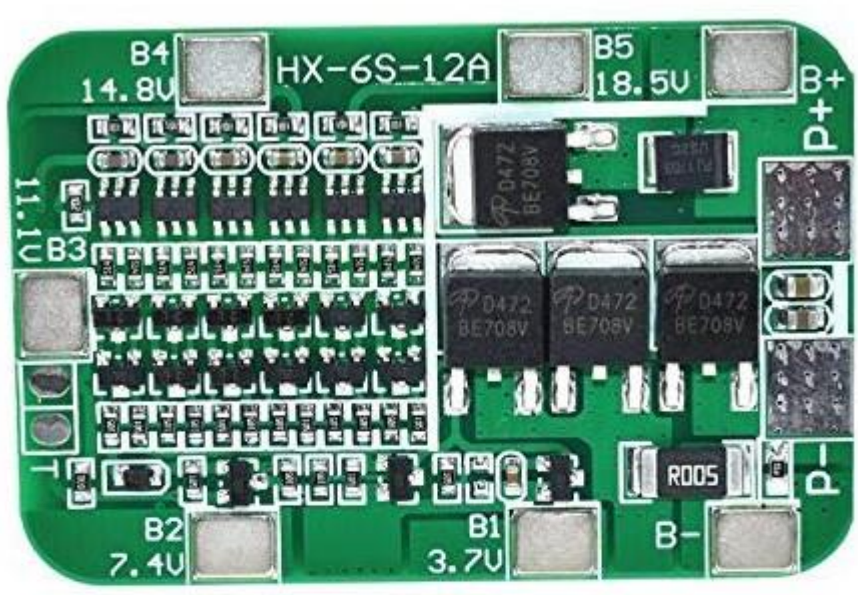

Figure 4.7 Battery Management System

A battery management system (BMS) is any electronic system that manages a rechargeable battery (cell or battery pack). such as protecting it from operating outside its safe operating range, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it, and/or balancing it. A smart battery pack is one that has been designed to work in tandem with a battery management system and an external communication data bus. A smart battery charger is required to charge a smart battery pack.

Lithium Ion Battery:

Figure 4.8 Lithium Ion Battery

A lithium-ion battery (or Li-ion battery) is a type of rechargeable battery that stores energy by the reversible reduction of lithium ions. It is the most common type of battery used in portable consumer gadgets and electric vehicles. It is also widely used in grid-scale energy storage, as well as military and aerospace applications. Li-ion batteries feature high energy densities, low self-discharge, and negligible memory effect as compared to other rechargeable battery technologies (however a small memory effect claimed in LFP cells has been traced to badly produced cells) The chemistry performance pricing and safety properties of lithium-ion batteries differ the active ingredients in most commercial Li-ion cells are intercalation chemicals.

Voltage sensor:

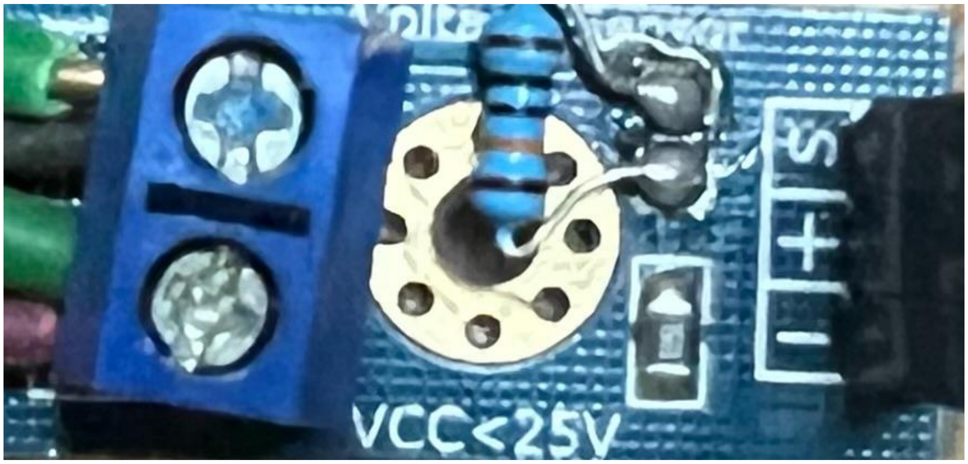

Figure 4.9 Voltage sensor

The voltage sensor module is a resistive voltage divider-based 0-25 V DC voltage sensing device. It multiplies the input voltage signal by 5 and generates the equivalent analog output voltage This is why you can measure voltages up to 25 volts with any microcontroller's 5-volt analog port.

Veroboard Dotted:

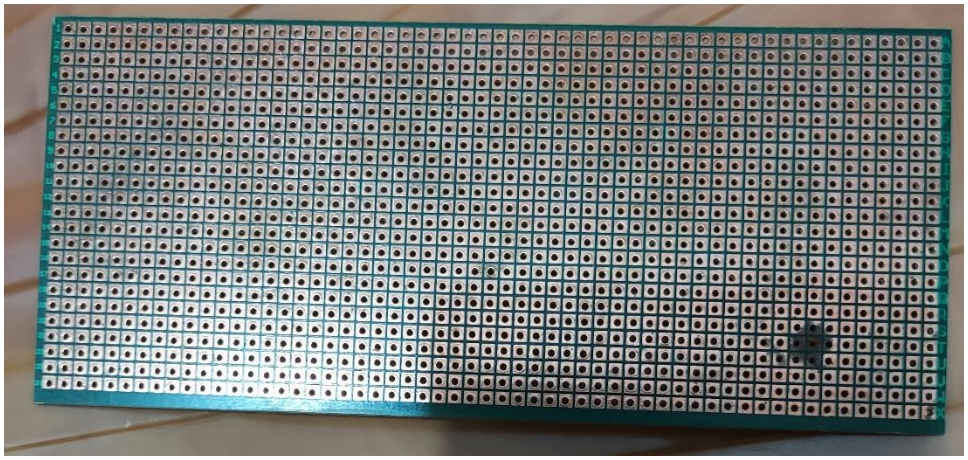

Figure 4.10 Veroboard Dotted

Dotted Small Veroboard Stripboard is designed primarily for the hard wiring of discrete components, generally in analog circuits, although it can also be used when a number of common bus or signal lines are necessary.

Lead Acid Battery:

The lead-acid battery is a type of rechargeable battery designed by French physicist Gaston Plant in 1859. It is the first rechargeable battery ever invented. Lead-acid batteries have low energy density when compared to current rechargeable batteries. Despite this, the cells have a reasonably high power-to-weight ratio due to their capacity to supply strong surge currents. These characteristics, together with their low cost, make them appealing for use in motor vehicles to supply the high current required by starter motors.

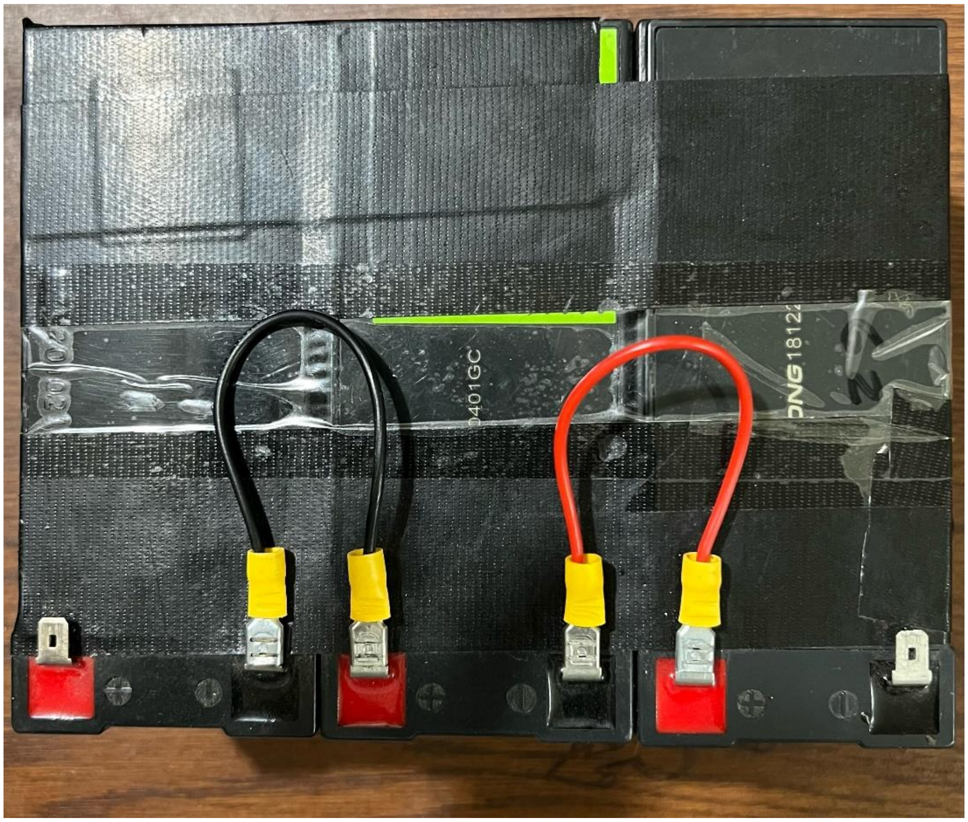

Figure 4.11 Lead Acid battery

Buck Converter (5V):

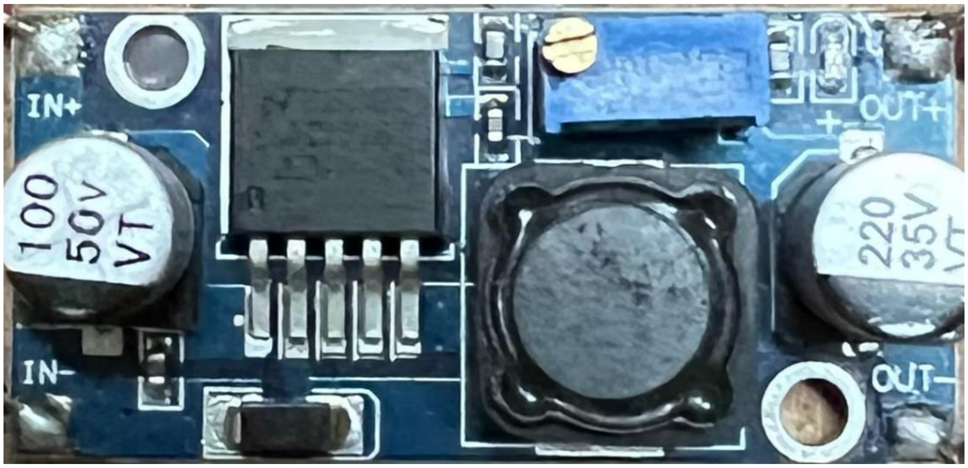

Figure 4.12 Buck converter (5V)

The adjustable LM2596 step-down (buck) switching regulator, capable of driving a 5A load with excellent line and load regulation, is used in this module.

LCD2004 20×4:

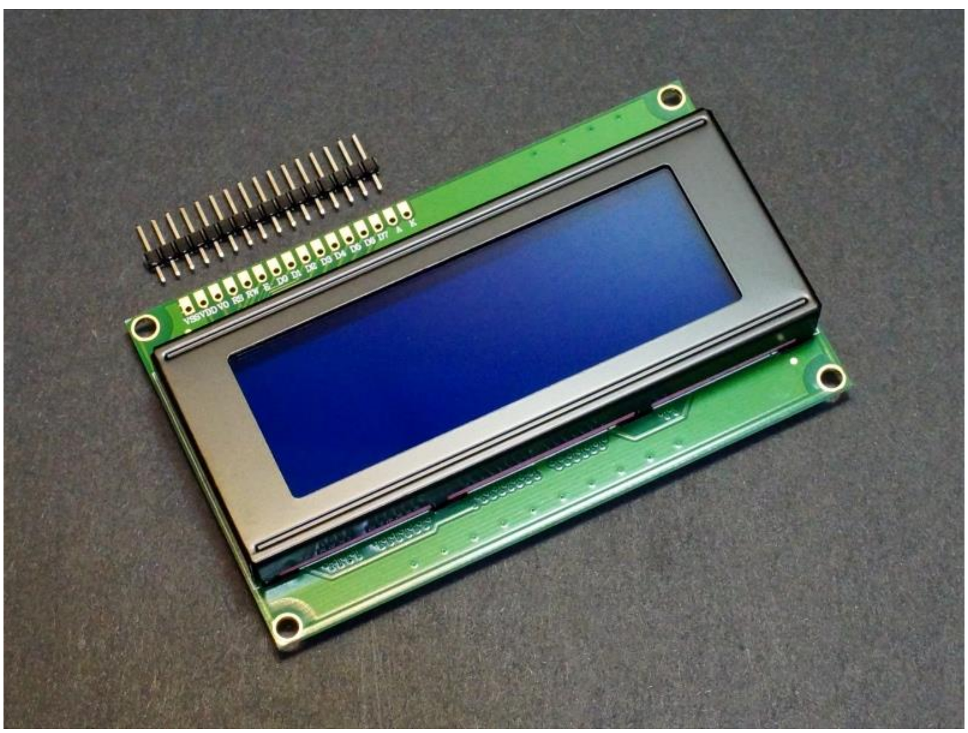

Figure 4.13 LCD2004 20×4

A 20-character by 4-line LCD panel with a blue backlight and white characters makes up the display. For accurate character representation, each character is made up of a 5 x8 dol matrix The lighting incorporates a potentiometer for adjusting the display's contrast for optimal viewing. The intensity of the illumination cannot be directly controlled via the 12C interface: however, there is a jumper on the I2C board that delivers power to the backlight. To power the backlight individually, remove the jumper and apply a voltage to the header pin closest to the 'LED" marks on the board.

LCD1602 16×2 Display:

Figure 4.14 LCD1602 16×2 Display

A 16-character by 2-line LCD panel with a blue backlight and white characters makes up the display. For accurate character representation, each character is made up of a 5 x8 dot matrix. Custom characters can be defined and used in conjunction with the display.

IC (Integrated Circuits) 12C interface LCD Module:

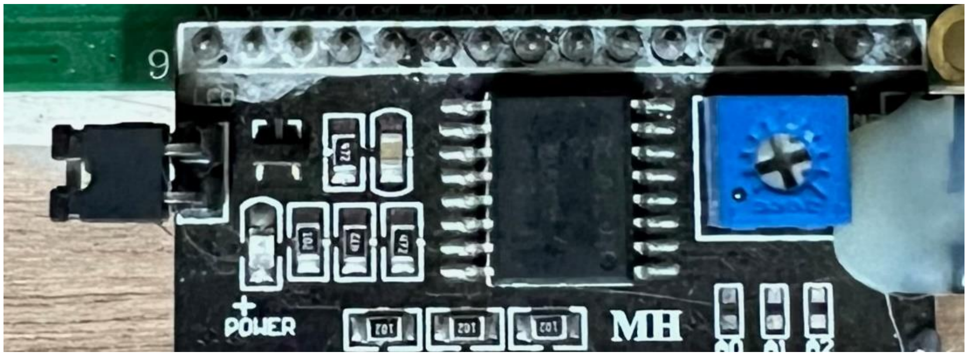

Figure 4.15 IC 12C interface LCD Module

This module realizes a fast IC interface with the familiar LCD displays (16×02, 16x04, and 20x04), which makes the control of these displays much easier and more economical with 1/00 pins. It is possible to control 8 of these interface modules simultaneously with only 2 connections. By means of the built-in potentiometer on this module, it is possible to adjust the backlight and contrast of the LCD.

Arduino Uno R3:

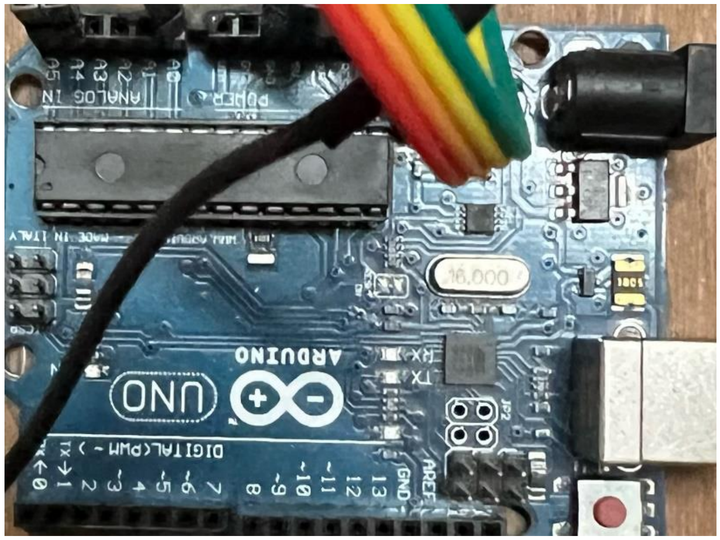

Figure 4.16 Arduino Uno R3

The Arduino Uno R3 is a microcontroller board based on a removable dual-inline-package (DIP) ATmega328 AVR microcontroller. It has 20 digital input output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs) Prenames can be loaded onto it from the easy-to-use Arduino computer program.

Arduino mega:

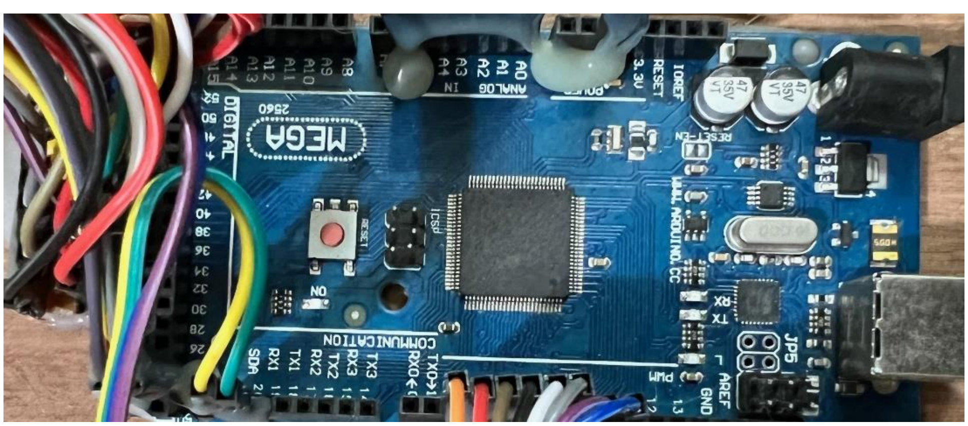

Figure 4.17 Arduino mega

The ATmega2560-based Arduino Mega 2560 is a microcontroller board. It features 54 digital I/0 pins (of which 15 are PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It comes with everything you need to support the microcontroller; simply connect it to a computer through USB or power it using an AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields built for the Uno and preceding boards Decimal.

ALLPOWERS 20A Solar Charger Controller:

A solar charger controller is a device that regulates the charging of a battery or batteries using solar panels. It is typically used in off-grid photovoltaic (PV) systems, where the solar panels are the primary source of power and the battery stores excess energy for use when the sun is not shining. The solar charger controller ensures that the battery is not overcharged or discharged too deeply, which can damage the battery and shorten its lifespan. It may also include features such as load control, to prevent the battery from being drained too quickly, and display and monitoring capabilities to provide information on the system's performance. ALLPOWERS 20A. Solar Charger Controller Solar Panel Battery Intelligent Regulator with USB Port Display 12V 24V.

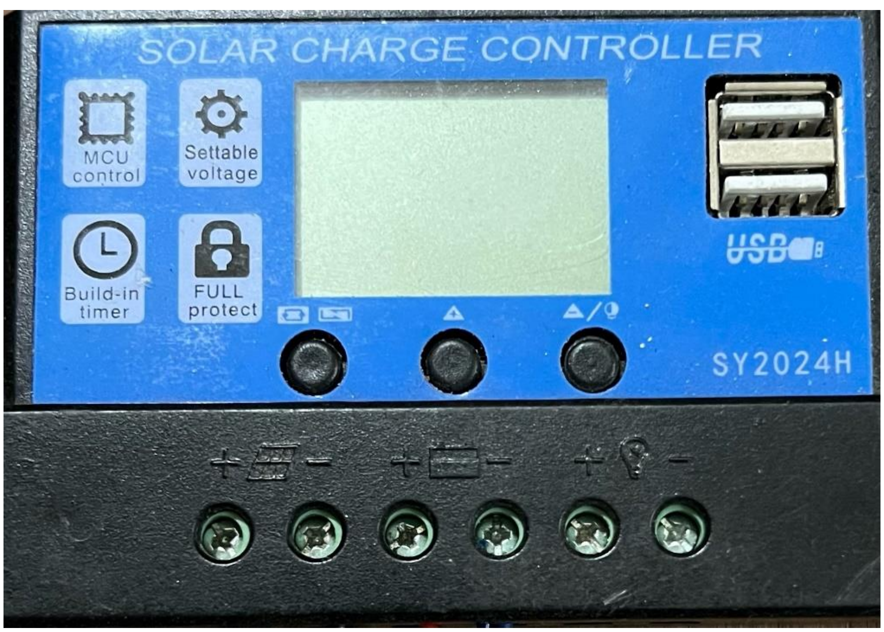

Figure 4.18 ALLPOWERS 20A Solar Charger Controller

Relay:

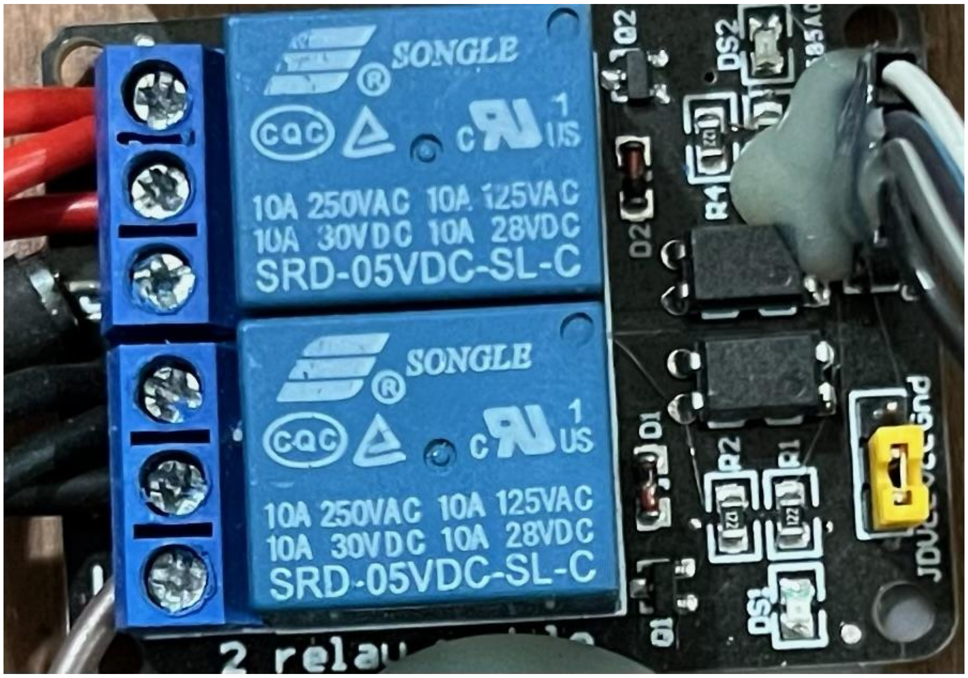

Figure 4.19 Relay

A relay is a straightforward electromechanical switch. While regular switches are used to manually close or open a circuit, a relay is also a switch that connects or disconnects two circuits. A relay, on the other hand, uses an electrical signal to drive an electromagnet, which in turn connects or disconnects another circuit, rather than a manual process.

Solar module:

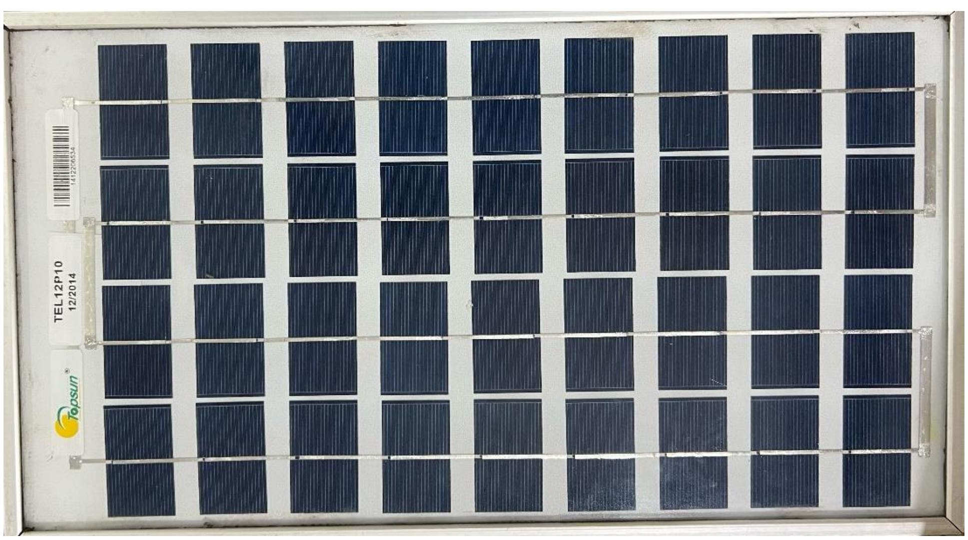

Figure 4.20 Solar module

A solar cell panel, solar electric panel, photovoltaic (PV) module, PV panel, or solar panel is an assembly of photovoltaic solar cells installed in a (typically rectangular) frame; a photovoltaic system or solar array is a neatly ordered collection of PV panels. Solar panels catch sunlight as a source of radiant energy, which is then turned into direct current (DC) power. Photovoltaic arrays can be used to create solar electricity that can be utilized to power electrical equipment directly or to feed power back into an alternative current (AC) grid via an inverter system.

4.3. Implemented Models

4.3.1. Simulation Model

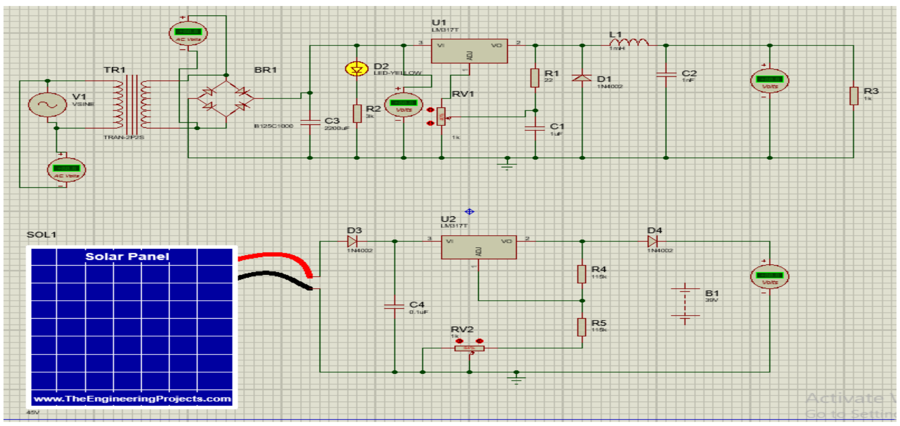

Figure 4.3.1 Grid & Solar to Battery voltage conversion and controlling system schematic diagram.

4.3.2. Hardware Model

Phase by phase Implemented Hardware and final configurations.

Full hardware set-up:

Figure 4.3.2 Hardware Implementation

Transformer:

This is step down transformer. This transformer can convert high voltage to low voltage. Here this transformer has been converted high voltage 220V AC to 27.5V output AC voltage.

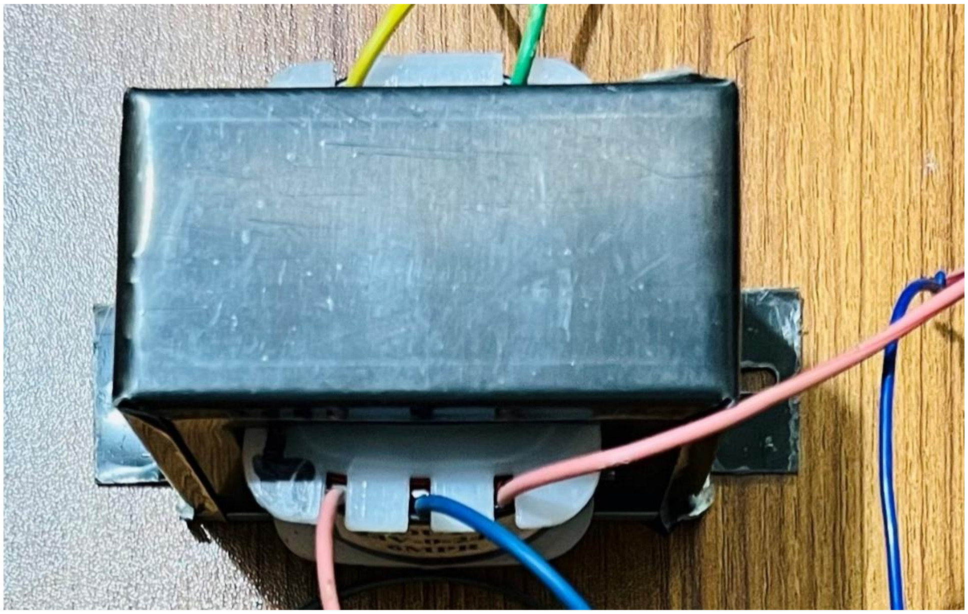

Figure 4.3.3 Step Down Transformer

Initially Transformer Output voltage:

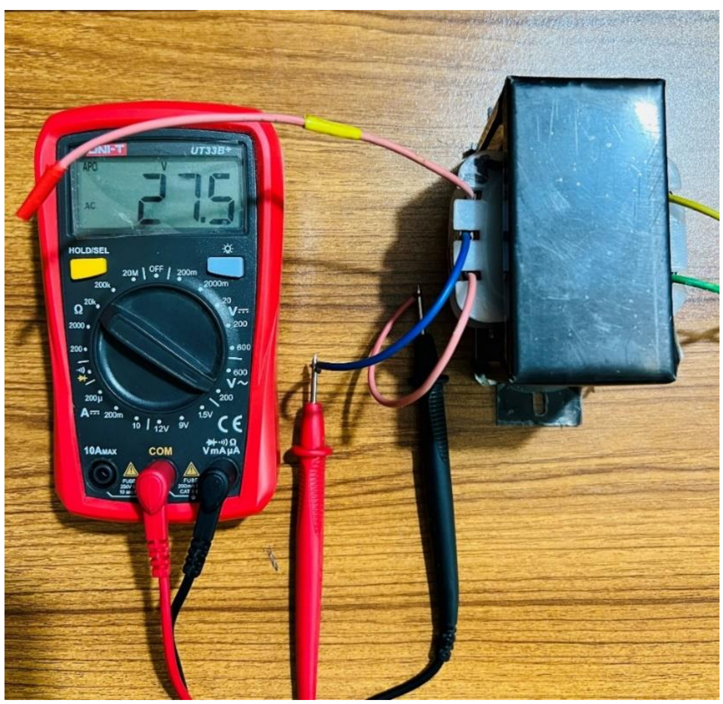

Figure 4.3.4 Output voltage of Transformer

This is the AC output we get from the transformer after it steps down the grid voltage from 220V to 27.5V

Bridge rectifier system with capacitor:

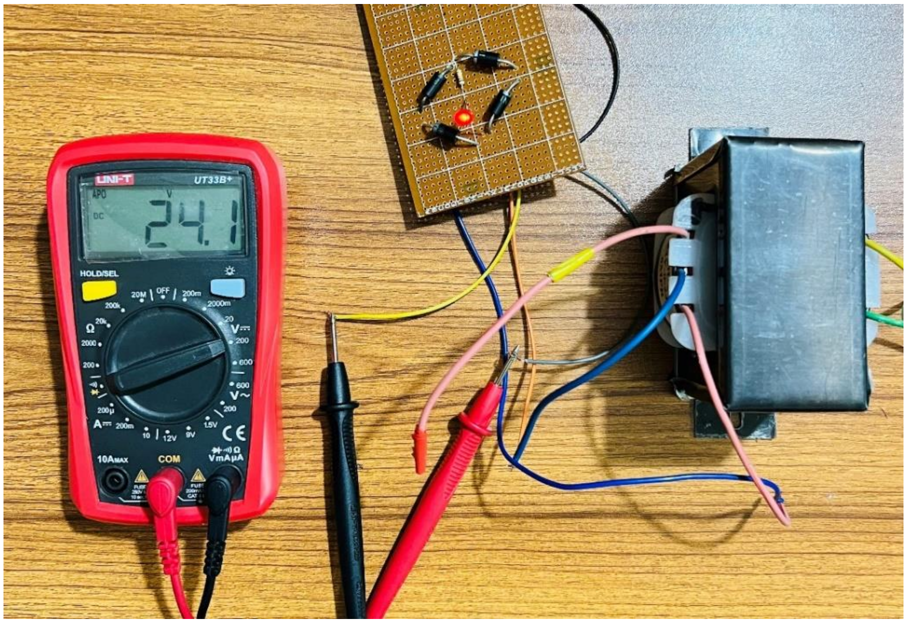

Figure 4.3.5 Full-wave bridge rectifier

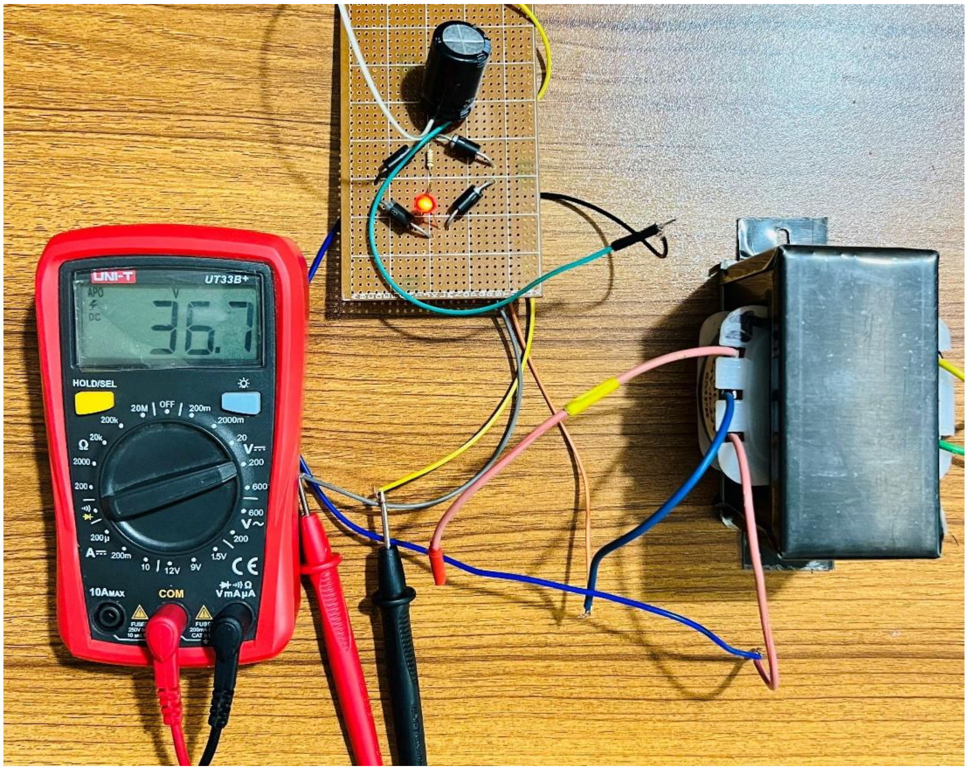

Figure 4.3.6 Full-wave bridge rectifier with link-capacitor

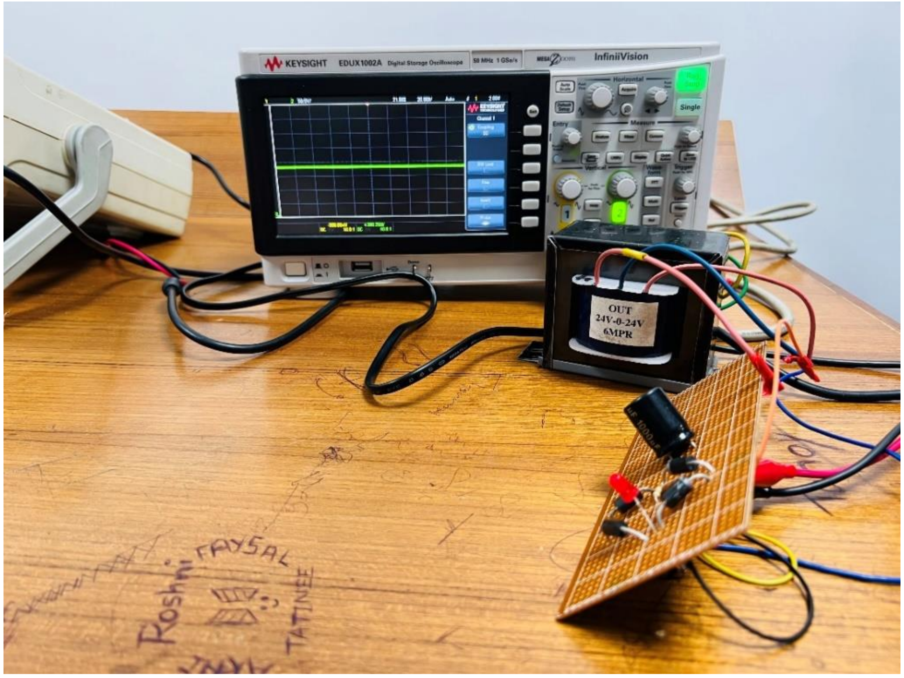

Figure 4.3.7 Pure DC voltage show in oscilloscope

This full-wave bridge rectifier is used to convert the AC 27.5 volt of the transformer to DC voltage as batteries only receive DC voltage. Therefore, four diodes were used to build the full-wave bridge rectifier. After rectifier process now voltage is 24.1V. A capacitor of 2200uF was added so that it cancels out the AC pulses and produce pure DC voltage. This link capacitor has been not made pure DC but also boost voltage After passing to this entire system, the AC 27.5V becomes 36.7V DC voltage.

Initially Display value: When grid and solar battery both were disconnected that time display all value were zero.

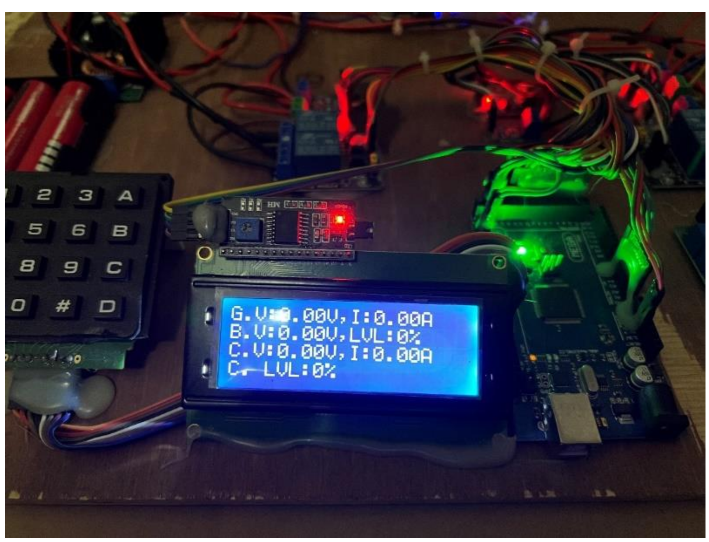

Figure 4.3.8 Display at off state

This is the initial values the microcontroller display. All the values are zero as the system is turned off. Here, G.V. means grid voltage. B.V., C.V, C. LVL represents battery voltage, car voltage & car battery charging level respectively.

Initially Car battery Condition: Before charger plug in car battery

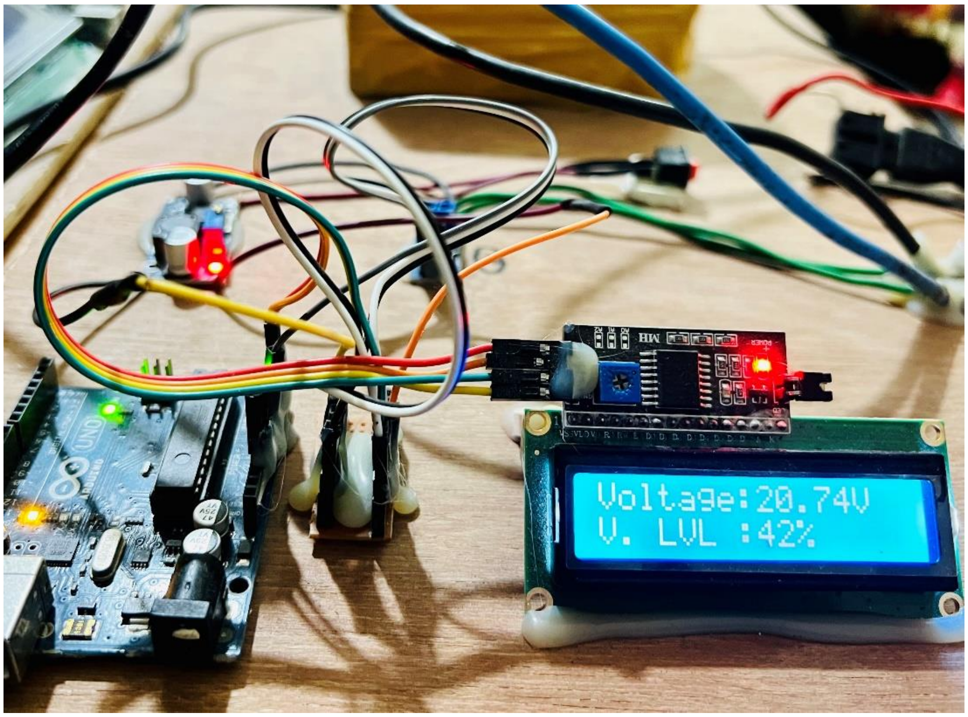

Figure 4.3.9 Initially Car battery Condition

Car Battery Charging from Grid:

Figure 4.3.10 Vehicle Charging Process

Customers can request the amount of charge they need in percentage and it can be provided to the microcontroller through the keypad. To enter the desired amount, one simply has to press the start (*) button, then enter the value in percentage form and after that press "A". After the charging is completed, the relay will cut the supply.

Figure 4.3.11 Charging State when grid is on

The grid voltage is turned to 26.12Volt using a buck converter. Therefore, it is showing Grid Voltage (G.V.) at 26.12V. This can be turned according to customers need from 2 to 40 volts.

Car battery charging from solar Battery:

Figure 4.3.12 Vehicle Charging Process

Figure 4.3.13 Charging from Solar battery

Here, S.V represents the solar voltage and B.V represent solar battery voltage. Here, C.V and I represent the passing voltage and current from solar battery to car battery. It is the voltage and current the vehicle is getting from the Lead Acid battery storage which charges from the solar panels.

Lead Acid Battery: Lead Acid Battey has been used to store solar energy. Here three lead acid battery has been used to construct this entire battery pack system. One battery can store maximum 13 volts, as a result, all three batteries can store 39 volts in total. This 39V is a practical value. In **figure 5.3.10** B. V value is total lead Acid battery value.

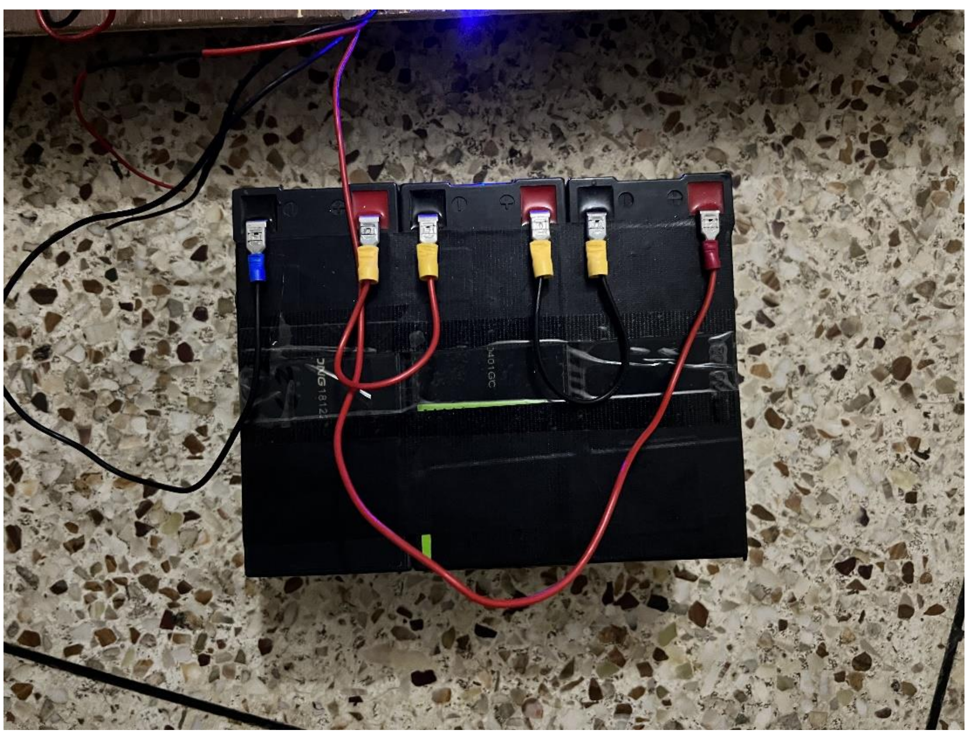

Figure 4.3.14 Lead Acid Battery Pack connected in series

In Charging time Car battery Condition:

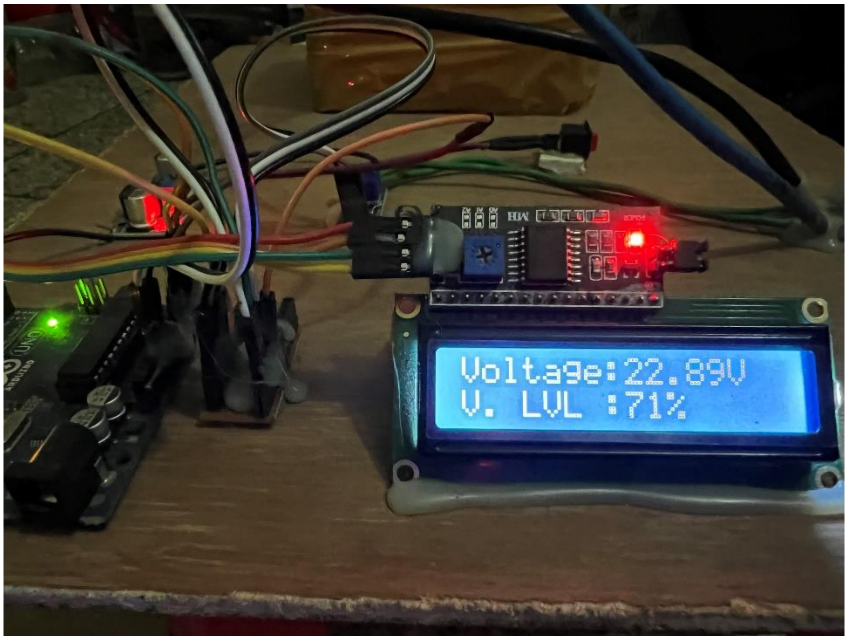

Figure 4.3.15 Vehicle display during charging

This is the display which is connected to the vehicle side. The voltage here shows the voltage level of the vehicle & the V. LVL represents the amount of charge stored in the vehicle's Li-ion battery.

4.4. Engineering Solution in accordance with professional practices

The electric vehicle charging system is aligned with engineering professional practices by ensuring that it is designed, built, and maintained in a way that is safe for the public. This involves adhering to relevant safety codes and standards, as well as conducting thorough testing and risk assessments to identify and mitigate potential hazards. The engineer's professional responsibility to public safety includes ensuring that the charging system is reliable and safe to use, and that any potential risks or hazards are properly addressed. This involves consulting with relevant stakeholders, such as electrical utilities, and considering the impacts of the charging system on the surrounding environment. In terms of the impacts of engineering activity, the charging system is designed to minimize any negative impacts on the environment and to consider sustainability. This involves using environmentally-friendly materials and construction methods, and incorporating features that promote energy efficiency and conservation. Finally, the charging system was designed and built with economic, social, and cultural factors in mind. This may involve considering the needs and preferences of the intended users, and ensuring that the system is accessible and convenient for them to use.

4.5. Summary

At first, the voltage is reduced to 27.5 volts using a 220-volt step-down transformer. The AC is then converted to DC with a full-wave rectifier. A DC-link capacitor is used to convert this DC to pure DC, which becomes pure DC and has its voltage increased as a result of using the DC link capacitor. The final output voltage, which is now 36.7 volts (for DC-link capacitor), must be regulated to meet the needs of the customer. Our market has a range of buck, boost, and buck-boost converters that go from 2 to 40 volts. As boost converter maximum voltage range near about output voltage. so, it is better not to use boost or buck-boost converters. Therefore, buck converters are used to regulate the voltage as per customer request. If 24 volts are needed, the potentiometer on the buck converter must be tuned up to 40% in order to get 24 volts. If another customer needs 35 volts, the potentiometer must be tuned up to 87% before the 35-volt supply can be turned on.

Chapter 5

RESULTS ANALYSIS & CRITICAL DESIGN REVIEW

5.1. Introduction

The solution proposed was to develop a charging station for electric vehicles which will provide clean renewable energy and reduce pressure from grid. To solve this problem, our project is the best option as it is mainly based on the renewable energy received from solar panels and taking the grid only as a secondary option reducing the pressure on grid. EVs produce zero emissions from the tailpipe, which means they do not contribute to air pollution or greenhouse gas emissions. This is in contrast to gasoline-powered cars, which emit a variety of harmful pollutants, including carbon dioxide, nitrogen oxides, and particulate matter. EVs are generally more energy efficient than gasoline-powered cars, which means they can go further on a single charge. This is because the electric motor is more efficient than the internal combustion engine, and because EVs do not experience energy losses due to friction and other factors. In this project, we have successfully implemented the proposed model and charged EV batteries. All the parameters that were set to qualify the proposed solution were met and therefore, this project can be declared as successful.

5.2. Results Analysis

To display the result analysis, we have done a simulation test and then implemented the hardware parts. Below the simulated and hardware results will be illustrated and compared to get a better view of this project.

5.2.1. Simulated Results

Grid to Battery voltage conversion and controlling system.

1. Grid to Car battery full conversion system

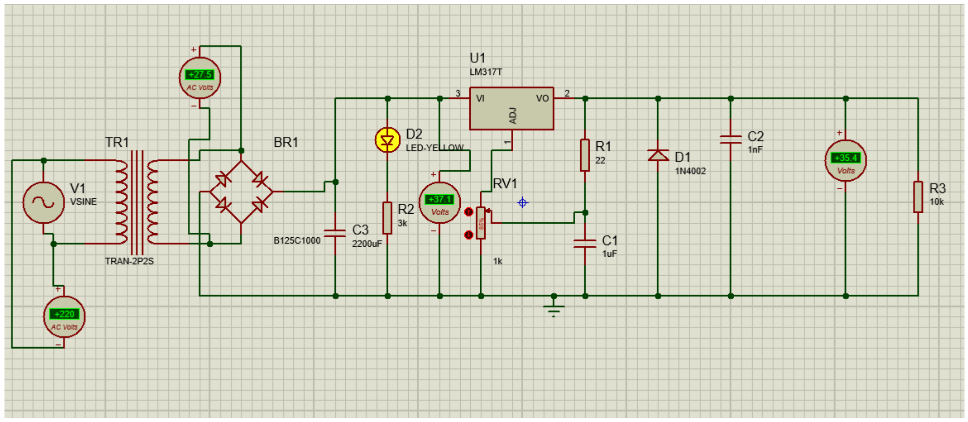

Figure 5.2.1 Grid to Car battery full conversion system

2. If consumer want to output voltage is 24V, buck-converter value should be 40%

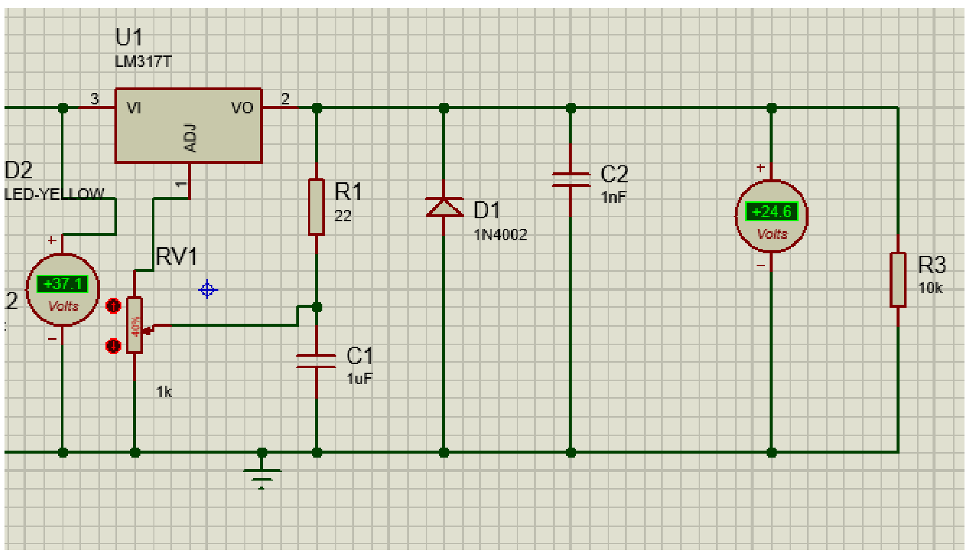

Figure 5.2.2 when buck-converter value is 40% output voltage will be 24V

3. If consumer want to output voltage is 35V, buck-converter value should be 87%

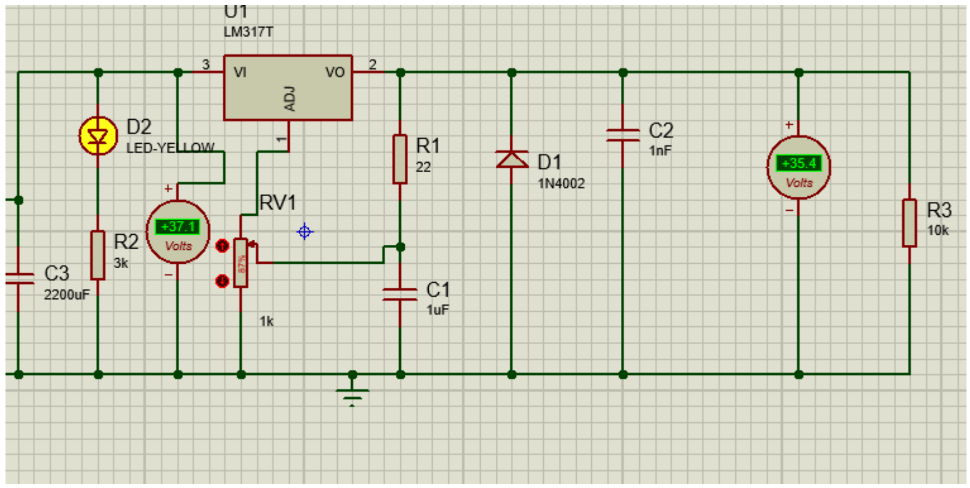

Figure 5.2.3 when buck-converter value is 87% output voltage will be 35V

The use of a step-down transformer at the beginning of the process was crucial, as it allowed us to reduce the initial 220-volt AC voltage to a level that was more manageable and suitable for our purposes. By stepping down the voltage, we were able to lower the amount of electrical current flowing through the system, which in turn reduced the risk of electrical accidents and damage to the equipment. After the AC voltage had been transformed, we used a full-wave rectifier to convert it to DC. This rectifier consisted of a set of diodes that allowed current to flow in only one direction, effectively eliminating the negative half of the AC waveform and producing a pulsating DC signal. The DC-link capacitor that we used served to filter out any remaining AC components from the rectified DC waveform, resulting in a pure DC voltage. The capacitor was connected in parallel with the rectifier and acted as a charge storage device, smoothing out the pulsations and providing a constant DC voltage to the load. Once we had obtained a pure DC voltage, we needed to regulate it to meet the specific requirements of our customers. Since our market offered a variety of voltage converters with different capabilities, we had to carefully select the appropriate type for this task. In this case, we chose to use buck converters, which are capable of reducing the magnitude of the input voltage to produce a lower output voltage. By adjusting the potentiometer on the converter, we were able to fine-tune the output voltage to the desired level. For instance, if a customer needed a voltage of 24 volts, we would adjust the potentiometer to around 40% and then activate the supply. Similarly, if another customer required a voltage of 35 volts, we would adjust the potentiometer to approximately 87% and then turn on the supply. By following these steps, we were able to provide our customers with a regulated DC voltage that met their specific needs.

5.2.2. Hardware Results

In hardware models, two energy sources have been used to charge the electric car battery. One is grid, while the other is solar. As the sun's radiation is not fixed, that's why solar voltage is not always fixed always. So, at first, it is necessary to store solar energy in batteries. To store solar energy, three 12-volt lead acid batteries are connected in series. This three-battery set can hold up to 39 volts. A relay has been used to control whether the car battery will be charged from the grid or from the solar battery. This relay is controlled by an Arduino Mega. If the solar battery voltage is above 31 volts, then the car battery will be charged from the solar battery. And if the solar battery voltage is below 31 volts, then the relay will be cut off. The car's battery will be charged from the grid. Initially, a 220-volt step-down transformer is used to lower the voltage to 27.5V shown in **Figure 5.3.4**. A full-wave rectifier is then used to convert the AC to DC. A DC-link capacitor is used to convert this DC to pure DC, which becomes pure DC and has its voltage enhanced as a result of its use. Value measure with oscilloscope which is shown in **Figure 5.3.7. To** fulfill the needs of the client, the final output voltage, which is now 36 volts (for DC-link capacitor), must be adjusted. Buck converters are thus used to regulate voltage as required by the consumer.

When the keypad was pressed to charge the car battery, the car battery began to differ from the solar battery because the solar battery's voltage was 100%. Where, 19.6V and 5.47Amp was passing in car battery which is shown in **chapter 5.3.13** picture. Again, when the energy of the solar battery was exhausted, the battery of the car started drawing from the grid. And the voltage in the buck converter was adjusted and kept at 26. And the battery of the car was being charged at that same voltage. Almost 26.12V and 4.1Amp was passing in car battery which is shown in **chapter 5.3.10** picture.

Aside from that, the values of all the sensors are sent to the Arduino Mega, which displays them. As a result, the current and voltage can be seen on the display.

5.3. Comparison of Results

The simulated results are quite similar to the hardware results. However, in case of the hardware implementation, if we use a DC link capacitor of 2200uF, the output is around 36.7 V. But if we use a DC link capacitor of 2200uF in simulation, the output voltage is 37.1 volts. Though the components used in both cases are same, there is a difference of 0.4V between them. In hardwire, tuning a small value is easy, but in simulation, tuning a small value is a little bit difficult.

5.4. Summary

To summarize the results and review, it can be seen that, the above model is capable of charging electric vehicles of different specifications. Generally, the voltage of an EV battery is around 25 volts. This charging system provides just that and it is also adjustable according to the configuration of the vehicle. The solar and grid supply around 25 volts to the vehicle battery and that is the objective to implement the project properly.

Chapter 6

CONCLUSION

6.1. Summary of Findings

In this project to design and build an electric vehicle (EV) charger station, some potential findings could include the requirements for charging different types of EVs, best practices for installation, options for design and construction, challenges and opportunities in the EV charger market, and user experience considerations. Researching and identifying the charging requirements for different EVs involved looking at factors such as connector type, power needs, and charging time. Best practices for installation cover topics such as location, permits, and compatibility with electrical infrastructure. Design and construction options could include various materials, sizes, and configurations. Examining the EV charger market could involve identifying key trends and challenges, and suggesting strategies for addressing them. Finally, studying user experience could involve finding ways to make the charging process as convenient and easy to use as possible for drivers.

6.2. Novelty of the Work

Electric vehicles (EVs) and EV charging stations are relatively new in Bangladesh. The country has only recently begun to explore the use of EVs as a means of transportation, and as such, there are currently no EV charging station available. The Bangladesh Power Development Board (BPDB) has announced plans to install EV charging stations in various locations across the country, including in the capital city of Dhaka by 2025. In addition, private companies and organizations are interested in installing EV charging stations in certain areas.

Our project will help the government and the other private companies to develop charging stations for EV which will be the first in the whole country. It will be a revolutionary change in the history of car industry in Bangladesh. The sooner EV charging infrastructures are established, the earlier electric vehicles can entry in the market of Bangladesh. This will reduce air pollution significantly, especially in Dhaka. This is the novelty of our work.

6.3. Cultural and Societal Factors and Impacts

There are a few cultural and societal factors that should be considered during the design phase of an EV charging infrastructure:

Community needs: It's important to thoroughly research the needs of the community where the charging infrastructure will be located. This may include gathering data on the types of EVs that are most commonly driven in the area, as well as the availability of public transportation and other transportation options. Based on this research, it may be necessary to adjust the design of the charging infrastructure to meet the specific needs of the community. For example, if a high percentage of the local EV fleet consists of long-range electric vehicles, it may be necessary to install Level 3 (DC fast charging) stations to enable faster charging.

Accessibility: The charging infrastructure should be accessible to all members of the community, including those with disabilities. This may include installing charging stations with features such as wheelchair ramps, Braille signage, and audio announcements for the visually impaired. It's also important to consider the location of the charging stations, as they should be easily accessible by pedestrians and drivers of EVs.

Sustainability: Many communities are interested in sustainability and reducing their environmental impact. Incorporating sustainable design elements into the charging infrastructure can help to address this concern. This may include using renewable energy sources to power the charging stations, such as solar panels or wind turbines. It's also important to consider the materials used in the construction of the charging stations, as using eco-friendly materials can further reduce the environmental impact of the infrastructure.

Safety: The charging infrastructure should be designed with safety in mind. This may include features such as fencing around the charging stations to prevent unauthorized access, lighting for safety and security, and clear signage indicating the proper use of the charging equipment. It's also important to consider the location of the charging stations, as they should be placed in areas that are well-lit and visible to security personnel.

Aesthetics: The design of the charging infrastructure should be visually appealing and blend in with the surrounding community. This may involve considering factors such as the materials used, the overall aesthetic of the charging stations, and the landscaping around them. It is also important to consider the size and scale of the charging stations, as they should be appropriate for the location and not overpower the surrounding environment.

Charging fees: Depending on the location and target audience of the charging infrastructure, it may be necessary to charge fees for the use of the charging stations. It is important to consider the pricing structure for the charging fees, as well as any discounts or incentives that may be offered to encourage the use of the charging stations.

Payment options: The charging infrastructure should offer a variety of payment options to make it convenient for EV drivers to pay for their charging sessions. This may include options such as credit card payments, smartphone app payments, and RFID payments.

Network connectivity: It's important to consider the network connectivity of the charging stations, as this will be necessary for monitoring the status and usage of the charging stations, as well as facilitating payment transactions. It may be necessary to install dedicated network infrastructure to support the charging stations, or to use existing network infrastructure if available.

Maintenance and management: The charging infrastructure will require regular maintenance and management to ensure that it is operating safely and efficiently. It is important to have a plan in place for maintaining and managing the charging stations, including procedures for handling equipment failures, handling payment disputes, and addressing customer complaints.

By considering these additional points, it is possible to design an EV charging infrastructure that is convenient, efficient, and well-maintained for the benefit of EV drivers and the community.

6.4. Limitations of the Work

It would have been possible to use better quality and high price equipment to produce better results. But it was not possible because of economical limitations. Additionally, in Bangladesh, the available range of buck converter & buck-boost converter is maximum 40 Volts. As a result, after stepping-down the voltage, it has to be under 35 Volts. These are the limitations of our project which needs to be overcome in the future.

6.5. Future Scopes

There are several areas where the shortcomings of an EV charging infrastructure project can be addressed in the future:

Network expansion: One potential shortcoming of an EV charging infrastructure project is the limited coverage of the charging network. In the future, it may be necessary to expand the charging network to reach more locations and meet the needs of a growing number of EV drivers.

Charging speed: Another potential shortcoming of an EV charging infrastructure project is the charging speed of the stations. In the future, it may be necessary to upgrade the charging stations to provide faster charging speeds, or to install additional Level 3 (DC fast charging) stations to meet the needs of long-range EV drivers.

Battery technology: The battery technology used in EVs is constantly evolving, and it is important to ensure that the charging infrastructure can accommodate these developments. In the future, it may be necessary to upgrade the charging infrastructure to support the charging-needs of new EV models with advanced battery technology.

Payment options: In the future, it may be necessary to expand the payment options available at the charging stations to make it more convenient for EV drivers to pay for their charging sessions. This could include adding support for new payment technologies or integrating with existing payment systems.

Network connectivity: Ensuring reliable network connectivity is essential for the operation and management of the charging infrastructure. In the future, it may be necessary to upgrade the network infrastructure or to adopt modern technologies to improve the connectivity of the charging stations. This could include installing dedicated networking equipment or leveraging existing networks such as Wi-Fi or cellular networks.

6.6. Social, Economic, Cultural and Environmental Aspects

6.6.1. Sustainability

The Sustainable Development Goals (SDGs) are a set of global goals adopted by the United Nations in 2015 to guide efforts towards a more sustainable and equitable future. Building an EV charging infrastructure can contribute to several of the SDGs, including:

SDG 7: Affordable and Clean Energy: EV charging infrastructure can contribute to the goal of providing affordable and clean energy for all. By enabling the use of electric vehicles, the charging infrastructure can help to reduce the use of fossil fuels and reduce greenhouse gas emissions.

SDG 11: Sustainable Cities and Communities: The charging infrastructure can contribute to the goal of creating sustainable cities and communities by enabling the use of electric vehicles, which can help to reduce air pollution and improve the livability of urban areas.

SDG 13: Climate Action: The charging infrastructure can contribute to the goal of taking urgent action to combat climate change by enabling the use of electric vehicles, which can help to reduce greenhouse gas emissions.

SDG 3: Good Health and Well-Being: The charging infrastructure can contribute to the goal of ensuring good health and well-being for all by enabling the use of electric vehicles, which can help to reduce air pollution and improve public health.

By considering the SDGs during the design and implementation of an EV charging infrastructure, it is possible to contribute to a more sustainable and equitable future.

6.6.2. Economic and Cultural Factors

There are a few standards and codes of ethics that are relevant to an EV charging infrastructure project and its economic & cultural factors in Bangladesh or internationally. Here are a few examples:

International Electrotechnical Commission (IEC) standards: The IEC is a global organization that develops and publishes international standards for the electrical and electronic industries. The IEC has several standards related to electric vehicle charging infrastructure, including IEC 61851-1 (EV charging stations - Part 1: General requirements) and IEC 61851-23 (EV charging stations - Part 23: Particular requirements for AC charging stations for EVs).

National Electric Code (NEC): The NEC is a set of electrical safety standards published by the National Fire Protection Association (NFPA) in the United States. The NEC contains requirements for the installation and maintenance of EV charging stations, including guidelines for electrical system design and protective measures to ensure the safety of users.

Code of Ethics for Engineers: The Code of Ethics for Engineers is a set of ethical principles adopted by professional engineering organizations around the world, including the Bangladesh Association of Engineers (**BAE**) and the Institute of Electrical and Electronics Engineers (**IEEE**). The Code of Ethics for Engineers includes principles such as integrity, honesty, and responsibility, which can be applied to the design and implementation of an EV charging infrastructure project.

By adhering to these standards and codes of ethics, it is possible to ensure that the EV charging infrastructure project is designed and implemented in a professional, responsible, and ethical manner.

6.7. Conclusion

There were several goals of this project which was accomplished by completing this project. The primary aim was to develop a charging infrastructure for the Electric Vehicle industry of Bangladesh which will produce clean renewable energy and reduce the pressure on national grid. After the execution of this project, all the above-mentioned criteria were properly fulfilled. We were able to build a charging station for EV which is powered up mainly by the solar panels and has a backup system from the grid to serve electric vehicles with clean energy. This project is a prototype to experience the real-world challenges and prospects.

Furthermore, this project also helps reduce the high fuel cost per person in Bangladesh and it also helps to reduce the costing to build EV charging stations in Bangladesh which were the secondary objectives of this project.

To conclude, it can be agreed with that, the primary and secondary aims of this project were met with the completion of this whole project.

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Appendix A

Datasheet of the ICs used

Appendix B

iThenticate Plagiarism Report

Appendix C

Codes of Arduino Mega & Uno

Arduino Mega (Code for the charging actions of the charging station):

```
#include <Wire.h>
#include <Keypad.h>
#include <Robojax_AllegroACS_Current_Sensor.h>
#include <LiquidCrystal_I2C.h>

#define CurrentSensor A2
#define CurrentSensor1 A4
#define CurrentSensor2 A7
const float VCC   = 5;
const int MODEL   = 0;
float II = 0, III = 0, IIII = 0;

Robojax_AllegroACS_Current_Sensor robojax(MODEL, CurrentSensor);
Robojax_AllegroACS_Current_Sensor robojax1(MODEL, CurrentSensor1);
Robojax_AllegroACS_Current_Sensor robojax2(MODEL, CurrentSensor2);

const byte numRows = 4;         //number of rows on the keypad
const byte numCols = 4;         //number of columns on the keypad

char keymap[numRows][numCols] =
{
  {'1', '2', '3', 'A'},
  {'4', '5', '6', 'B'},
  {'7', '8', '9', 'C'},
  {'*', '0', '#', 'D'}
};

char keypressed;
short a = 0, i = 0, s = 0, j = 0;

byte rowPins[numRows] = {6, 7, 8, 9};
byte colPins[numCols] = {2, 3, 4, 5};

LiquidCrystal_I2C lcd(0x27, 20, 4);
Keypad myKeypad = Keypad(makeKeymap(keymap), rowPins, colPins, numRows, numCols);
int VSET = 0;

#define Volt_Meter A0
float Vout = 0.00, voltage = 0.00, voltageV1 = 0.00;
```

```
float R1 = 100000.00;
float R2 = 7300.00;
int val = 0, perc = 0;

#define Volt_Meter1 A1
float Vout1 = 0.00, voltage1 = 0.00, voltageV2 = 0.00;
int val1 = 0;

#define Volt_Meter2 A3
float Vout2 = 0.00, voltage2 = 0.00, voltageV3 = 0.00;
int val2 = 0;

#define Volt_Meter3 A5
float Vout3 = 0.00, voltage3 = 0.00, voltageV4 = 0.00;
int val3 = 0, perc1 = 0, perc11 = 0;

#define relay1 22
#define relay2 23
#define relay3 24
#define relay4 25

unsigned long previousMillis = 0;
const long interval = 1000;

void setup()
{
  pinMode(Volt_Meter, INPUT);
  pinMode(Volt_Meter1, INPUT);
  pinMode(Volt_Meter2, INPUT);
  pinMode(Volt_Meter3, INPUT);
  pinMode(CurrentSensor, INPUT);
  pinMode(CurrentSensor1, INPUT);
  pinMode(CurrentSensor2, INPUT);
  pinMode(relay1, OUTPUT);
  pinMode(relay2, OUTPUT);
  pinMode(relay3, OUTPUT);
  pinMode(relay4, OUTPUT);
  digitalWrite(relay1, HIGH);
  digitalWrite(relay2, HIGH);
  digitalWrite(relay3, HIGH);
  digitalWrite(relay4, HIGH);
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();
}


void loop()
{
```

```
keypressed = myKeypad.getKey();
if (keypressed != NO_KEY) {
  Serial.println(keypressed);
}
if (keypressed == '*') {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("* ENTER CHARGING % *");
  ReadVolt();
  lcd.clear();
}
if (perc11 < VSET && VSET > 0) {
  digitalWrite(relay3, LOW);
  digitalWrite(relay4, LOW);
}
else {
  VSET = 0;
  digitalWrite(relay3, HIGH);
  digitalWrite(relay4, HIGH);
}

Volt();
SVolt();
GVolt();
CVolt();
unsigned long currentMillis = millis();
if (currentMillis - previousMillis >= interval) {
  previousMillis = currentMillis;
  if (voltage > 30.6) {
    lcd.setCursor(0, 0);
    lcd.print("S.V:");
    lcd.print(voltage1);
    lcd.print("V,I:");
    lcd.print(II);
    lcd.print("A  ");
    digitalWrite(relay1, LOW);
    digitalWrite(relay2, LOW);
  }
  else {
    lcd.setCursor(0, 0);
    lcd.print("G.V:");
    lcd.print(voltage2);
    lcd.print("V,I:");
    lcd.print(III);
    lcd.print("A  ");
    digitalWrite(relay1, HIGH);
    digitalWrite(relay2, HIGH);
  }
  if (VSET > 0) {
```

```
      if (perc11 >= perc1) {
        perc11 = perc1;
      }
      else {
        perc11 = perc11 + 1;
      }
    }
    lcd.setCursor(0, 1);
    lcd.print("B.V:");
    lcd.print(voltage);
    lcd.print("V,LVL:");
    lcd.print(perc);
    lcd.print("%  ");
    lcd.setCursor(0, 2);
    lcd.print("C.V:");
    lcd.print(voltage3);
    lcd.print("V,I:");
    lcd.print(IIII);
    lcd.print("A  ");
    lcd.setCursor(0, 3);
    lcd.print("C. LVL:");
    lcd.print(perc11);
    lcd.print("%  ");
  }
}

void ReadVolt() {
  i = 0;
  a = 0;
  j = 0;
  String asdf;
  while (keypressed != 'A') {
    keypressed = myKeypad.getKey();
    if (keypressed != NO_KEY && keypressed != 'A' ) {
      lcd.setCursor(j, 1);
      lcd.print(keypressed);
      j++;
      asdf = asdf + String(keypressed);
    }
  }
  VSET = asdf.toInt();
  Serial.println(VSET);
  keypressed = NO_KEY;
}

void Volt() {
  val = analogRead(Volt_Meter);
  Vout = (val * 5.00) / 1024.00;
  voltage = Vout / (R2 / (R1 + R2));
```

```
  if (voltage < 0.30) //condition
  {
    voltage = 0.00;
  }
  if (voltage < voltageV1) {
    val = analogRead(Volt_Meter);
    Vout = (val * 5.00) / 1024.00;
    voltage = Vout / (R2 / (R1 + R2));
  }
  voltageV1 = voltage;
  perc = map(voltage, 30.0, 36.0, 0, 100);
  if (perc >= 100) {
    perc = 100;
  }
  if (perc <= 0) {
    perc = 0;
  }
}

void SVolt() {
  val1 = analogRead(Volt_Meter1);
  Vout1 = (val1 * 5.00) / 1024.00;
  voltage1 = Vout1 / (R2 / (R1 + R2));

  if (voltage1 < voltageV2) {
    val1 = analogRead(Volt_Meter1);
    Vout1 = (val1 * 5.00) / 1024.00;
    voltage1 = Vout1 / (R2 / (R1 + R2));
  }
  voltageV2 = voltage1;

  II = robojax.getCurrentAverage(300);
  if (II < 0.20) {
    II = 0;
  }
  if (voltage1 < 2.50) //condition
  {
    voltage1 = 0.00;
  }
}

void GVolt() {
  val2 = analogRead(Volt_Meter2);
  Vout2 = (val2 * 5.00) / 1024.00;
  voltage2 = Vout2 / (R2 / (R1 + R2));
  if (voltage2 < voltageV3) {
    val2 = analogRead(Volt_Meter2);
    Vout2 = (val2 * 5.00) / 1024.00;
    voltage2 = Vout2 / (R2 / (R1 + R2));
```

```
  }
  voltageV3 = voltage2;

  III = robojax1.getCurrentAverage(300);
  if (III < 0.20) {
    III = 0;
  }
  if (voltage2 < 2.50) //condition
  {
    voltage2 = 0.00;
  }
}

void CVolt() {
  val3 = analogRead(Volt_Meter3);
  Vout3 = (val3 * 5.00) / 1024.00;
  voltage3 = Vout3 / (R2 / (R1 + R2));

  if (voltage3 < voltageV4) {
    val3 = analogRead(Volt_Meter3);
    Vout3 = (val3 * 5.00) / 1024.00;
    voltage3 = Vout3 / (R2 / (R1 + R2));
  }
  voltageV4 = voltage3;

  IIII = robojax2.getCurrentAverage(300);
  if (IIII < 0.20) {
    IIII = 0;
  }
  if (voltage3 < 2.50) //condition
  {
    voltage3 = 0.00;
  }
  if (VSET > 0) {
    perc1 = map(IIII, 0.0, 7.0, 100, 0);
    if (perc1 >= 100) {
      perc1 = 100;
    }
    if (perc1 <= 0) {
      perc1 = 0;
    }
  }
  else {
    IIII = 0;
    perc1 = 0;
    perc11 = 0;
  }
}
```

Arduino Uno (Code of the Vehicle side)

```
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 16, 2);

#define Volt_Meter A0
float Vout = 0.00, voltage = 0.00, voltage1 = 0.00;
float R1 = 100000.00;
float R2 = 7300.00;
int val = 0, perc = 0;

void setup() {
  pinMode(Volt_Meter, INPUT);
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();
}

void loop() {
  val = analogRead(Volt_Meter);
  Vout = (val * 5.00) / 1024.00;
  voltage = Vout / (R2 / (R1 + R2));
  if (voltage < voltage1) {
    val = analogRead(Volt_Meter);
    Vout = (val * 5.00) / 1024.00;
    voltage = Vout / (R2 / (R1 + R2));
  }
  voltage1 = voltage;
  if (voltage < 0.09) //condition
  {
    voltage = 0.00;
  }
  perc = map(voltage, 17.0, 24.00, 0, 100);
  if (perc >= 100) {
    perc = 100;
  }
  if (perc <= 0) {
    perc = 0;
  }
  if (voltage >= 26) {
    lcd.setCursor(0, 0);
    lcd.print("Battry Charging..");
    lcd.setCursor(0, 1);
    lcd.print("                ");
  }
  else {
    lcd.setCursor(0, 0);
```

```
    lcd.print("Voltage:");
    lcd.print(voltage);
    lcd.print("V  ");
    lcd.setCursor(0, 1);
    lcd.print("V. LVL :");
    lcd.print(perc);
    lcd.print("%  ");
  }

  Serial.print("Voltage= ");
  Serial.println(voltage);
  Serial.print("Battery level= ");
  Serial.print(perc);
  Serial.println(" %");
  delay(3000);
}
```