Hybrid Charging Terminal for Electric Vehicles

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بسم الله الرحمن الرحيم

In the name of Allah (SWT), the most beneficent and the most merciful

FYP submitted to the Dept. of Electrical and Computer Engineering, International Islamic University, Islamabad, as a requirement for the Bachelor of Science degree in Electrical Engineering.

Declaration

We affirm that the content presented in this work, in its entirety or in part, is original and has not been plagiarized from any source. No section of this work has been previously submitted to obtain any other degree or qualification from this or any other university or educational institution. Furthermore, all referenced materials have been appropriately cited in the references section.

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- Arduino ide
- PCB Creator
- MIT APP Inventor

Abstract

During the last many decades, the use of coal and other petroleum in automobiles has given rise to pollution. To address environmental concerns and decrease reliance on fossil fuels, there is a growing demand and increasing popularity for electric vehicles. With the increase in Electric Vehicles (EV), the need for charging infrastructure will be on the rise.

In this project, an EV charging terminal is designed that is powered by solar energy and WAPDA. The charging module is equipped with IoT that provides information to users as well as the owner/operator who can monitor and control the system remotely. Further, the proposed system also incorporate automatic SMS alerts for the user in case of any power shortage in the charging terminal.

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Chapter 1
Introduction

1.1 Motivation

Energy is the basic source of development of any country. However, conventional energy sources are finite and will eventually be depleted. Moreover, the production and utilization of fossil fuels, the primary energy source, contribute significantly to climate change through the emission of CO2, a potent greenhouse gas, and also pose environmental and human health risks.

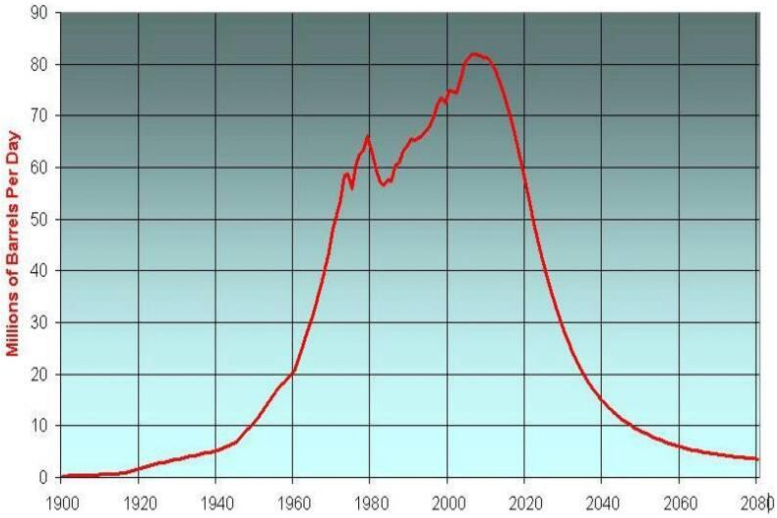


Figure 1.1: Fossil fuels depletion period

In addition, the rapid growth of urbanization and smart cities has led to an upsurge in conventional automobiles, resulting in high greenhouse gas emissions. For instance, in 2011, the transport sector alone accounted for over 5 million metric tons of CO2 emissions. These concerns have prompted the exploration of alternative energy sources that are renewable and less detrimental to the environment.

This has spurred the electrification of transportation, with electric vehicles emerging as a viable alternative to fossil fuel-powered vehicles. Electric cars offer a significant advantage in terms of improving air quality in urban areas. Since they have no tailpipe emissions, pure electric vehicles produce no carbon dioxide while driving, resulting in a substantial reduction in air pollution. Over the course of a year, just one electric car on the roads can save an average of 1.5 million grams of CO2.

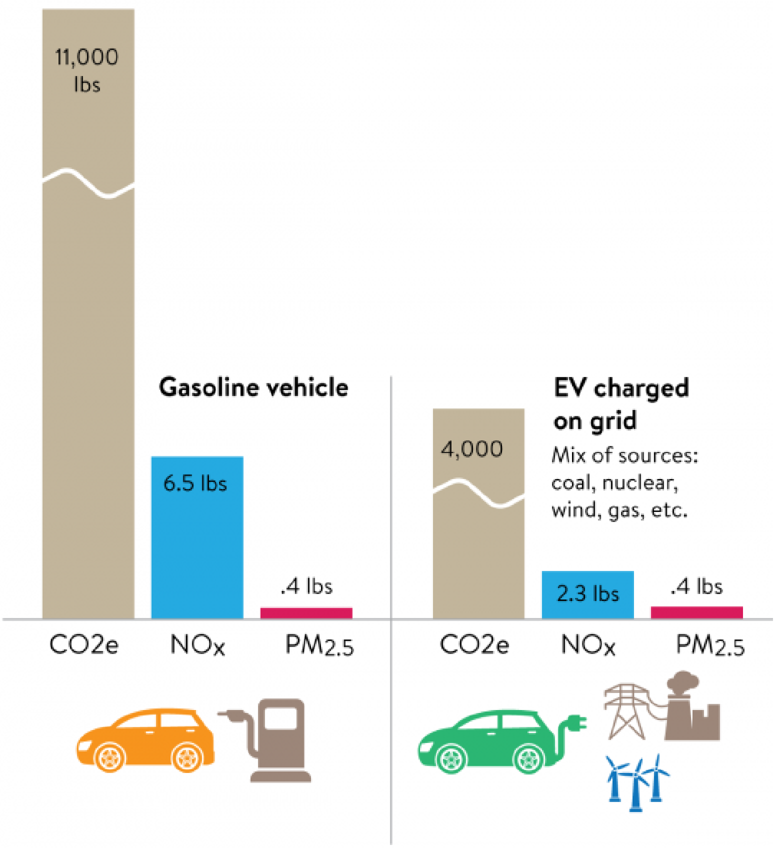


Figure 1.2: Greenhouse gasses emission by conventional vs EVs

As electric vehicles become increasingly affordable each year, the demand for charging stations is on the rise. However, the current electricity grids rely heavily on fossil fuels rather than renewable energy sources. Charging electric vehicles from such grids does not yield entirely zero net emissions. To achieve truly sustainable electric vehicle charging, the use of electricity generated from photovoltaic (PV) panels is necessary. However, PV generation is subject to diurnal and seasonal variability, which necessitates an AC grid connection to supplement excess PV power and fulfill the charging demands of electric vehicles.

Motivated by these challenges, this project focuses on the development of a solar and WAPDA-based charging terminal for electric vehicles. The aim is to create an efficient, sustainable, and scalable solution that provides reliable and convenient charging services for EV owners. By harnessing solar power through photovoltaic (PV) cells, the charging terminal can convert sunlight into electricity for EV charging, reducing reliance on traditional energy sources and minimizing carbon emissions. Additionally, the integration of IoT technology allows for real-time monitoring and control of the charging process, enabling EV owners to remotely access the charging status of their vehicles and receive notifications. The incorporation of automatic SMS alerts ensures that users are promptly notified in the event of any power shortage in the charging terminal.

The motivation behind this project is rooted in the urgent need to transition to sustainable transportation solutions and mitigate the environmental impacts associated with conventional automobiles. By developing an innovative charging terminal that leverages solar power and integrates with existing power grids, this project aims to contribute to the widespread adoption of electric vehicles and the development of a greener and more sustainable transportation ecosystem.

1.2 Project Overview

Our project aims to develop a charging system for electric vehicles (EVs) that combines solar power and the existing power grid infrastructure provided by the Water and Power Development Authority (WAPDA). This project is a scaled-down version of a Level 2 charging system, which is widely recognized as an effective and efficient charging solution for EVs.

The Level 2 charging system is a widely adopted standard that provides faster charging compared to Level 1 charging. It operates at higher power levels, typically between 3.3 kW and 22 kW, allowing EVs to charge more quickly and efficiently. However, our project focuses on developing a scaled-down version of the Level 2 charging system to suit the specific requirements and constraints of our target users.

By integrating solar power into the charging system, we aim to harness the abundant and renewable energy from the sun to charge EVs. Solar power offers numerous advantages, including reducing reliance on traditional energy sources and minimizing carbon emissions associated with EV charging. By utilizing photovoltaic (PV) cells, we can convert sunlight into electricity, providing a clean and sustainable energy source for charging EVs. Additionally, the integration with the existing power grid infrastructure provided by WAPDA enhances the reliability and availability of the charging system. It allows EV owners to charge their vehicles even during periods of low solar availability or high charging demand. The connection to the power grid also serves as a backup power source, ensuring uninterrupted charging services in case of any solar energy limitations or grid disruptions.

To enhance user experience and control, the charging system incorporates IoT technology. This enables remote monitoring and control of the charging process, providing real-time information about the charging status and allowing users to manage their charging preferences conveniently. Through platforms such as Thing speak and a mobile application developed with MIT App Inventor, EV owners can stay informed and in control of their charging activities.

Moreover, the charging system includes a reservoir battery with a capacity of 12 volts and 12 ampere-hours. This battery acts as a storage device, allowing excess solar energy generated during peak periods to be stored for later use. The stored energy can then be utilized during periods of low solar availability or grid disruptions, ensuring uninterrupted charging services, and maximizing the utilization of solar power.

Safety and reliability are paramount in the design of the charging system. To address this, automatic SMS alerts are incorporated into the system. In the event of a power shortage or any other critical issue, the system sends alert messages to the owner, enabling timely notifications and necessary actions to be taken.

1.2.1 Block Diagram

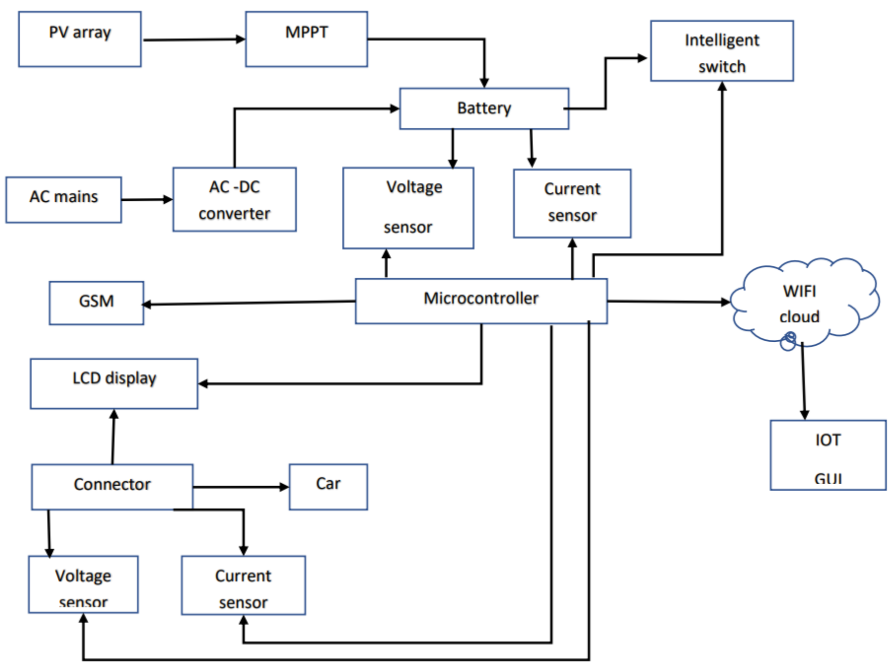


Figure 1.3: Block Diagram

1.2.2 EV charging framework and standards

The charging terminal in our project is designed as a micro-grid system, offering options for AC, DC, or hybrid power sources. High voltage AC or DC sources are utilized to supply the charging terminal, and the charger converts the electrical energy to the required level for charging the electric vehicle (EV) battery. The power levels available for different types of EV chargers are listed in Table 1 [4].. For DC power charging, the charging power (Pch) is determined by the charging current (Ich) and the EV battery voltage (Vev), as expressed by the equation

$$Pch = Vev * Ich. \quad (1)$$

The energy supplied to the EV battery pack (Ech) during a specific time interval (Tch) is calculated using the integral of the charging power over time.

To meet the varying charging requirements globally, different charging systems and standards are in place, classified as AC or DC chargers. International organizations such as the Society of Automotive Engineers (SAE), International Electro-Technical Commission (IEC), and CHAdeMO have established EV charging standards, while Tesla has its own proprietary standards [5-7]. Table 1 provides a summary of the different AC and DC connectors currently used worldwide.

Table 1.1: An analysis of EV charging levels and their alignment with global standards

Charging Level		***Type of Charging***		***Charging Time***		***Power Rating (kW)***	***Voltage (V)***	***Max Current Rating (A)***
		On-board	***Offboard***					
AC Charging: SAE Standards								
AC	***Level 1***	√	-	PHEV 7 h	BEV 17 h	1.4–1.9	120	12–16
	Level 2	√	-	PEV 0.4 h	BEV 1.2 h	19.2	208–240	80
	Level 3		√	0.5 h	1 h	>48	480	>100
DC Charging: SAE Standards								
DC	***Level 1***	-	√	PHEV 0.4 h	BEV 1.2 h	36	200–450	80

	Level 2	-	√	PHEV 0.2 h	BEV 0.4 h	90	200–450	200
	Level 3	-	√	-	BEV 0.2 h	240	200–600	400
AC Charging: IEC Standards								
AC	***Level 1***	√	-	Up to 2 h	Up to 3 h	4–7	250–450	16
	Level 2	√	-	1 h	2 h	22	250–450	63
DC	***CHAdeMO Standards***							
	Fast Charging	-	√	-	Up to 0.5 h	60	500	125
	Tesla supercharging							
	Fast Charging	-	√	Model S 80–90% soc; 0.5 h	Model S 20–80% soc; 1.25 h	>135	Up to 480	200

On-board chargers provide charging solutions for electric vehicles (EVs) at levels 1 and 2, enabling daytime charging at workplaces and overnight charging at home. Level 3 off-board chargers offer high-output power for rapid charging, ensuring quick charging times. Integrated on-board chargers combine the features of both on-board and off-board chargers, allowing for fast-charging capabilities. These chargers play a vital role in facilitating convenient and efficient charging options for EV owners.[8]

1.2.3 Charging Levels for Electric Vehicles

The AC charging system allows for battery charging by converting AC (alternating current) to DC (direct current) using the integrated AC/DC power converter in an electric vehicle (EV), typically through a single or three-phase AC connection. The AC charging system is categorized into three levels based on SAE (Society of Automotive Engineers) and IEC (International Electrotechnical Commission) standards [8].

Level 1 chargers are designed to provide low-power charging to electric vehicle (EV) batteries using a standard single-phase AC power source of 120 V. They typically operate at a current range of 12-16 A and a power output of 4-7 kW, with a voltage of 250-450 V. Level 1 chargers are compatible with domestic power outlets and require no additional electronic components or onboard chargers. Connectors commonly used at this level include NEMA 5-15, SAE-J1772, and IEC. Charging an EV using a Level 1 charger usually takes 7-17 hours, making it suitable for overnight charging. However, the charging time is longer due to limitations in charging current imposed by cable size and thermal constraints [9].

Level 2 chargers enable a direct connection between the electric vehicle (EV) and the main electrical grid to facilitate faster charging of the batteries. These chargers typically utilize a single-phase connector with specifications of 240 V, 80 A, and a power output of approximately 19.2 kW, following SAE standards and Tesla supercharging. IEC standards, on the other hand, utilize a 400 V, 63 A, and 22 kW connector for Level 2 charging. In Level 2 charging, an onboard charger is commonly used. Level 2 AC charging stations form the majority of the typical charging infrastructure. However, due to their higher voltage requirements and power management capabilities, Level 2 chargers necessitate dedicated installations at specific load location.

Level 3 chargers, also known as DC fast chargers, employ three-phase 480 V connectors capable of handling currents exceeding 100 A and power levels surpassing 48 kW. These chargers use standard connectors such as SAE standards and Tesla supercharging for efficient EV charging at this level. Level 3 charging is designed for rapid charging of EV battery packs, allowing for full recharging within 30 minutes to 1 hour. The use of Level 3 AC power is the preferred high-power option for fast and convenient charging, although there is currently no IEC standard established specifically for Level 3 AC chargers. The SAE-J1772 standard introduces Level 3 AC power and categorizes it as an off-board charger.[10].

1.2.4 Why Level 2 Charging?

In our project, we have specifically chosen Level 2 charging as the primary charging method for electric vehicles (EVs). This decision is based on the numerous advantages and strong rationale associated with Level 2 charging infrastructure.

First and foremost, Level 2 charging offers a significantly faster charging time compared to Level 1 charging. With Level 2 charging stations, EVs can gain a range of 10-20 miles per hour of charging, making it a much more efficient and convenient option for EV owners. This accelerated charging rate enables users to quickly recharge their vehicles, minimizing downtime and enhancing the overall usability of electric vehicles.

Another crucial factor is the enhanced efficiency of Level 2 charging. Studies have shown that Level 2 charging can achieve up to a 3% gain in efficiency compared to Level 1 charging. This increased efficiency translates to a higher energy transfer rate, resulting in reduced charging times and improved overall charging performance for EV batteries.

Moreover, Level 2 charging infrastructure is widely compatible with various electric vehicle models. It has become the industry standard, ensuring that EV owners can easily access charging stations and benefit from the advantages of Level 2 charging. This compatibility fosters a broad adoption of Level 2 charging solutions, promoting interoperability and convenience across different EV models.

Scalability is another significant advantage of Level 2 charging. It offers flexibility in terms of implementation, allowing for the deployment of charging stations in various settings, including homes, workplaces, and public locations. This scalability makes Level 2 charging suitable for both residential and commercial use, supporting the growing demand for EV charging infrastructure.

From a cost perspective, Level 2 charging solutions tend to be more cost-effective compared to Level 3 charging infrastructure. Level 2 charging stations require less complex technology and infrastructure, resulting in lower installation and maintenance costs. This cost-effectiveness makes Level 2 charging a more viable and affordable option, enabling a wider accessibility to EV charging for both individuals and businesses.

Lastly, Level 2 charging is highly practical for everyday use. It strikes a balance between charging speed and infrastructure requirements, making it suitable for various scenarios. Whether it is charging EVs at home overnight, providing charging solutions at workplaces for employee convenience, or establishing public charging networks in urban areas, Level 2 charging offers a practical and reliable option that aligns with the evolving needs of EV owners.

Overall, our decision to implement a scaled-down version of Level 2 charging is based on the advantages it offers in terms of faster charging, increased efficiency, compatibility, scalability, and cost-effectiveness. By customizing and optimizing the Level 2 charging infrastructure, we aim to provide a reliable, efficient, and accessible charging solution that meets the specific needs of our project while supporting the growing demands of electric vehicle owners.

1.3 Problem Statement

During the last many decades, the use of coal and other petroleum in automobiles has given rise to pollution. To reduce greenhouse gas emissions and fossil fuels, electric vehicles are in demand and gaining popularity. With the increase in Electric Vehicles (EV), the need for charging infrastructure will be on the rise.

In this project, we aim to design an EV charging station that is powered by solar energy and grid supply. The charging module will be equipped with IoT that provides information to users as well as the owner/operator could monitor and control the system remotely. Further, the proposed system will also incorporate automatic SMS alerts for the user in case of any power shortage in the charging terminal.

1.4 Project Objectives

To accomplish the motive of designing the Hybrid charging terminal for electric vehicle , the subsequent tangible objectives have been formulated.

- To design and develop a micro grid using Solar and WAPDA.
- To design and develop a battery charging terminal for electric vehicle.
- Management of Micro-grid supply and Battery charging terminal through IOT.
- Developing a GUI for User at charging terminal.
- Remote monitoring and controlling using IOT.

By achieving these objectives, our project aims to provide a sustainable and efficient charging solution for electric vehicles while utilizing solar energy and integrating with the existing utility grid. The combination of microgrid technology, IoT connectivity, and user-friendly interfaces will contribute to the widespread adoption of electric vehicles and promote a greener and more sustainable transportation system.

1.5 Brief Project Methodology

A hybrid charging station for electric cars (EVs) requires a systematic strategy that considers numerous elements such as energy sources, charging technology, and infrastructural needs. Following the methodology outlined below can help ensure the successful development of a hybrid charging station for EVs.

Stage 1: Design and Development of the micro grid using renewable resources.

Stage 2: Design and Development of battery storage system.

Stage 3: Building a user interface at charging terminal and remote end to show the charging and power status.

Stage 4: Implementation of IOT system with grid and battery charging terminal.

Stage 5: Final testing and monitoring.

1.6 Report Outline

The thesis is structured into five chapters, aligning with the objectives and outlines of the study. The chapters are organized as follows:

Chapter 1 introduces our project, outlining its main components, objectives, and the scope of the work. It sets the context for the entire thesis and establishes the foundation for the subsequent chapters.

Chapter 2 focuses on conducting a comprehensive review of existing literature and research related to our project. We analyze previous studies and identify key findings, gaps in knowledge, and areas that require further investigation. The literature review serves as a basis for understanding the current state of research in our field and informs our approach.

Chapter 3 of the thesis focuses on providing detailed information about the electronic modules used in the project. It includes an extensive description of each module, along with their specifications and capabilities. This chapter serves as a foundation for understanding the hardware components employed in the project, ensuring clarity on their roles and functionalities.

Chapter 4 dives into the circuit design aspect of the project. It discusses the schematic diagrams and circuitry of the modules, highlighting the connections and interactions between them. The chapter also covers the rigorous hardware testing conducted to validate the functionality and performance of the circuits. Detailed results and observations obtained from the testing process are presented, offering insights into the effectiveness of the implemented circuits.

Chapter 5 explores the integration of IoT technology into the project. It elaborates on the creation of channels on the Thing Speak platform for data transmission and monitoring. Additionally, the chapter includes the circuit designs and hardware results related to the modules responsible for sending data to Thing Speak. Furthermore, the integration of MIT App Inventor is discussed, highlighting its role in enabling remote monitoring and control.

Chapter 6 focuses on the development and integration of the prototype. It encompasses the physical construction of the charging terminal system, incorporating the circuits and modules. The chapter details the step-by-step process of assembling the prototype, ensuring proper integration and functionality of the components.

Chapter 7 concludes the thesis by summarizing the key findings and contributions of the project. It reflects on the achieved objectives and discusses the overall success of the charging terminal system. Furthermore, future recommendations are provided, highlighting potential areas of improvement, and suggesting avenues for further research and development in the field.

References: At the end of the report, a comprehensive list of the sources cited throughout the thesis is provided, ensuring proper acknowledgment and citation of the relevant literature.

Annexure A: Code Listings. This section contains all the codes used in the project, providing a comprehensive reference for the implementation of various functionalities. It serves as a valuable resource for understanding and replicating the software implementation.

Chapter 2
Literature Review

In this chapter, we provide a comprehensive review of the relevant literature and previous work related to our project. We begin by establishing the background of our project, providing necessary context and outlining the key concepts and factors that influence our research. We then explore existing studies, research papers, and projects that are closely related to our topic, highlighting their methodologies, findings, and contributions. We also discuss how our project contributes to the existing body of knowledge, identifying the unique aspects and advancements we bring to the field. Finally, we summarize the main points covered in this chapter, setting the stage for the subsequent chapters that delve into the design, implementation, and evaluation of our project.

2.1 Background of Project

Transportation is a critical sector that contributes significantly to carbon dioxide emissions and environmental pollution. More than 35% of the carbon dioxide emissions are from transportation sector. The increasing awareness of climate change and the need to reduce greenhouse gas emissions have driven the global shift towards electric vehicles (EVs). As a cleaner and more sustainable mode of transportation, EVs offer significant advantages in terms of reducing carbon emissions and dependence on fossil fuels.

Pakistan, like many other countries, faces the challenge of transitioning its transportation sector to more sustainable alternatives. The country's electricity production is predominantly reliant on non-renewable sources such as coal, oil, and biomass. This dependency on fossil fuels for power generation raises concerns about the environmental impact and sustainability of EV charging infrastructure.

To address these challenges and promote a greener transportation ecosystem, the integration of renewable energy sources in EV charging systems has gained prominence. Solar energy has emerged as a promising solution due to its abundance, accessibility, and environmental benefits. Solar-powered charging stations offer a sustainable and cost-effective method of charging EVs while reducing carbon emissions and reliance on non-renewable energy sources.

As solar power varies based on factors such as weather conditions and time of day, it is crucial to ensure a consistent power supply for the charging terminal. To address this, our system incorporates a backup power source from the grid (WAPDA) to charge the reservoir battery when solar energy is insufficient. By continuously monitoring the real-time solar power output, we can intelligently switch to grid power when the solar power falls below a predefined threshold. This dynamic power management strategy ensures that the reservoir battery remains sufficiently charged, providing a reliable and uninterrupted power supply for the charging terminal. By seamlessly transitioning between solar and grid power sources, we can optimize the use of renewable energy while ensuring a consistent and dependable charging experience.

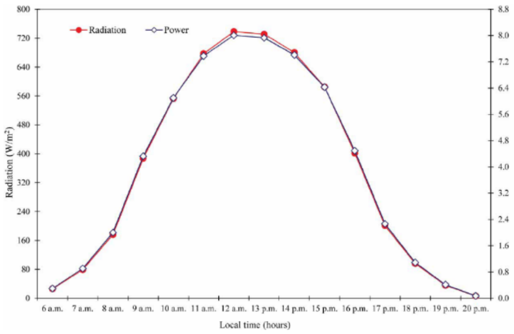


Figure 2.1: Solar radiation variation with time

In addition to the environmental benefits, the project also addresses the rising demand for EV charging infrastructure. As the adoption of EVs increases, there is a growing need for a robust and accessible charging network. The hybrid charging terminal provides a scalable and sustainable solution that can cater to the evolving needs of EV owners.

Furthermore, the integration of advanced technologies such as Internet of Things (IoT) enables remote monitoring, control, and data exchange, enhancing the functionality and efficiency of the charging system. Real-time monitoring of charging status, power consumption, and system alerts can be achieved, ensuring optimal performance and user convenience.

Overall, this project aims to contribute to the sustainable development of transportation infrastructure in Pakistan by promoting the adoption of EVs and the integration of solar energy in charging systems. The successful implementation of the hybrid charging terminal will pave the way for a cleaner and more environmentally friendly transportation sector, reducing carbon emissions and fostering a low-carbon future.

2.2 Related Work/Projects

Numerous research studies and projects have been conducted worldwide to explore and implement solar-powered charging infrastructure for electric vehicles. These initiatives have provided valuable insights and knowledge that inform the development and design of the hybrid charging terminal in this project.

2.2.1 Solar Electric Vehicle Charging Station (SEVCS) Project

One notable example of related work is the Solar Electric Vehicle Charging Station (SEVCS) project carried out in California, The SEVCS project, conducted in California, USA, aimed to demonstrate the technical feasibility and economic viability of solar-powered EV charging stations. It evaluated the performance and efficiency of solar panels, battery storage systems, and charging infrastructure, providing valuable data on energy generation, storage, and consumption. The project findings highlighted the potential of solar energy in meeting EV charging demands and reducing reliance on the grid.

2.2.2 EU-SOLARIS Project

The EU-SOLARIS project focused on the development and deployment of solar charging stations across several countries in Europe. It aimed to evaluate the environmental and economic impacts of solar charging infrastructure, as well as the user experience and acceptance. The project outcomes provided insights into the operational challenges, cost-effectiveness, and integration of solar charging stations into existing transportation networks.

2.2.3 Solar Electric Charging Stations for Electric Vehicles (SECS4EV) Initiative

Research conducted in India explored the implementation of solar-powered charging infrastructure in urban settings. Projects like the SECS4EV initiative demonstrated the feasibility and benefits of solar energy integration for EV charging. The research highlighted the importance of system design, battery storage capacity, and smart grid integration for optimal performance and efficient energy management.

2.2.4 Modeling and Control of a Hybrid Renewable Energy-Based EV Charging Station

In a study by R. Mahometh [11], a hybrid renewable energy-based EV charging station model is discussed. The charging station integrates a solar power generation unit, wind turbine, and fuel cell, enabling efficient charging of multiple electric vehicles. A control method is proposed that combines PV, wind, and fuel cell technologies to balance power distribution among different charging ports. The system includes three input ports and three output ports, accommodating electric cars, electric bikes, and electric autos. By incorporating multiple renewable energy sources, the charging station reduces the burden on the electrical grid and can export excess energy. This research contributes to the development of hybrid charging solutions and highlights the benefits of integrating renewable energy sources in EV charging infrastructure.

2.2.5 Fast Charging Technique for Electric Vehicles Powered by Renewable Energy Sources: A Decentralized Approach

In the study conducted by Lucas Richard and Marc Petit [2], a fast-charging technique for electric vehicles (EVs) powered by renewable energy sources was proposed. The charging system design included a solar power generation unit, an energy storing unit, and an interconnection to the local grid. Notably, the system utilized a decentralized control system. This fast-charging station operated primarily as a stand-alone system, relying on renewable energy sources. However, it could also receive occasional support from the local grid when required. The objective of this design approach was to enhance the efficiency and reliability of the EV charging process while utilizing renewable energy sources.

2.2.6 Optimized Design and Control of a DC Microgrid Charging Station

In their paper [1], Hamidi A, Weber L, and Nasiri A present a comprehensive study on the design and control of a DC microgrid charging station. The charging station incorporates bulk storage Li-Ion batteries and integrates renewable energy sources, including wind energy and solar energy. The paper focuses on proposing an optimized control logic method to maximize power absorption from the Distributed Energy Resources (DERs) available. By efficiently utilizing renewable energy sources and effectively managing the charging process within the microgrid, this approach ensures optimal utilization of resources and enhances the overall performance of the charging station.

2.2.7 Stand-alone PV Charging Station with Energy Storage for EVs

In paper [3], Mohamed Ahmed Mohamed introduces a charging station design that utilizes a stand-alone photovoltaic (PV) system with an energy storage system for charging electric vehicle (EV) batteries. The study incorporates an MPPT (Maximum Power Point Tracking) controller with an Incremental Conductance algorithm to optimize power extraction from the PV system, ensuring efficient charging. Additionally, the paper models and simulates the charge and discharge stages using a bidirectional converter for battery energy storage. A logic controller for the bidirectional converter is designed and simulated, demonstrating its effectiveness in conjunction with the bidirectional converter. The results highlight the successful integration of the PV system, energy storage, and bidirectional converter for reliable EV charging.

2.2.8 Design of an Integrated EV Charging Station with Solar Power and Battery Energy Storage System for Optimal Power Management

In their paper [12], T.S. Biya and Dr. M.R. Sindhu propose an innovative approach for charging electric vehicles (EVs) by integrating a Battery Energy Storage System (BESS) with solar power. The authors design an integrated electric vehicle charging station that ensures continuous power supply while minimizing the strain on the grid. The charging station incorporates an efficient design, utilizing Maximum Power Point Tracking (MPPT), Proportional-Integral-Derivative (PID) control, and current control strategies. These strategies enable optimal power management between the solar panels, BESS, grid, and EVs within the charging station. The primary objective is to maximize the utilization of renewable energy sources while ensuring reliable and efficient charging for electric vehicles, contributing to sustainable transportation.

2.2.9 Hybrid Charging Station for Electric Vehicles: Integration of Solar Power and Grid with Advanced Boost Converter for Efficient Power Management

In paper [13], Soham Bhadra and Snehasis Debnath propose a hybrid charging station model for electric vehicles (EVs) that combines the utilization of solar power and the grid. The system design employs solar arrays to directly charge EVs when solar energy is available, seamlessly switching to grid power when solar energy is not accessible. Moreover, the system facilitates the delivery of excess solar power back to the grid when no EV is connected to the charging system. A notable advancement introduced in the study is the implementation of an advanced high-gain boost converter instead of traditional transformers, resulting in a significant reduction in both system cost and size. While the hardware implementation of this hybrid charging scheme remains a future work, the authors present promising prospects for its practical application.

2.2.10 Hybrid Energy Storage System Integration for Efficient and Reliable Electric Vehicle Charging

In paper [14], Dr. T. Porselvi, Nisha J, and Thendral present an efficient power supply solution for electric vehicle (EV) charging systems. The study highlights the importance of battery, solar PV source, and supercapacitors in achieving extended power supply and high reliability. The battery serves as the main power source, while the supercapacitor assists during transient phases such as overloading and starting. To enhance the charging and discharging characteristics of the battery and increase instantaneous output power, a Hybrid Energy Storage System (HESS) comprising the supercapacitor and battery is widely employed. Initially, power from the PV array is utilized to charge both the supercapacitor and battery. In situations where the PV array cannot supply sufficient power for EV charging, the power stored in the battery and supercapacitor can be utilized. This approach ensures efficient and reliable power supply for charging EVs.

2.2.11 Efficient and Reliable Solar PV-Battery-Diesel Hybrid Charging System with Microgrid Integration

In the cited paper [15], V. Prasanna Moorthy discusses the integration of microgrids in the project. Microgrids have emerged as a viable solution for providing electricity to isolated locations, such as islands and villages, by utilizing distributed power sources. The proposed microgrid structure in the study focuses on efficient operation and fast response through the analysis of hybrid power systems and the implementation of fuzzy-PI-based control techniques. The project specifically aims to design a hybrid power system based on solar photovoltaic (PV), battery, and diesel generator. The battery serves as a storage component that can be charged by the PV source. In situations where the battery is depleted and PV generation is unavailable, the charging station can rely on the grid and a diesel generator for power supply.

2.2.12 Solar-Powered EV Charging Station: Maximizing Solar Energy Utilization and Cloud-Based Monitoring for Sustainable Mobility

In the referenced paper [16], A. Gayathri presents a Solar Based Charging Station for Electric Vehicles. The charging station utilizes multiple-axis solar panels to maximize the power derived from solar energy, effectively reducing the dependency on grid power and conserving nonrenewable energy sources. Furthermore, the power generated by the solar panels and the power consumption of the charging station are monitored and tracked through a cloud server. This enables real-time monitoring of the charging station's performance and facilitates efficient utilization of renewable energy resources.

2.2.13 Optimized Charging Strategy for Grid-Connected Electric Vehicle Charging Stations

In paper [17], Bacha Seddik presents a charging strategy that utilizes binary and linear programming to effectively manage the charging plan of vehicles. The proposed model has the potential to reduce costs by up to 60% compared to systems without proper management. The charging station, which is grid-connected, divides the charging time into intervals to minimize peak consumption. The study draws insights from related works, providing a foundation for the development and implementation of a hybrid charging terminal in this project. By analyzing the successes, challenges, and lessons learned from previous initiatives, this project aims to build upon existing knowledge and contribute to the advancement of solar-powered EV charging infrastructure.

2.3 Project Contribution

Solar based hybrid charging terminal for electric vehicles with automatic control through iot is an innovative solution for charging electric vehicles. One potential contribution to this project is to optimize the energy management system for charging terminals. By using advanced algorithms, the power output of solar panels, the battery storage capacity and the demand from electric vehicle battery. By analyzing these factors, the charging terminal automatically adjusts the charging rate to ensure efficient use of the available energy.

Another contribution is that our project is hybrid as we are using two sources to charge the battery one from solar energy and another from main grid so by using advanced techniques /coding in case no solar power available the battery charging will switch to main Wapda to ensure uninterrupted charging of car's battery.

Another significant contribution of our project is the implementation of an Internet of Things (IoT) system to enhance the functionality and monitoring capabilities of the charging terminal. The IoT system allows for real-time communication and data exchange between the microgrid, charging terminal, and a central control unit. This enables remote monitoring and control of the charging process, providing information on the charging status, power consumption, and system alerts or notifications. Our project demonstrates the practical application of IoT technology in the context of solar-powered EV charging infrastructure.

By using renewable energy source and advanced Iot technology this system could provide a sustainable and convenient charging solution for electric vehicle.

Chapter 3
Electronic Modules

In this chapter, a detailed analysis is presented on the various electronic modules utilized in the project. The chapter delves into the functionalities and specifications of each module, including the Arduino board, voltage, and current sensors, NodeMCU board, GSM module, RTC module, and the 16x2 LCD display. The purpose of this chapter is to provide an in-depth understanding of the components and their roles in the charging terminal system.

3.1 Electronic modules

3.1.1 Solar panel

Solar panels, also known as photovoltaic (PV) panels, are devices that convert sunlight into electrical energy. They are a key component of solar power systems and play a crucial role in harnessing renewable energy from the sun. Solar panels create power without producing greenhouse gases or other hazardous pollutants, making them a clean and renewable energy source. They have a lengthy lifespan (usually 25 to 30 years) and require little upkeep. Furthermore, solar energy is abundant and widely available in most areas, making solar panels a feasible alternative for generating electricity globally. In our project we are using the solar panel as a source for the microgrid and so to charge the reservoir battery as the output of the solar panel is pure dc. In our project we used solar panels as it contributes to reduce dependence on fossil fuels, mitigating climate change, and promoting sustainability. The solar panel that we used is 150 Watt monocrystalline. Monocrystalline solar panels consist of solar cells made from single crystals of silicon, whereas polycrystalline panels are formed by melting multiple silicon solar cells together. Monocrystalline modules typically exhibit an efficiency of 19%. Under favorable environmental conditions, a 150-watt monocrystalline solar panel can generate a current of approximately 7 to 7.5 amps and a voltage range of 18 to 20 volts.

Figure 3.1: 150 W solar panel

3.1.2 MPPT Controller

Maximizing the power output of solar panels is crucial for efficient operation, and this is achieved using an MPPT (Maximum Power Point Tracking) charge controller. In our project, we have implemented an MPPT controller due to its ability to optimize the performance of solar panels. Unlike the linear characteristics of solar panels, the output power varies based on factors such as irradiance, temperature, and weather conditions. The MPPT controller, employing algorithms like the perturb and observe algorithm, continuously monitors the voltage and current of the solar panel and adjusts the load or output voltage to maintain the maximum power point (MPP). This approach ensures that the solar panel operates at its highest power output, resulting in increased energy production, improved system efficiency, and faster battery charging. The MPPT controller used in our project has a rated voltage of 12/24V, a rated current of 40A, and a maximum PV voltage of 50V.

Figure 3.2: MPPT solar charge controller

3.1.3 Battery

In our project we are using the battery as the reservoir battery for storage capabilities. Battery storage for the charging station is used to store electrical energy during periods of low demand or surplus generation and discharge it during periods of high demand or when renewable energy source such as solar energy is not available. So, the battery serve to balance electrical supply and demand, delivering a consistent and reliable power source for electric vehicles (EVs). So, in this way battery can be charged during off-peak hours when electricity demand is low and energy prices are typically more economical. This stored energy can then be utilized during peak hours when the demand for charging EVs is higher. By utilizing stored energy, charging stations can avoid strain on the electrical grid and reduce peak demand charges. We are using the DRY battery as reservoir battery. Dry batteries are called so because they do not contain free-flowing liquid electrolytes like their counterparts, such as wet-cell batteries. Instead, they use a solid or gel electrolyte that is immobilized within the battery. This design allows for easy handling, portability, and eliminates the risk of leakage. The battery that we used is 12 V and 12 Ah so overall the battery is 144 Watt.

Figure 3.3: 12 Ah battery

3.1.4 Transformer

A transformer is an electrical device that transfers energy between circuits through electromagnetic induction. It consists of primary and secondary coils that enable voltage conversion. Widely used in power systems and electrical devices, transformers play a crucial role in efficient energy transfer. In our project we are using the step-down transformer because we are charging our reservoir battery with two sources, one from solar energy and the other is the energy from the grid.

As the energy from the grid is 220_230V so we must step it down to charge our battery. So we are using the step down shell type transformer that steps down 230V to 12V.

3.1.5 Rectifier

A rectifier is a type of converter that converts the AC into DC. In our project we are using the rectifier circuit because we are using grid energy and it is in the form of AC. As we must charge the battery with the DC so we must convert the AC output of the grid into DC with the help of the rectifier circuit so that we can charge the battery from the power grid. We are using a rectifier circuit that can bear up to 24A of current by connecting the power diode in such manner. Also we have used the capacitor for filtering purposes so that we can get a better version of the dc output to charge our battery.

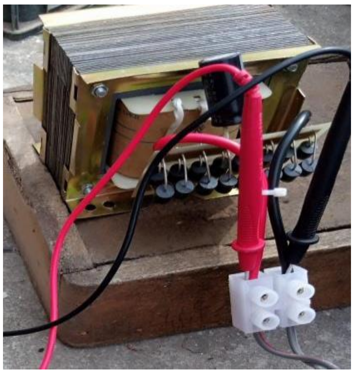


Figure 3.4: Rectifier

3.1.6 Current sensor

In our project we are using the ACS712 current sensor. The ACS712 utilizes the Hall effect principle to measure current. Inside the sensor, a conductive path is formed to allow the current flow to be measured. When an electric current passes through this path, a magnetic field is generated perpendicular to the current flow. This magnetic field can be sensed by a Hall-effect sensor integrated into the ACS712. It can measure both direct current and alternating current. We are using a current sensor to measure the current flowing through the reservoir battery. This will let us know the power status of reservoir battery. Also, we are using a current sensor in the connector of our charging terminal to++ let us know the power status of the incoming car battery. This would help us to avoid the backflow from the incoming car battery to reservoir battery in case when the power of the incoming car battery is greater than the reservoir battery a message would be sent to the owner so that the owner can act accordingly. Also, we used one current sensor with the solar panel and one with the rectifier this is to know the power status of both so that the source selection to charge our reservoir battery can happened accordingly with the condition. So overall we have used 4 current sensors.

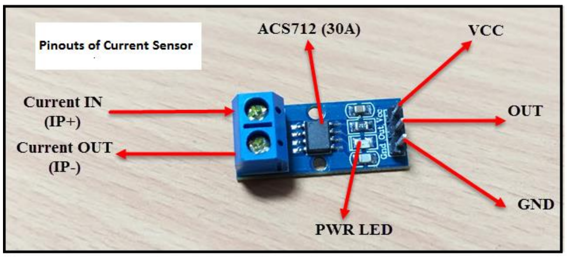


Figure 3.5: Current sensor pinout

3.1.7 Voltage sensor

A voltage sensor, also known as a voltage detector or voltage sensor module, is an electronic device used to measure and detect the presence or level of voltage in an electrical circuit. In our project, we utilized a resistive voltage divider as the voltage sensor. The resistive voltage divider consists of a series of resistors connected in a specific ratio to divide the input voltage. By measuring the output voltage across a specific resistor in the divider circuit, we can determine the proportional value of the input voltage. The voltage sensor module we employed is designed to work with Arduino or any other microcontroller that can tolerate input voltages up to 5V. This module allows us to measure external voltages that exceed the maximum acceptable value of the microcontroller, which is typically 5V for Arduino. The voltage sensor we used is capable of measuring voltages up to 25V. We incorporated a total of four voltage sensors in our project. One sensor is used to measure the voltage of the reservoir battery. The second sensor is employed to measure the voltage of the incoming car battery by connecting it to the charging terminal. This enables us to determine the charging level of both batteries, facilitating intelligent ON/OFF switching. The third sensor is utilized with the solar panel, while the fourth sensor is connected to the rectifier. These sensors provide us with information about the voltage levels of both power sources, enabling us to select the optimal source based on the prevailing conditions for charging our reservoir battery.

Figure 3.6: voltage sensor

3.1.8 Intelligent switch

The intelligent switch in our project is a 5V relay module. A relay is an electromechanical device that allows an electrical circuit to be controlled by a separate low-power signal. When combined with an Arduino microcontroller, relays provide a convenient way to interface with high-power or high-voltage devices using the Arduino's low-voltage outputs. It has a maximum current rating of 10A at 250VAC or 30VDC.The relay module has three terminals:

- COM

- Normally open (NO)
- Normally close (NC)

Table 3.1: The status of relay is indicated through LED

Sr. No	Pin Name	Function
1	COM	Common pin / Ground
2	Normally open (NO)	The relay module is an electrically operated switch that permits close up and switch ON a circuit.
3	Normally close (NC)	The relay is generally closed until Arduino sends a signal to relay to open the circuit.

In our project the relay relates to the Arduino to make it intelligent for switching. The relay is connected between the reservoir battery and the source battery so the switching is according to the condition that whenever the reservoir battery power is less than the incoming car battery power so as the relay is connected with the Arduino and we have write the code for this condition so the Arduino would send a message with the help of GSM module and the owner would switch off the connection between the reservoir battery and incoming car battery with the help of the app that is installed in the cellphone of the owner. So this intelligent switch would help to avoid the backflow from the incoming car battery to the reservoir battery. Also the second condition is we have set a threshold voltage level and when the reservoir battery is less than that threshold so in that condition also a message would be send to the owner and the owner can switch off the relay to charge the incoming car battery.

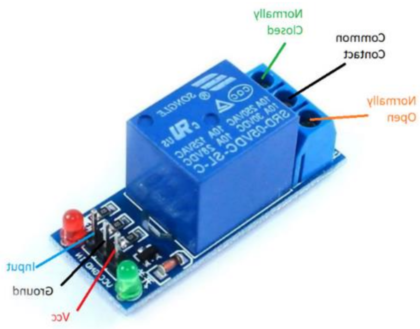


Figure 3.7: Relay module

3.1.9 16X2 LCD display

LCD (Liquid Crystal Display) screen is an electronic display module. In an LCD, pixels are electronically turned on or off by the use of fluid to rotate the polarized light. We are using 16x2 LCD in our project. There are two lines of a 16x2 LCD that can display 16 characters each. The LCD display we are using is the display of the charging terminal it shows the reservoir battery current, voltage and power and it also display the incoming car battery current, voltage and power. So, whenever a customer came to the charging station to charge his electric vehicle so the LCD would display all the information and in this way the customer would know that what is the charging status of his car and further how much charging is needed to fully charged the car battery.

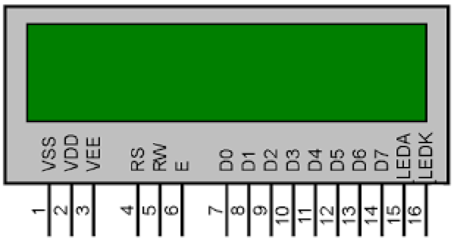


Figure 3.8: 16x2 LCD Display

3.1.10 GSM SIM 900A Module

The GSM SIM 900A module is a widely used communication module that allows devices to connect to the GSM (Global System for Mobile Communications) network. It provides a convenient and efficient way for devices to communicate over cellular networks. The module supports voice calls, SMS (Short Message Service), and GPRS (General Packet Radio Service) data transmission. The SIM 900A module is typically designed as a small-sized module with multiple pins for interfacing with other electronic devices. It uses standard serial communication to establish a connection with the host device, allowing easy integration into various applications. The GSM module that we used is 2G. We use the GSM module because in case the reservoir battery is not enough and to avoid the backflow a message should be sent to the owner. We have written certain types of codes on Arduino so as the GSM module is interfaced with Arduino so when one of these conditions happened an alert message would be sent to the owner and the owner with the help of an app would take action.

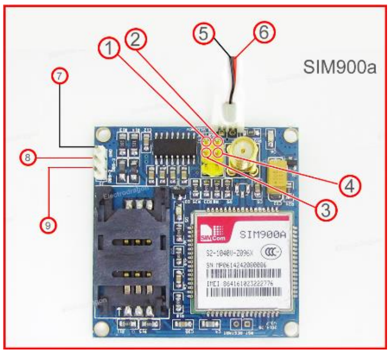


Figure 3.9: GSM SIM 900A module

3.1.11 NodeMCU ESP8266 Module

The NodeMCU ESP8266 module is a powerful development board that combines Wi-Fi connectivity with a microcontroller. It provides an affordable and accessible platform for building IoT projects, prototyping, and exploring the possibilities of connected devices. One of the main advantages of the NodeMCU ESP8266 module is its built-in Wi-Fi capability. It can connect to wireless networks, communicate with web servers, and send/receive data over the internet. This feature renders it well-suited for IoT projects that necessitate remote monitoring, control, or data exchange. Given that our project is IoT-based, it enables seamless communication between devices and humans, as well as interconnectivity among various devices. So in order to make our project IOT based there should be internet connection so the information of the embedded system is send to the IOT platform so for this we use the NodeMcu ESP8266 module which is best module for wireless internet connection with the help of which all the informative data from Arduino is send to the ThingSpeak after which the data is analyzed and an action is taken by the owner with the help of the app.

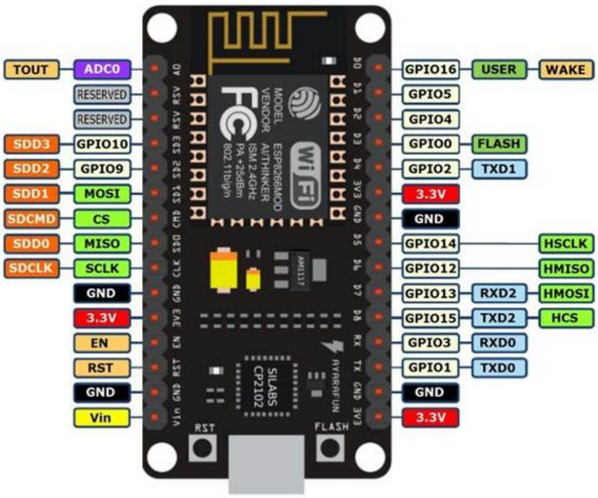


Figure 3.10: NodeMCU ESP8266 module

3.1.12 DS3231 Real-Time Clock Module

The DS3231 real-time clock module is a reliable and accurate timekeeping solution with additional calendar and alarm functions. Its precise timekeeping capabilities, I2C interface, and low power consumption make it a popular choice for a wide range of electronic projects and devices that require accurate timekeeping. The DS3231 module provides accurate timekeeping in hours, minutes, seconds, and even fractions of a second. It supports both 24-hour and 12-hour formats.

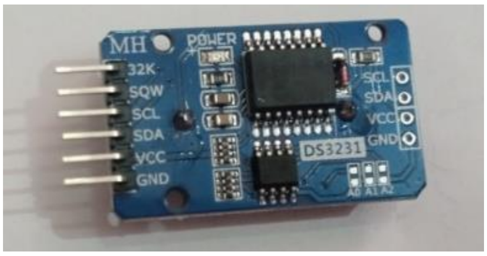


Figure 3.11: Real - time clock module

3.1.13 Arduino Mega 2560

The Arduino Mega 2560, also known as ATMEGA 2560, is a microcontroller board that offers an expanded memory space in comparison to the Arduino Uno board. It features a total of 54 digital pins, with 15 of them designated for pulse width modulation (PWM) applications. Additionally, the board includes 16 input pins on the analog side. The key components of the Arduino Mega are as follows:

- 16MHz oscillator

- USB cable port
- Reset button.
- Voltage regulator
- Power jack indicator
- Power semiconductor diode

The Arduino Mega 2560 can be powered through both DC and AC supplies, using a battery or an adapter. It supports power supplies of 3V and 5V. In terms of memory, the Arduino Mega 2560 offers a generous memory capacity of 256KB. It has 8KB of SRAM (Static Random Access Memory) and 4KB of EEPROM (Electrically Erasable Programmable Read-Only Memory). The Arduino Mega 2560 is compatible with the Arduino software integrated development environment (IDE), which allows users to write and upload programs to the board and make necessary modifications.

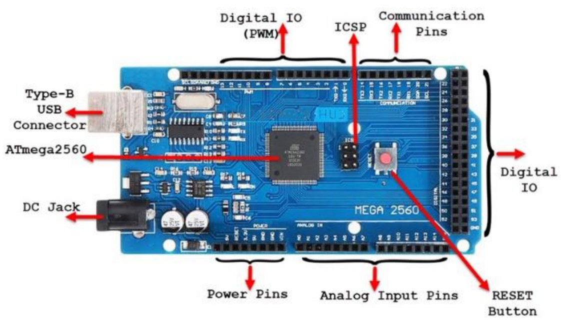


Figure 2.12: Arduino mega 2560 pinout

3.1.14 Jumper Wires and Connecting Wires

Jumper wires are versatile wires with connector pins at each end, enabling them to establish connections between two points without soldering. They are commonly used in conjunction with breadboards and other prototyping tools, making it convenient to modify and rearrange circuit connections during the design and testing process.

Figure 2.13: Jumper wires and connecting wires.

3.2 Software Used

3.2.1 Proteus

The Proteus Design Suite is a comprehensive software toolset that offers automation for electronic design. It is commonly utilized by technicians and engineers for schematic creation, circuit simulation, and generating prints for printed circuit boards (PCBs). The software consists of two main components: one for circuit design and the other for PCB design. The circuit design part allows users to create and design various circuits, while the PCB design component, known as ARES, is used for designing printed circuit boards. In our project, we employed the Proteus software to design circuits such as the rectifier and sensor connections. This allowed us to verify the feasibility of our circuit designs before proceeding with the hardware implementation.

3.2.2 ThingSpeak

ThingSpeak is a versatile open-source IoT platform designed to enable users to gather, analyze, and visualize data from connected devices. It serves as a comprehensive platform for IoT applications, allowing for the collection, storage, and processing of data originating from various sensors and devices. With its user-friendly interface and a wide array of tools and APIs, Thing Speak simplifies the process of data collection, analysis, and visualization. In our project, we utilize ThingSpeak as our IoT platform, connecting it with Arduino through an ESP8266 module. This setup allows us to transmit informative data from the Arduino to ThingSpeak, where it can be analyzed and subsequently forwarded to the designated application. The data includes voltage and current readings of both the reservoir battery and the incoming car battery, providing the necessary insights for informed decision-making by the system owner.

3.2.3 Arduino IDE

The Arduino IDE (Integrated Development Environment) is a versatile software tool specifically designed for programming and developing projects utilizing Arduino boards. It offers a user-friendly interface that simplifies the process of writing, compiling, and uploading code to Arduino microcontrollers. The IDE also features a built-in serial monitor, which allows users to establish communication with the Arduino board and receive real-time data through the serial port. In our project, where the Arduino serves as the main controller, we leverage the Arduino IDE to write different sets of code tailored to specific conditions. These codes are then uploaded to the Arduino, enabling it to execute the desired actions based on the given conditions.

3.2.4 MIT App Inventor

MIT App Inventor is a powerful and accessible platform that enables individuals to create mobile applications for Android devices without extensive programming knowledge. Its visual interface, real-time testing capabilities, and educational focus make it an excellent choice for beginners and educators interested in app development. MIT App Inventor is an open-source project, which means the source code and development tools are freely available to the public. This allows users to contribute to its development, customize it, and use it without any licensing restrictions.

Chapter 4

Electronic circuit diagram

In this chapter, we present the circuit diagrams and results of the implemented modules in our solar and WAPDA-based charging terminal for electric vehicles. We provide detailed circuit diagrams illustrating the interconnections between sensors, NodeMCU, GSM module, and Arduino. Each circuit is explained in terms of its purpose and functionality within the system. Additionally, we discuss the results obtained from each circuit implementation, highlighting the performance and successful integration of the components. The presented results validate the effectiveness of our system design and serve as empirical evidence for the functionality of the charging terminal. This chapter provides a comprehensive understanding of the hardware implementation and serves as a basis for further analysis and evaluation in subsequent sections.

4.1 Design and fabrication of AC to DC converter

In our project, we have incorporated a 220-volt AC to 15 V DC converter with a maximum current rating of 20 amps. This converter plays a crucial role in our charging terminal by converting the AC power from the main grid (WAPDA) into DC power suitable for charging the reservoir battery. With its high capacity, it can handle the power requirements of the charging system efficiently. This AC to DC converter ensures a reliable and stable power supply to the reservoir battery, enabling effective charging and maintenance of its optimal performance.

Simulation

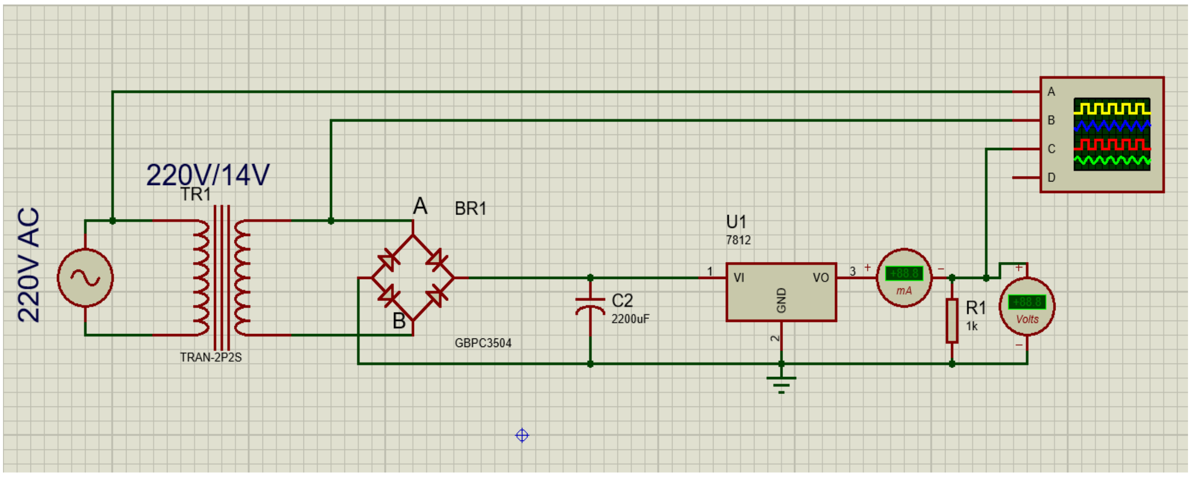


Figure 4.1: Schematic for rectifier

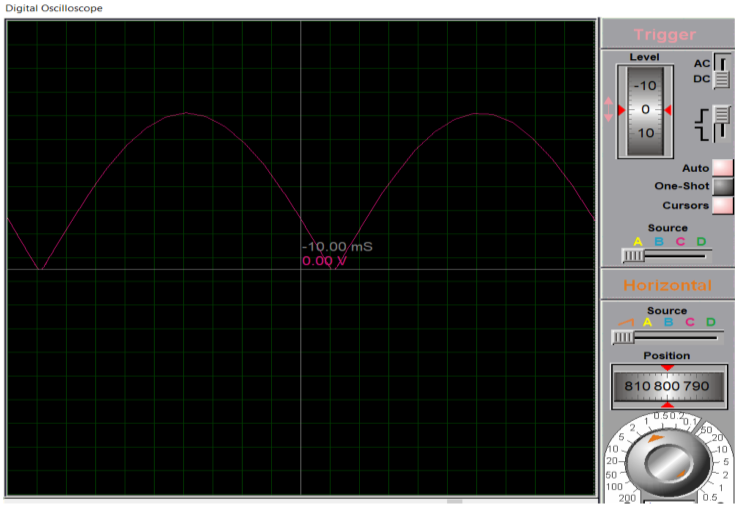


Figure 4.2: simulation result

PCB Layout

Figure 4.3: layout for rectifier

Hardware Testing and Results

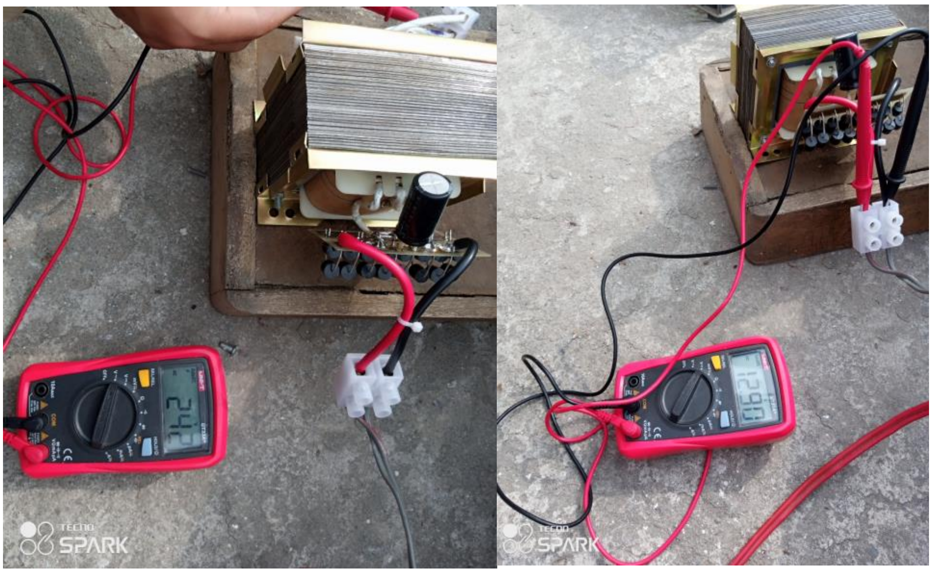


Figure 4.4: Hardware Testing of rectifier

4.2 Micro grid development

The micro grid system implemented in our project facilitates the charging of the reservoir battery through two primary power sources: solar energy and the grid (WAPDA). Solar power is harnessed using an MPPT solar charge controller, which optimizes the energy conversion process from the solar panels to maximize power output. In situations where solar power is insufficient, the system seamlessly switches to grid power. An AC to DC converter is employed to convert the AC power from the grid into DC power, ensuring efficient charging of the reservoir battery. This integrated approach ensures a reliable and continuous power supply for the charging terminal, enabling efficient charging of electric vehicles.

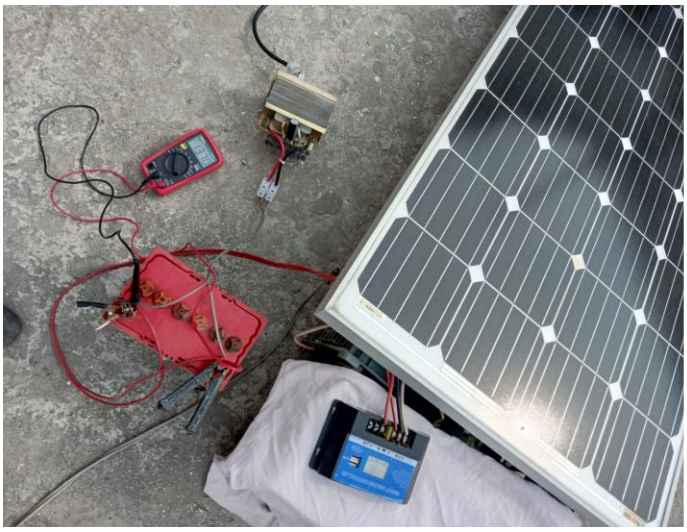


Figure 4.5: Micro-grid

4.3 Interfacing Current Sensor for Reservoir Battery with Arduino

In our project, we integrate the ACS712, a Hall effect-based current sensor, with the Arduino Mega. The ACS712 is capable of accurately measuring both direct current (DC) and alternating current (AC). We utilize the current sensor to measure the current flowing through the reservoir battery, providing us with essential information about the power status of the battery. Additionally, we employ the current sensor to measure the current of the incoming car battery, as well as the current of the PV (solar) system and the rectifier. By interfacing the ACS712 with the Arduino Mega, we enable precise current measurements across various components of our charging terminal, facilitating effective monitoring and control of the system.

Simulation

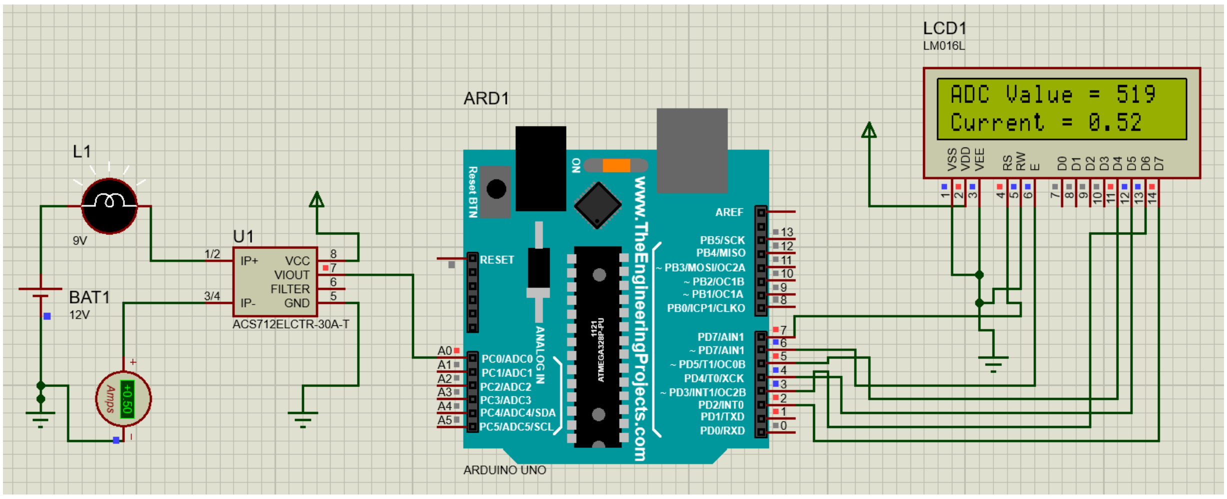


Figure 4.6: schematic of current sensor

Hardware Results and Testing

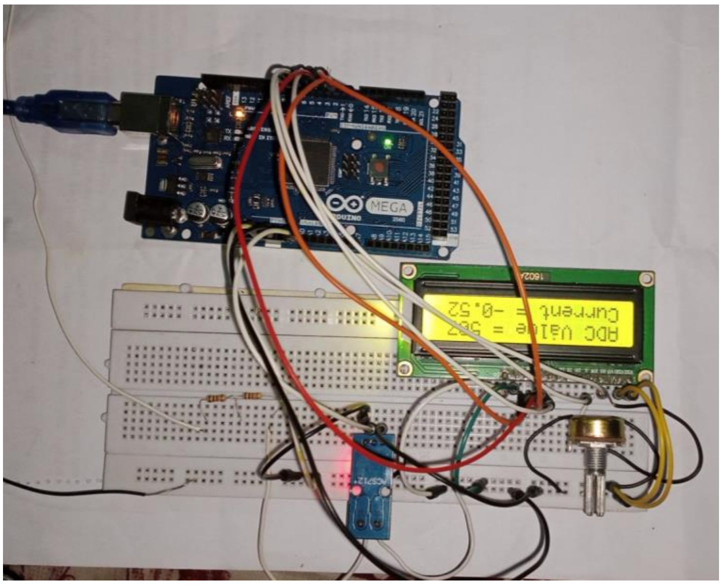


Figure 4.7: current sensor output

4.4 Interfacing voltage sensor with Arduino

The voltage sensor plays a crucial role in our project by enabling us to measure the voltage of various components, including the reservoir battery, incoming car battery, PV (solar panel), and rectifier. By obtaining voltage measurements, we can calculate the power associated with each source and make informed decisions regarding the charging process. For instance, we can compare the power generated by the PV system and the rectifier and select the appropriate source for charging the reservoir battery based on the higher power output. Additionally, monitoring the power of the reservoir battery allows us to assess its status and trigger alert messages in case of power shortages or when the incoming car's power exceeds that of the reservoir. The voltage sensor, in conjunction with other sensors and calculations, facilitates effective control and monitoring of the charging terminal's power flow and ensures efficient utilization of available energy resources.

Simulation

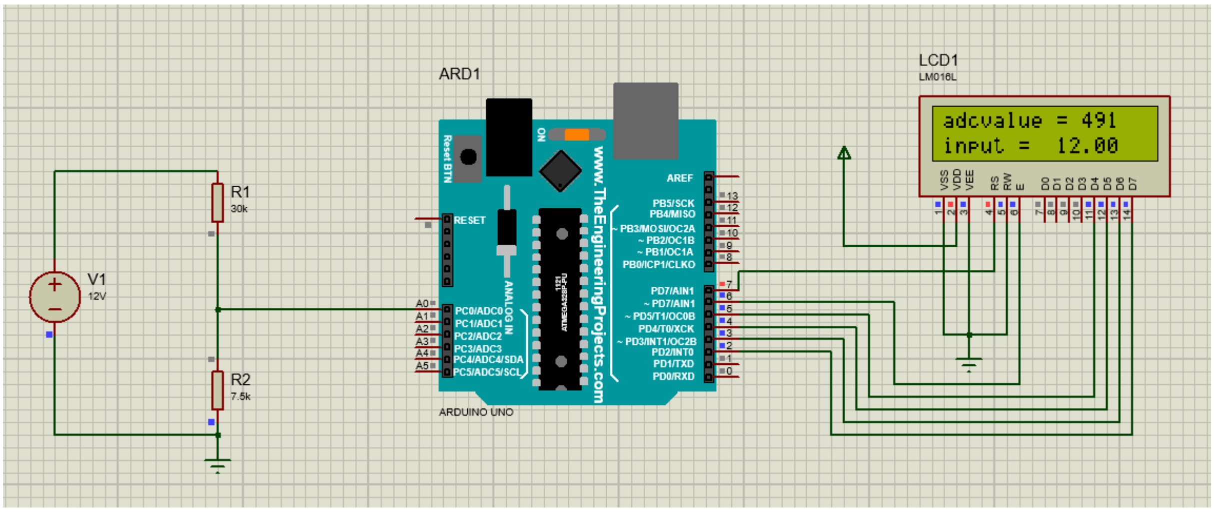


Figure 4.8: interfacing voltage sensor with Arduino

Testing

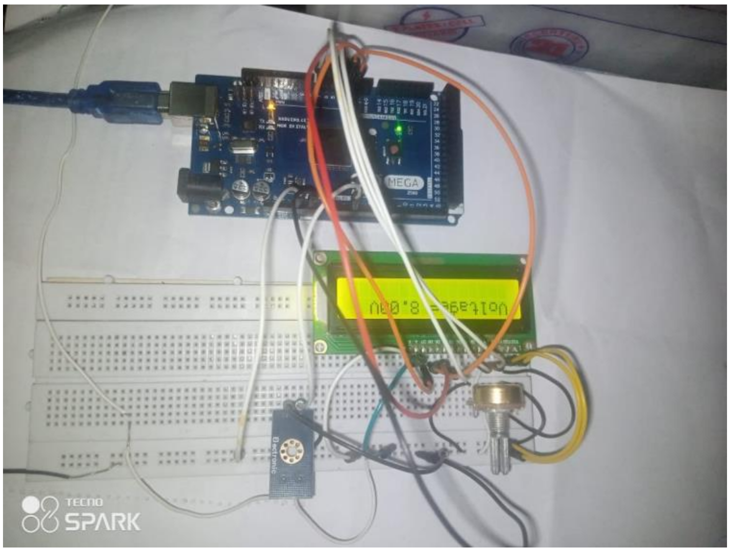


Figure 4.9: voltage sensor output

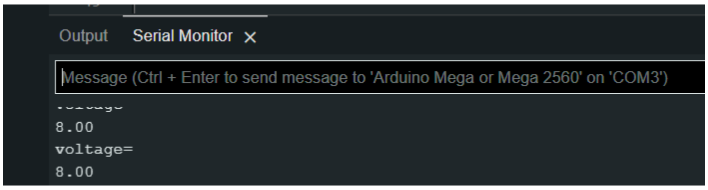


Figure 4.10: Serial monitor output

4.5 Sensing Alert SMS through GSM for Power Shortage and Backflow Detection

We have incorporated a GSM module to facilitate the sending of alert SMS messages when the power of the reservoir battery falls below a threshold value. Additionally, the GSM module also sends alert SMS messages when the power of the incoming car battery exceeds that of the reservoir battery. This functionality allows us to efficiently manage the charging process and ensure optimal power utilization in our system.

4.5.1 Reservoir battery is undercharge

In our project, we have implemented a power monitoring system to detect when the power level of the reservoir battery falls below a predefined threshold, indicating that it is undercharged. When a power shortage occurs, an alert message is sent to the owner through the GSM module, notifying them of the situation. In response, the charging of the incoming car battery from the reservoir battery is immediately stopped, and the entire charging terminal is switched off until the reservoir battery is recharged. This approach ensures the protection of the reservoir battery, prevents further power depletion, and avoids potential damage to the system. Once the reservoir battery is sufficiently recharged, the charging terminal can be safely restarted, enabling the resumption of the charging process for electric vehicle batteries.

Simulation

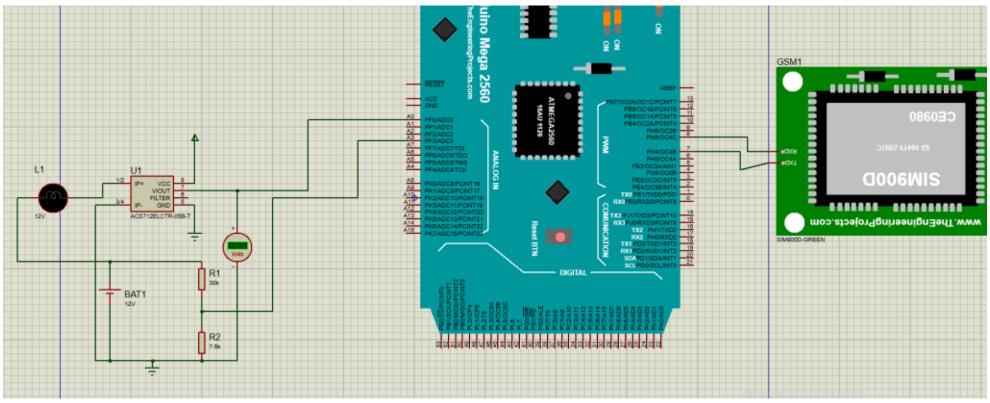


Figure 4.11: Sending alert SMS through GSM module when reservoir is undercharge

Testing

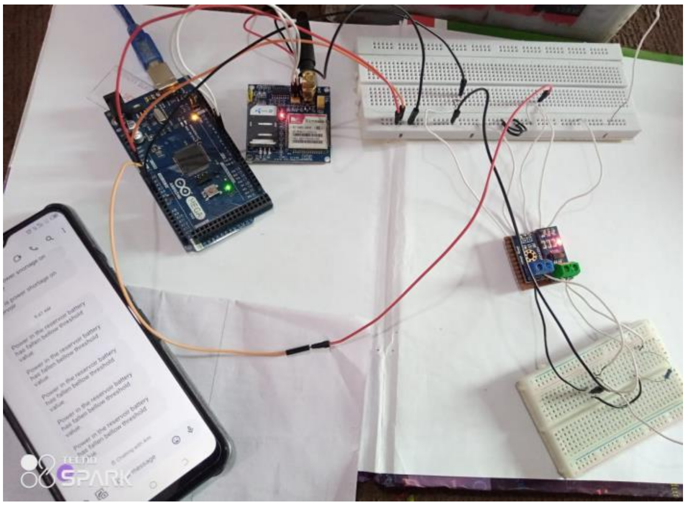


Figure 4.12: Hardware results and testing

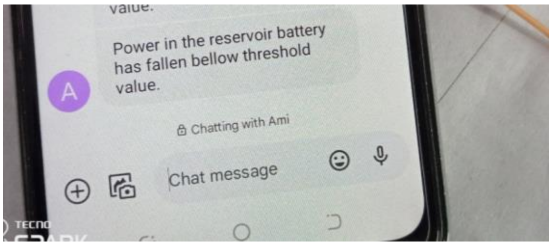
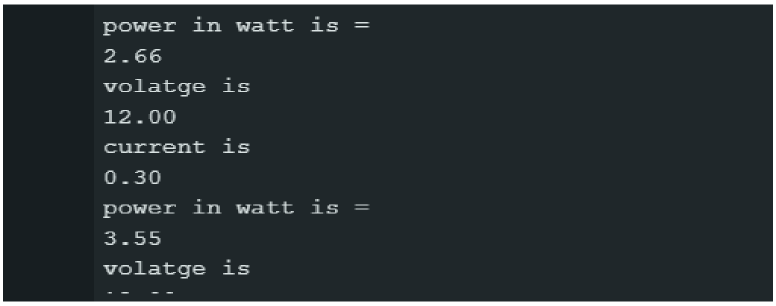


Figure 4.13: Alert SMS received by owner



```
power in watt is =
2.66
volatge is
12.00
current is
0.30
power in watt is =
3.55
volatge is
```

Figure 4.14: Serial monitor output

4.5.2 Power Backflow Protection

In our project, we have incorporated a GSM module to enable the reception of alert messages when the watt-hour value of the incoming car battery surpasses that of the reservoir battery. Upon receiving such an alert message, the charging process from the reservoir battery is promptly halted by deactivating the charging terminal. This ensures that the reservoir battery is not further depleted and prevents any potential damage to the system. By employing the GSM module and implementing this intelligent control mechanism, we ensure the optimal charging of electric vehicle batteries and maintain the overall efficiency and safety of the charging terminal.

Simulation

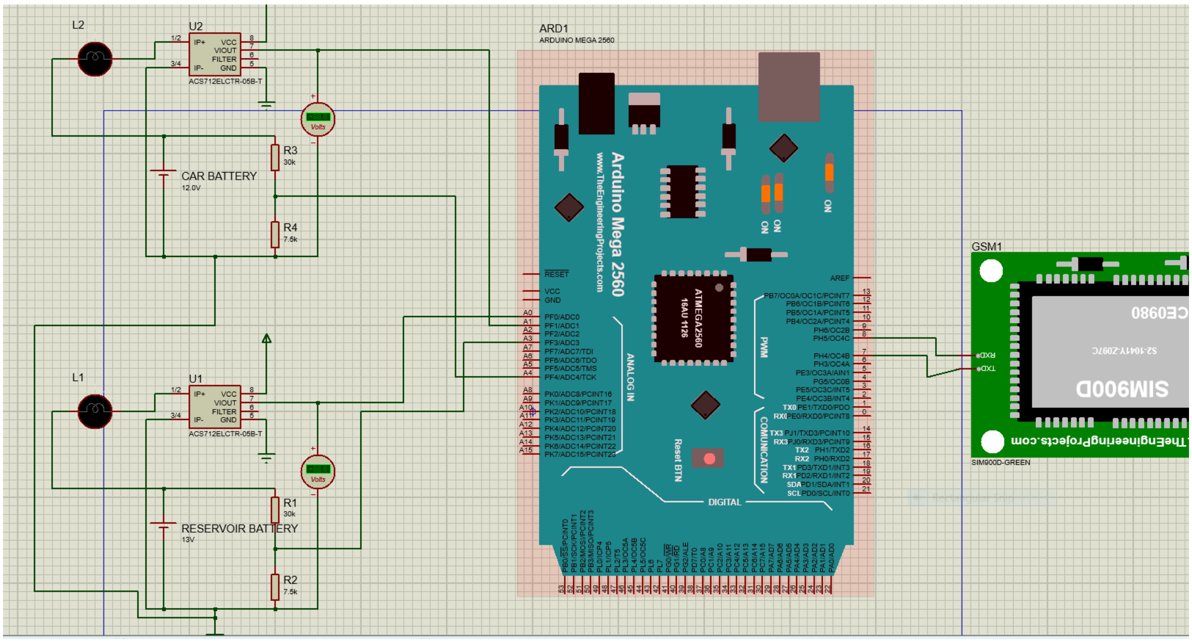


Figure 4.15: Schematic for power back flow protection

Testing

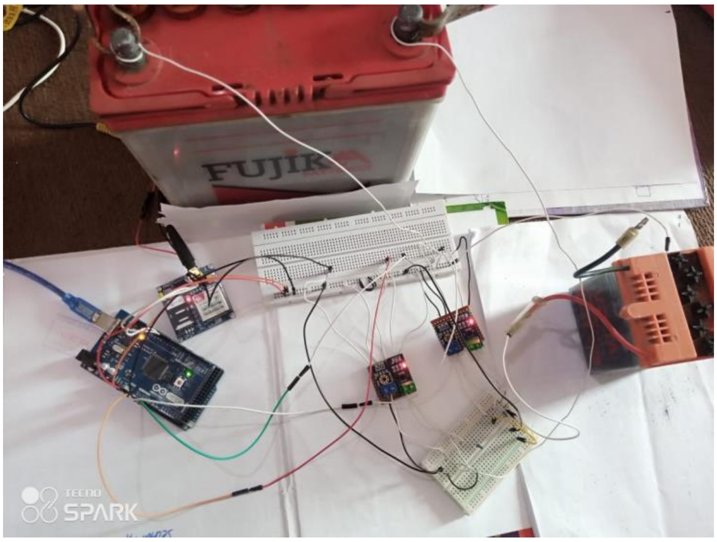


Figure 4.16: hardware integration and result

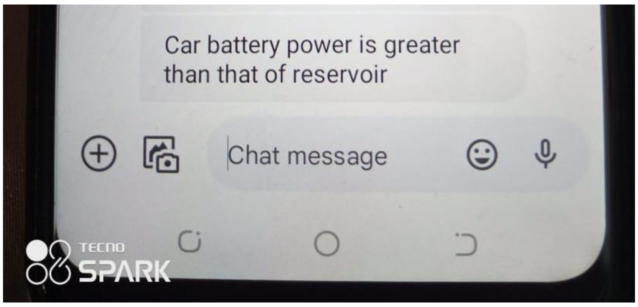


Figure 4.17: message received by owner.

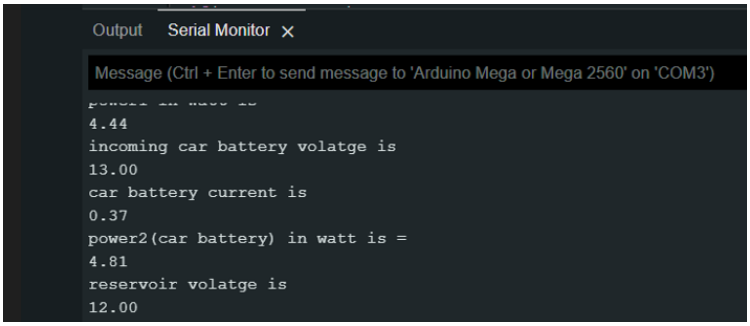


Figure 4.18: serial monitor output

4.6 Power Source Selection Strategy

To select between the two power sources, WAPDA (main grid) and PV (solar), for charging the reservoir battery in our hybrid charging terminal, we employ a smart power source selection strategy. During the daytime, we continuously monitor the voltage of the PV panel. If the PV voltage is above a predefined threshold, indicating sufficient solar power generation, we prioritize charging the reservoir battery using solar energy. However, if the PV voltage falls below the threshold, indicating insufficient solar power due to factors such as cloud cover, we automatically switch to the WAPDA as the power source. Before switching, we also check the availability of WAPDA power. If WAPDA power is not available, the entire charging terminal is turned off to prevent any disruption. During nighttime, when solar power is not available, the charging of the reservoir battery is solely dependent on the WAPDA power source. In the event that WAPDA power is not available during nighttime, the charging terminal is also turned off. This strategy ensures efficient and uninterrupted charging of the reservoir battery by utilizing the most suitable power source based on the time of day and availability of WAPDA power.

Simulation

Case1: On a cloudy day with the availability of WAPDA

During a cloudy day (7am – 6pm), if the solar power generated by the PV panel is insufficient, we automatically switch to WAPDA as the power source for charging the reservoir battery, ensuring uninterrupted charging.

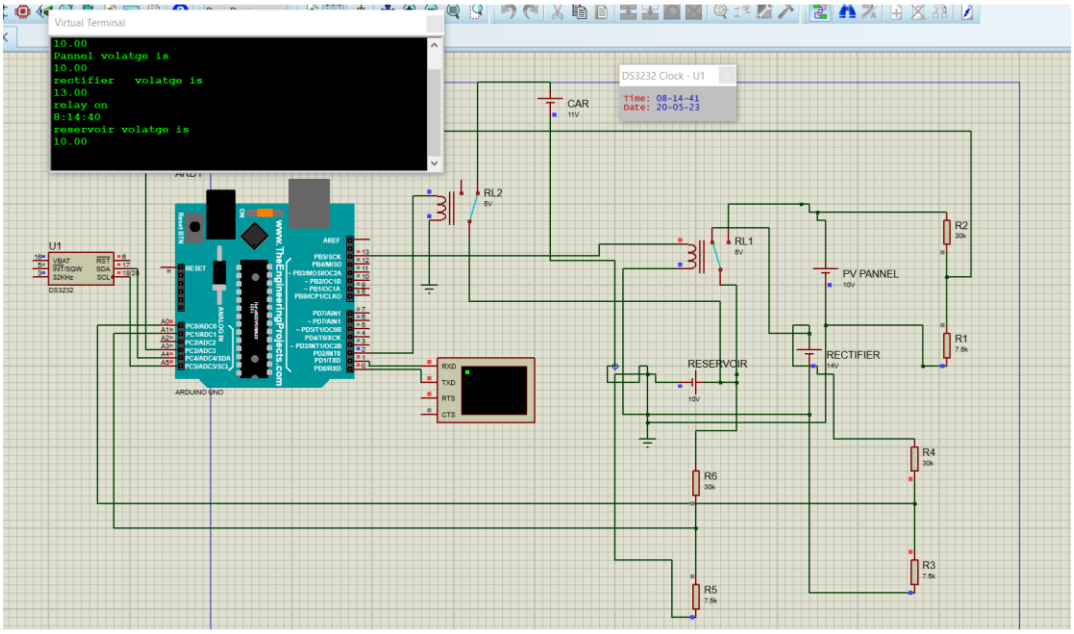


Figure 4.19: Charging from WAPDA on cloudy day

Case 2: On a cloudy day with no available WAPDA power

During a cloudy day, when the solar power generated by the PV panel is insufficient and WAPDA power is not available, the charging terminal is turned off to conserve energy and prevent any potential issues.

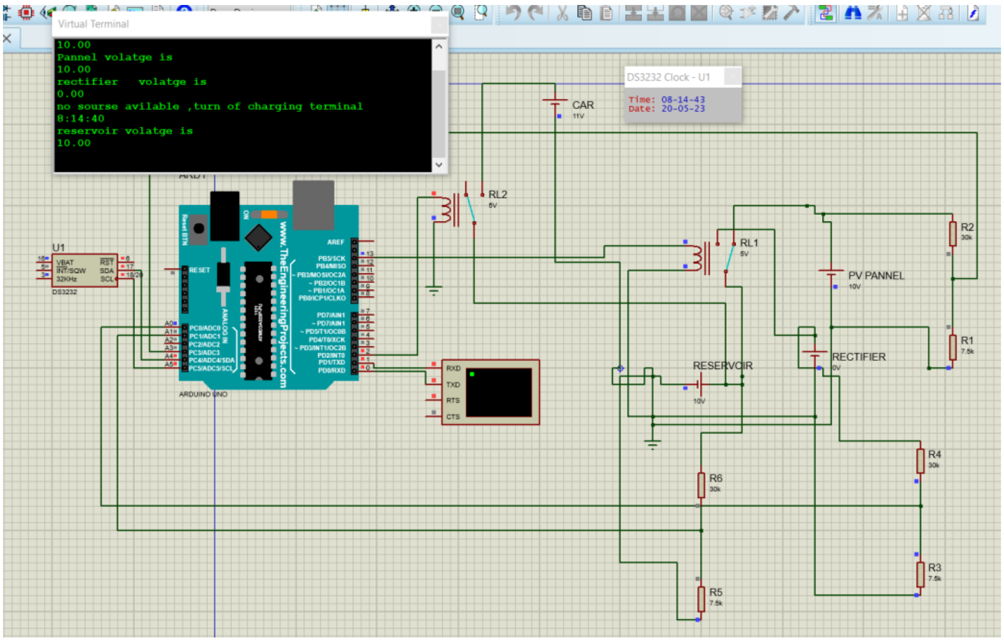


Figure 4.20: No source available on cloudy day

Case 3: On a sunny day

During a sunny day, when the solar power generated solar panel is sufficient and WAPDA power is available, the charging terminal utilizes the solar power for charging the reservoir battery. This allows for efficient and sustainable charging of the battery using renewable energy sources.

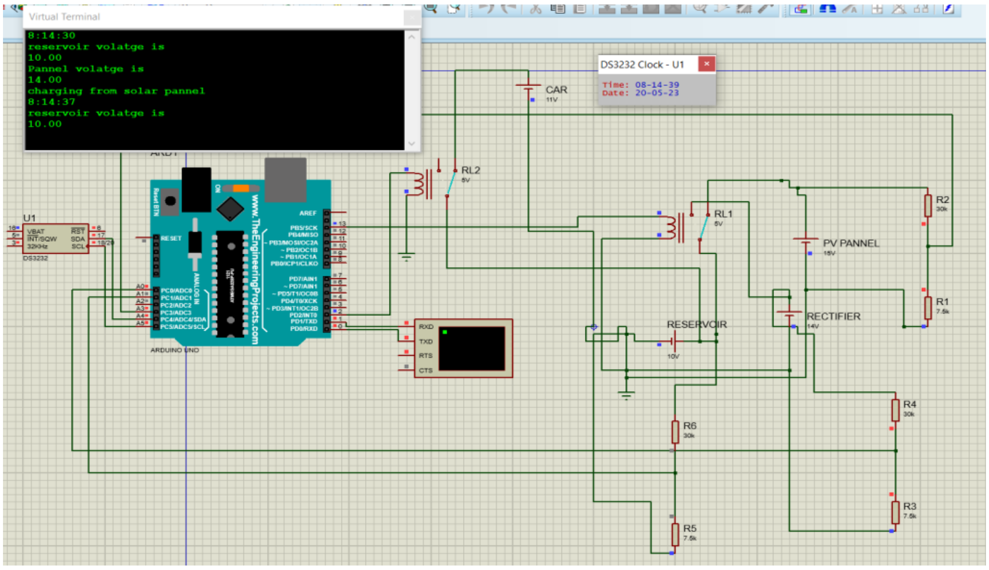


Figure 4.21: Charging from PV panel during daytime

Case4: During the nighttime from 6pm to 7am when WAPDA is available

During the nighttime period from 6pm to 6am, when solar power is not available, the charging terminal switches to WAPDA power for charging the reservoir battery. If WAPDA power is available, the charging process continues smoothly, ensuring uninterrupted charging of the battery. This allows for reliable charging during nighttime hours when solar power is not accessible.

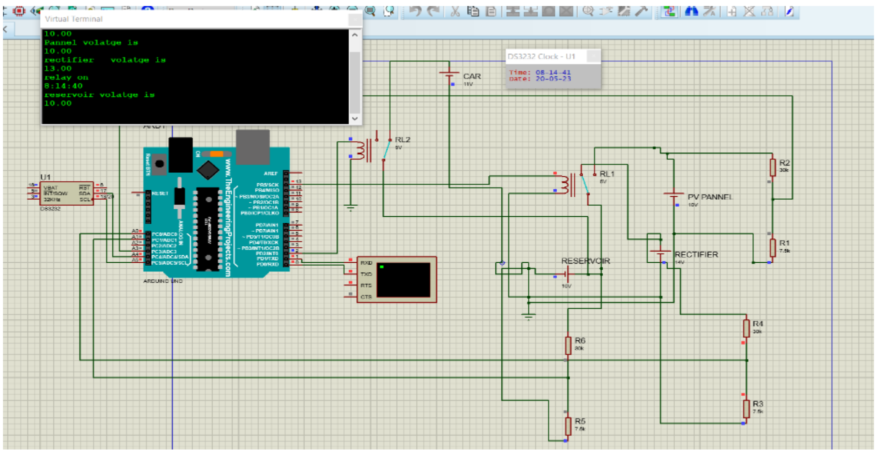


Figure 4.22: Charging from WAPDA during nighttime.

Case 5: No source available during nighttime:

In the case where no power source is available during the nighttime hours, the charging terminal cannot operate. Since both solar power and WAPDA power are not accessible, the charging process is halted, and the entire charging terminal is turned off. This ensures the safety of the system and prevents any potential issues that may arise from attempting to charge the reservoir battery without a power source. Once power becomes available again, the charging terminal can be restarted for normal operation.

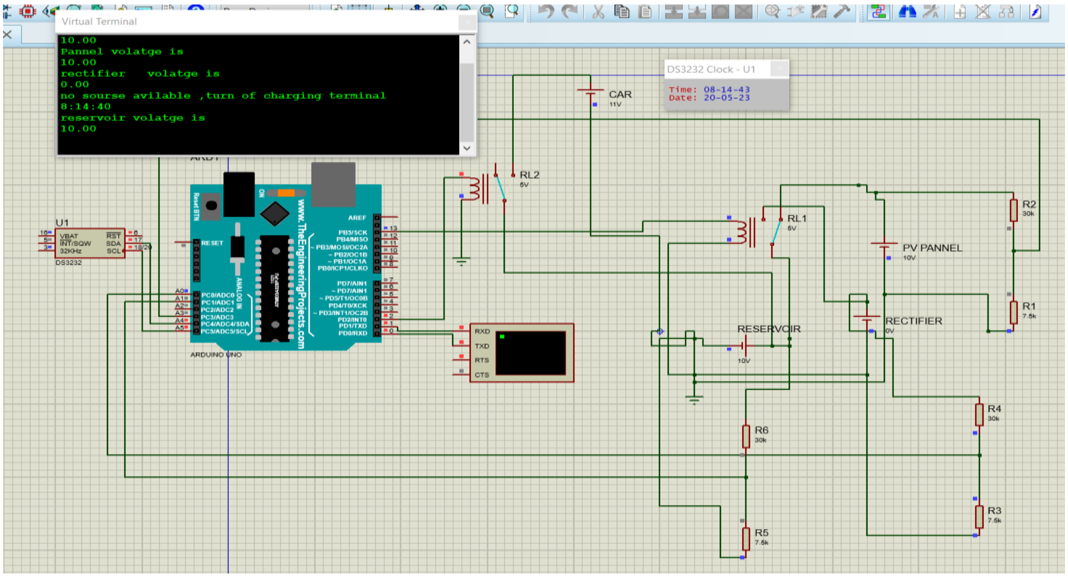


Figure 4.23: No source available during g nighttime.

Hardware testing and results

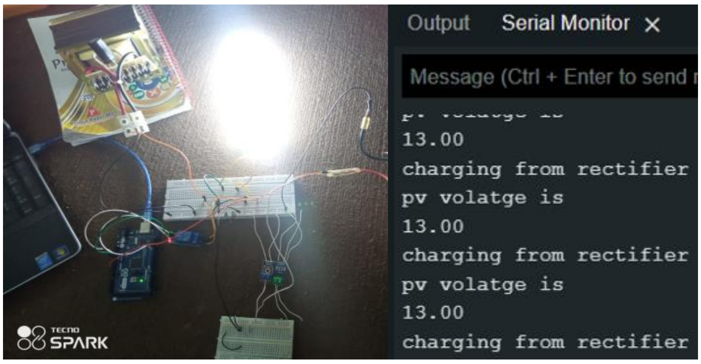


Figure 4.24: Results

Chapter 5
IOT Integration

5.1 Internet of Things

The Internet of Things (IoT) is a transformative technology that connects physical objects, equipped with sensors, processing capabilities, and software, to the internet or other communication networks. It enables these objects, or "things," to collect and exchange data, perform actions, and communicate with other devices and systems. IoT combines the power of embedded systems and the internet, allowing for intelligent, interconnected systems that can be remotely monitored, controlled, and automated.

One of the key advantages of IoT is its ability to facilitate seamless communication and interoperability among devices and systems. This is made possible through the use of various protocols. MQTT (Message Queuing Telemetry Transport) is a lightweight messaging protocol designed for resource-constrained devices and unreliable networks. It enables efficient data transfer using a publish-subscribe model. HTTP (Hypertext Transfer Protocol) and HTTPS (HTTP Secure) are widely used protocols that leverage the existing web infrastructure for data exchange and interaction with IoT devices. [18] These protocols offer compatibility, ease of integration, and support for web services.

IoT platforms play a crucial role in harnessing the potential of IoT by providing tools and services for data management, analytics, and application development. Thing Speak is an IoT analytics platform that enables aggregation, visualization, and analysis of live data streams in the cloud. It offers APIs and integration options, making it easy to connect devices and applications. Things board provides scalable data visualization, device management, and rule-based automation, supporting various connectivity protocols. Firebase, offered by Google, offers real-time database, user authentication, cloud messaging, and hosting services, simplifying backend infrastructure for IoT applications. Blynk focuses on mobile application development for IoT, offering a user-friendly interface and integration with popular development boards.

In our project, we have chosen to utilize IoT and the Thing Speak platform to enable remote monitoring and control of our hybrid charging terminal for electric vehicles. By leveraging IoT, we can monitor the power status of the reservoir battery, receive alerts for power shortages, and remotely switch between different power sources (solar and grid) based on their availability and power output. The integration of GSM module allows us to send alert messages to the owner when the power level of the reservoir battery falls below a threshold, ensuring prompt action can be taken. This not only enhances the safety and reliability of the charging process but also improves the overall efficiency and convenience for both the system operators and the electric vehicle owners. The real-time data and analytics provided by IoT enable us to make data-driven decisions, optimize energy utilization, and contribute to a more sustainable charging infrastructure.

5.2 Channel Creation on Thing speak

We have implemented a comprehensive data monitoring and control system using Thing Speak. We have created separate channels on thing Speak to continuously monitor the power status of the reservoir battery and the current battery. By doing so, we can collect real-time data on the voltage, current, and power levels of these batteries, allowing us to assess their performance and health.

The channels on Thing Speak serve as centralized repositories for the collected data, enabling us to visualize and analyze the trends and patterns over time. This information is invaluable for understanding the charging process and making informed decisions to optimize the utilization of the available power sources.

Moreover, we have also established a control channel on Thing Speak, which enables us to remotely manage and control the charging terminal. The integration of Thing Speak and the creation of dedicated channels for monitoring and control provide us with a robust and flexible framework for our IoT-based charging terminal. By leveraging the power of Thing Speak, we can remotely monitor, analyze, and control the charging process, leading to enhanced efficiency and improved performance.

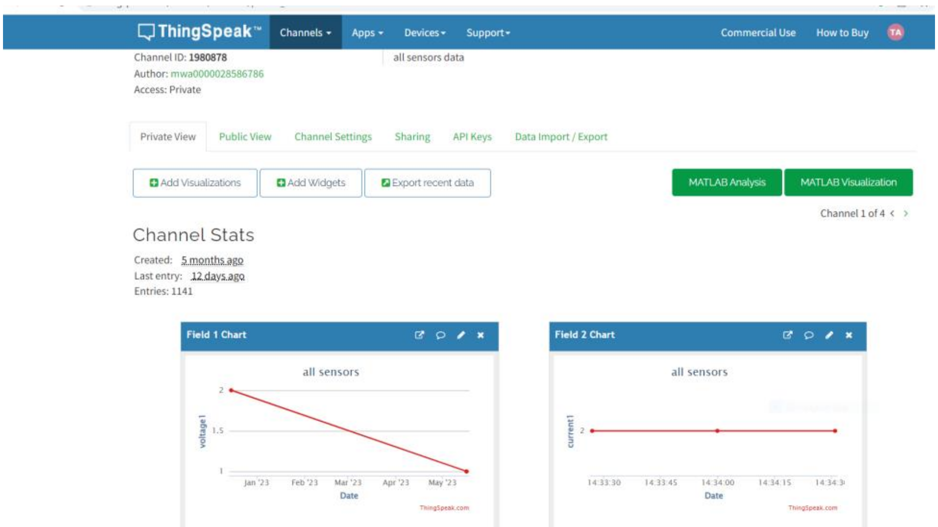


Figure 5.1: ThingSpeak channels

5.3 Real-Time Data Monitoring with NodeMCU on ThingSpeak

In our project, we utilize the NodeMCU ESP8266 Wi-Fi module to wirelessly transmit sensors data to the Thing Speak platform. This module acts as a bridge between sensors and the internet, enabling real-time data transmission. With its built-in Wi-Fi capabilities, the NodeMCU ESP8266 establishes a wireless connection, allowing us to remotely monitor the voltage and current flowing through the reservoir battery and other components. By securely sending the data to Thing Speak, we can analyze and visualize it for further insights. This integration provides a robust solution for real-time data transmission and monitoring. It enables us to optimize the performance and efficiency of our hybrid charging terminal. The NodeMCU ESP8266 module and Thing Speak platform offer a seamless and efficient way to remotely monitor and control our charging terminal.

5.3.1 Integration of Current Sensor with ThingSpeak

We have interfaced a current sensor with the Arduino board to accurately measure the current values. To transmit this data to the cloud for monitoring and analysis, we have integrated the system with ThingSpeak, an IoT platform. Through this integration, we can monitor and visualize the current values of the different components on the ThingSpeak platform in real-time.

Schematic

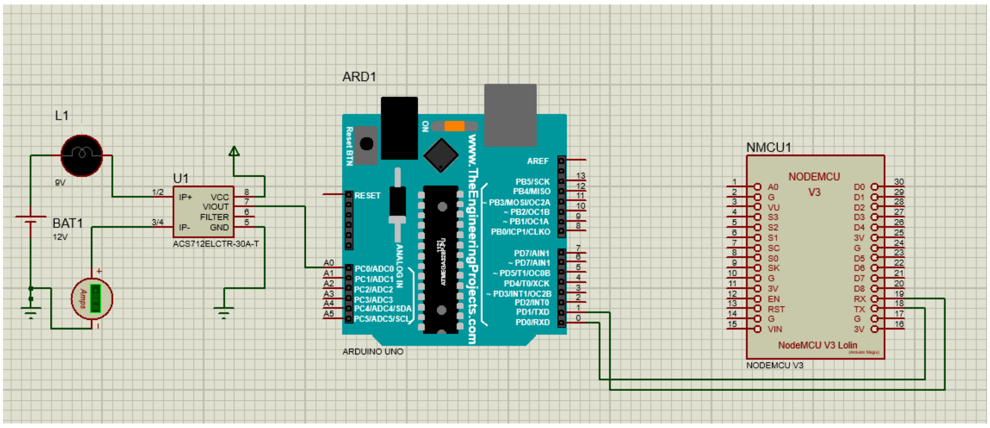


Figure 5.2: Schematic for Sending current sensor data to Thing speak

Hardware Testing and Results

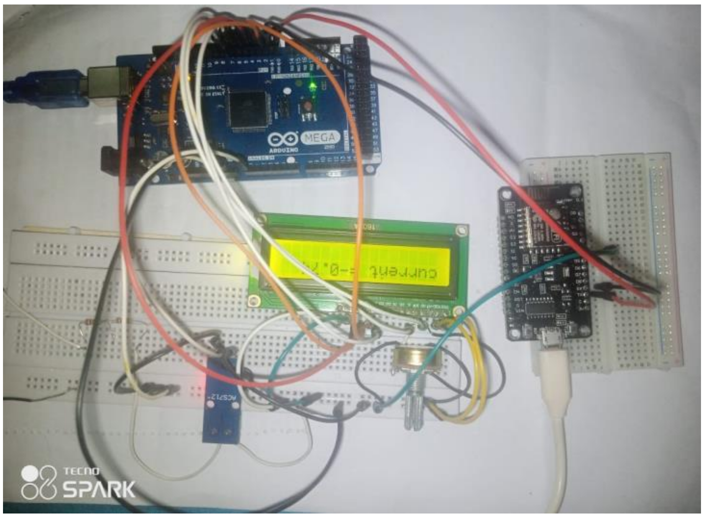


Figure 5.3: Current sensor output

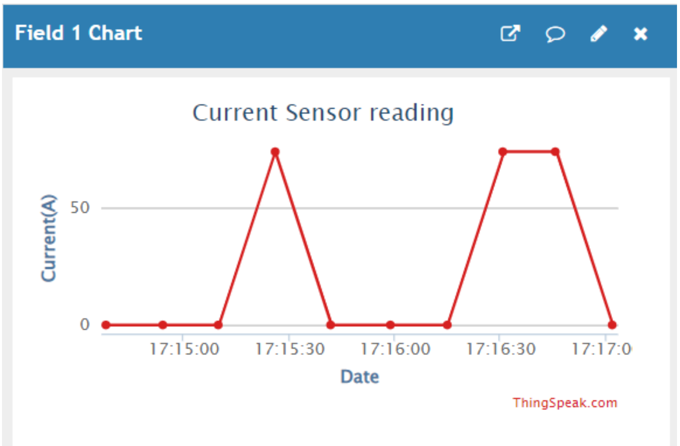


Figure 5.4: Real-time Current Monitoring on Thing speak

5.3.2 Integration of Voltage Sensor with ThingSpeak

The integration of the voltage sensor with Thing Speak enables us to monitor the voltage levels of various components in our charging system. By sending voltage sensor data to Thing Speak, we can remotely monitor and analyze the voltage of the PV (solar) panel, rectifier, reservoir battery, and car battery. This allows us to gain valuable insights into the performance and stability of these components. By continuously monitoring the voltage levels, we can ensure that the PV panel is generating sufficient power, the rectifier is providing the correct voltage for charging, and the reservoir and car batteries are operating within the desired voltage range. This integration enhances our ability to effectively manage and optimize the charging process, ensuring reliable and efficient operation of our hybrid charging terminal for electric vehicles.

Schematic

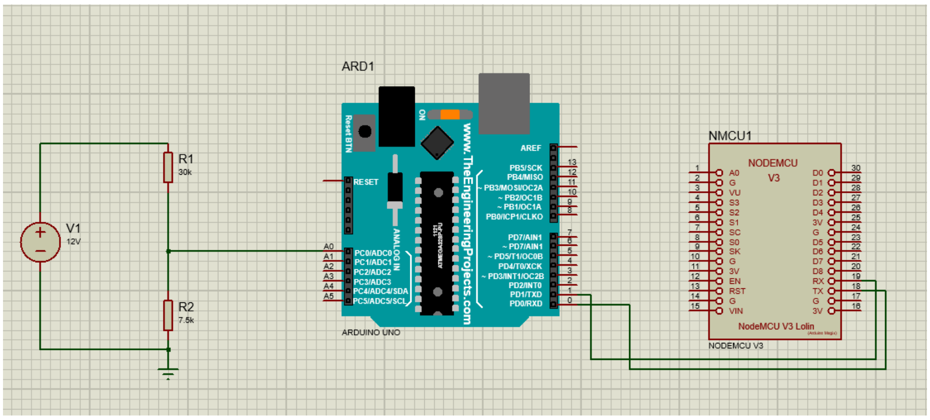


Figure 5.5: schematic for voltage sensor

Hardware Testing and Results

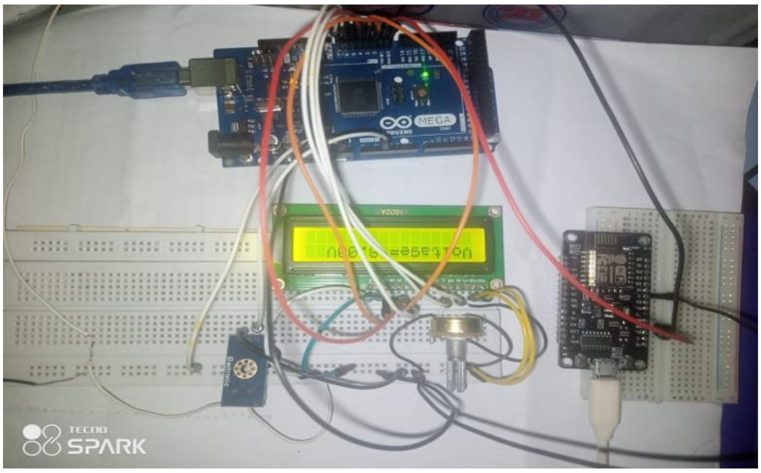


Figure 5.6: Voltage sensor output

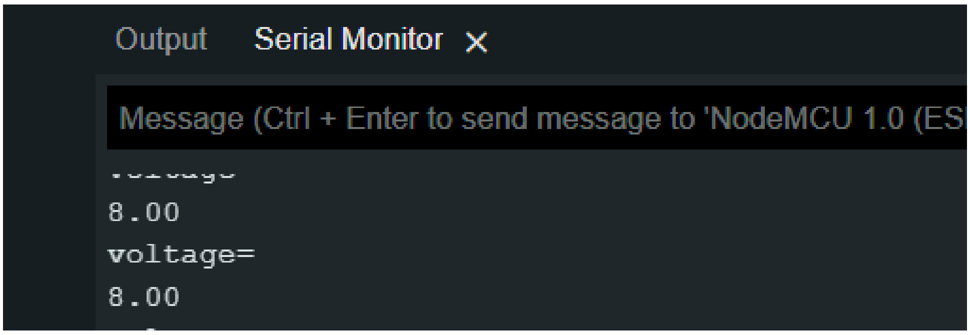


Figure 5.7: Serial monitor output

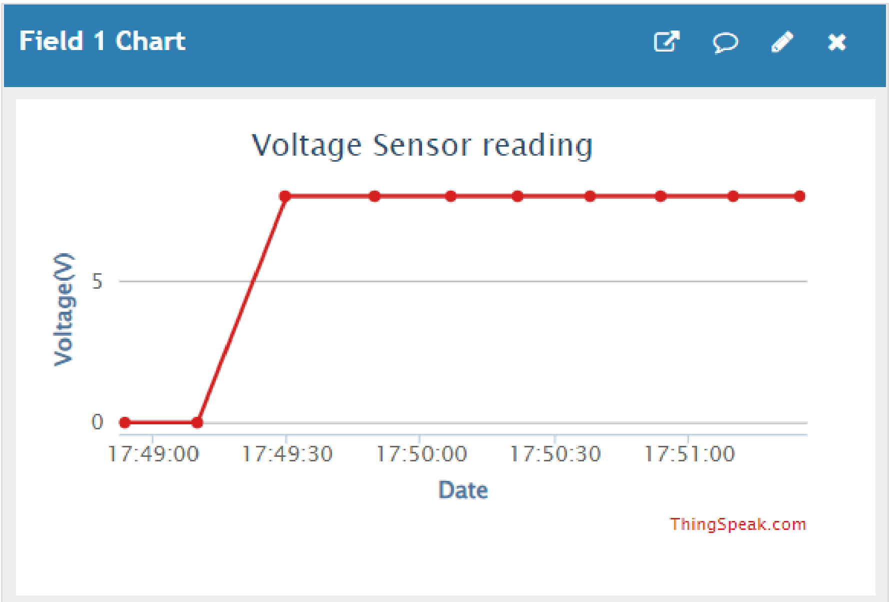


Figure 5.8: real time voltage monitoring on Thingspeak

5.4 Remote Monitoring and Controlling using MIT APP Inventor

MIT App Inventor is a user-friendly visual programming environment that allows individuals with no prior coding experience to create mobile applications for Android devices. With its intuitive drag-and-drop interface, users can easily design the user interface and functionality of their app. In our project, we have utilized MIT App Inventor to develop a mobile app that enables remote monitoring and control of our charging terminal. We have designed the app's interface to display the power status of the reservoir battery and the incoming car battery. Additionally, we have integrated the GSM module to receive alert messages in case of power shortages. Through the app, users can remotely turn off and on the charging, terminal based on the received alerts, providing a convenient and efficient way to manage the charging process.

The flexibility and simplicity of MIT App Inventor have allowed us to quickly prototype and deploy a customized mobile application that meets our project's specific requirements. By leveraging the power of mobile technology, we can now monitor and control our charging terminal remotely, enabling us to ensure optimal charging efficiency and respond promptly to any power-related issues. MIT App Inventor has provided us with a powerful tool to harness the capabilities of our IoT system and GSM module, making our charging terminal more accessible and user-friendly.

5.4.1 APP Designing

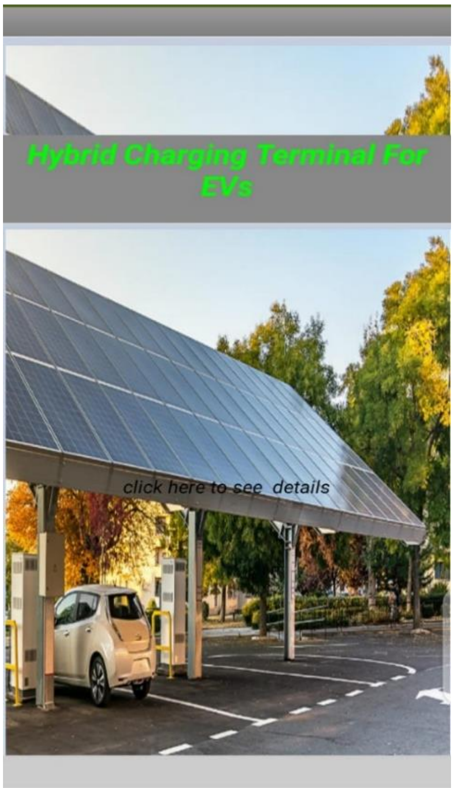


Figure 5.9: Front page

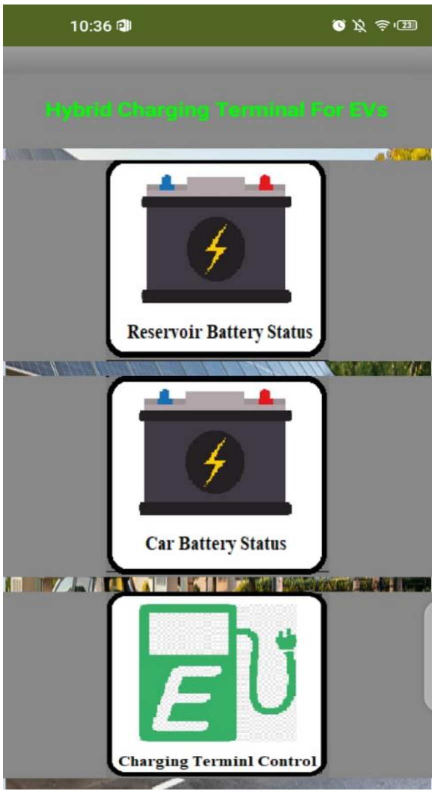


Figure 5.10: APP details

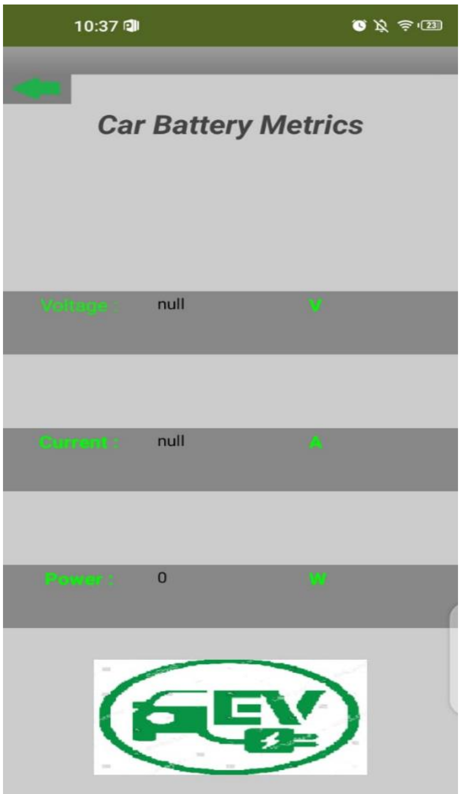


Figure 5.11: Car Battery Metrics

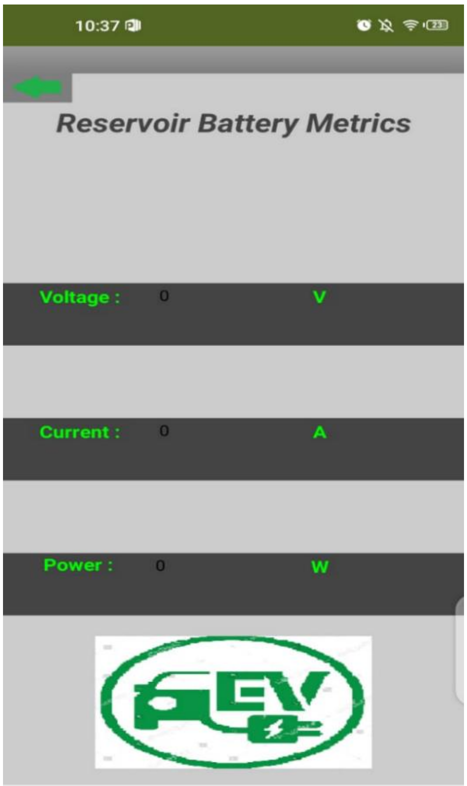


Figure 5.12: Reservoir Battery Metrics

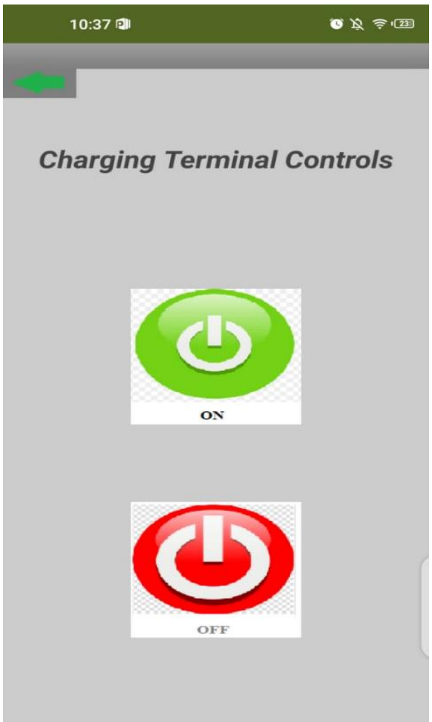


Figure 5.13:Charging Terminal Controls

The application's interface provides comprehensive monitoring capabilities for charging terminals, allowing users to remotely observe their status in real time. Additionally, it offers the functionality to control these terminals remotely by enabling users to interact with on/off buttons within the application. Through the intuitive interface, users can exercise precise control over the charging terminals, initiating or terminating charging processes as needed. This seamless integration of monitoring and remote-control functionalities empowers users with efficient management of charging terminal operations.

Chapter 6
Prototype Development and Integration

6.1 Prototype

Our prototype is a comprehensive charging terminal system designed to facilitate efficient and sustainable charging of electric vehicle batteries. The system incorporates various components and technologies to monitor, control, and display the power status of the reservoir and car batteries.

6.1.1 Equipment used

Arduino Board: The Arduino board serves as the central control unit for the system, interfacing with the sensors and modules to collect data and execute commands.

Voltage and Current Sensors: Four voltage sensors and four current sensors are integrated into the system to measure the voltage levels of the PV panel, rectifier, reservoir, and car battery.

NodeMCU Board: The NodeMCU board establishes a Wi-Fi connection and enables the transmission of sensor data to the Thing Speak platform for real-time monitoring and analysis.

GSM Module: The GSM module allows the system to send SMS alerts to the owner in case of critical events or power shortages.

RTC Module: The RTC module accurately measures and maintains the time, aiding in source selection for charging the reservoir battery.

16x2 LCD Display: The LCD display is incorporated into the system's enclosure to provide a visual representation of the power status of the reservoir and car battery.

6.1.2 Steps for Making the Prototype

Design the circuit layout: Create a PCB design that accommodates the Arduino board, sensors, NodeMCU board, GSM module, RTC module, and LCD display.

Assemble the components: Connect the sensors, modules, and boards as per the circuit layout, ensuring proper wiring and connections.

Program the Arduino: Develop and upload the required Arduino code to enable sensor data collection, transmission to ThingSpeak, and control of system operations.

PCB designing: Place the assembled circuitry into a suitable enclosure, ensuring proper protection and accessibility for the components.

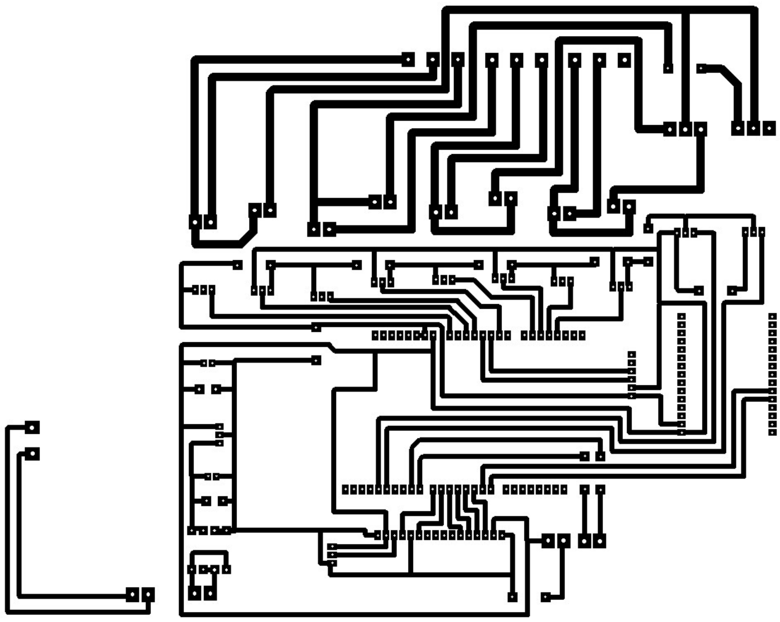


Figure 6.1: PCB layout

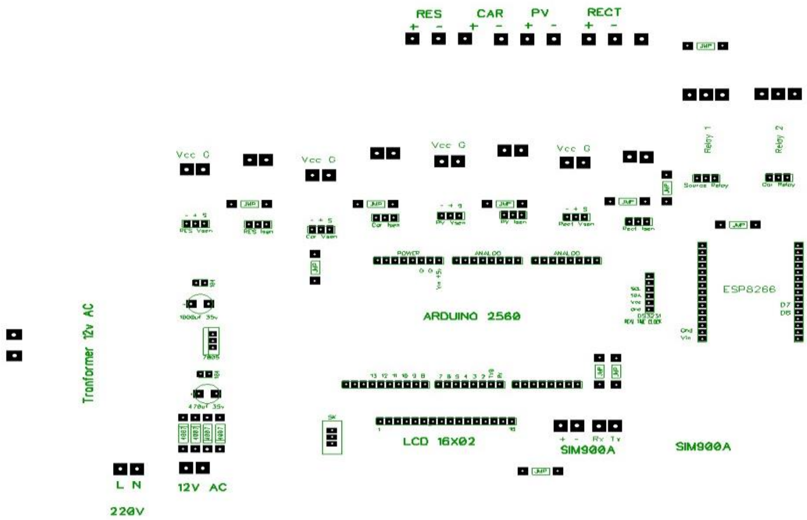


Figure 6.2: Components of PCB

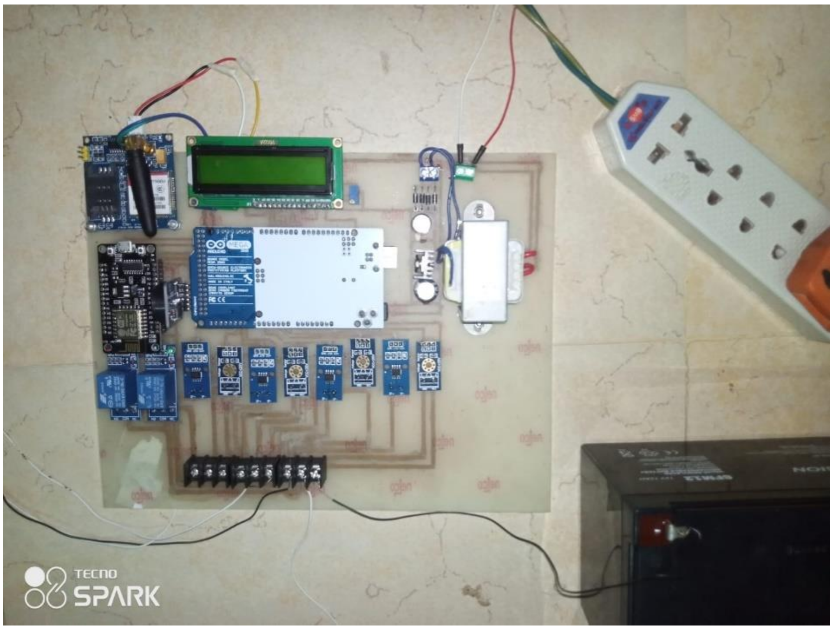


Figure 6.3: Integration of complete circuit

Install the solar panel and MPPT module: Connect the solar panel and MPPT module to form the microgrid system, optimizing solar power utilization.

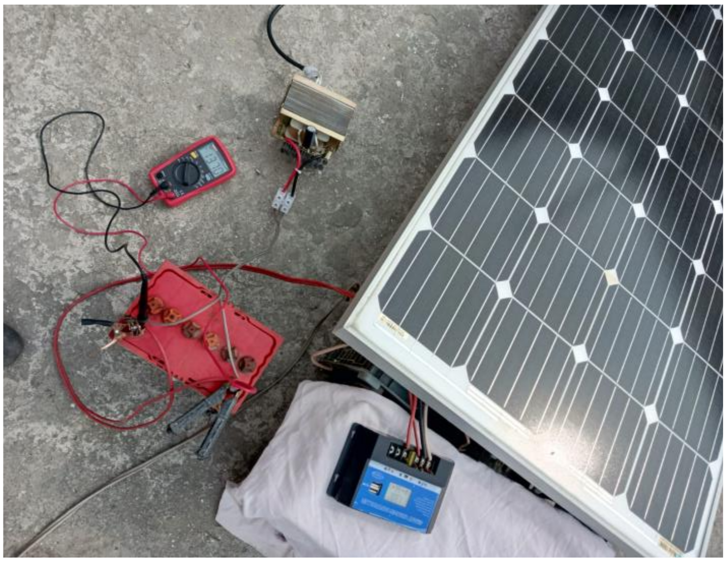


Figure 6.4: Microgrid Development

Test and calibrate: Verify the functionality of the prototype by monitoring the power status, verifying sensor readings, and ensuring proper communication with ThingSpeak.

Mount the LCD display: Attach the 16x2 LCD display to the enclosure, providing a clear and concise visualization of the power status.

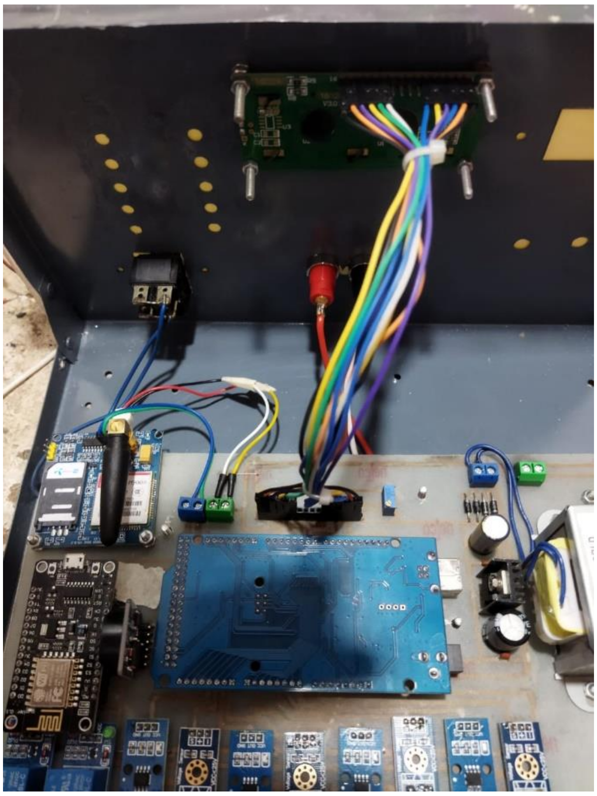


Figure 6.5: Enclosing in box

Fine-tune and optimize: Make any necessary adjustments or optimizations to enhance the system's performance and reliability.

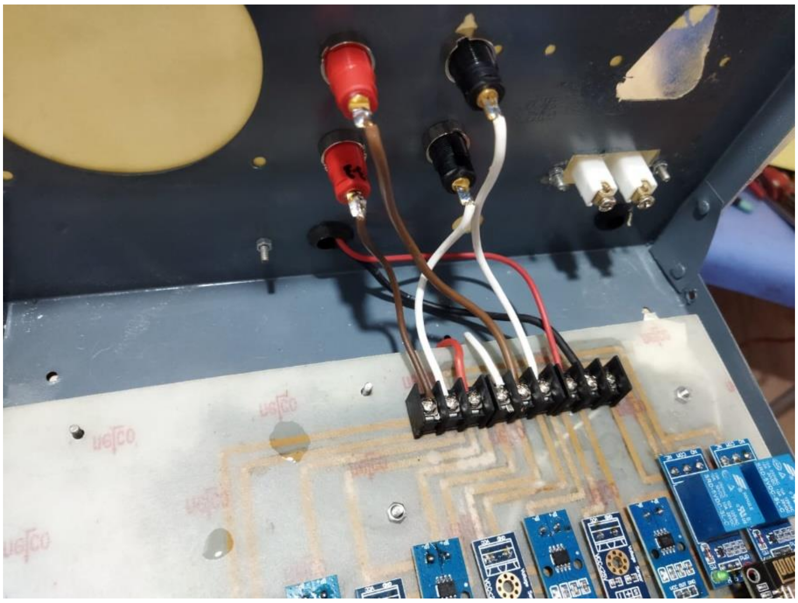


Figure 6.6: Making connections for PV and Rectifier

Chapter 7
Conclusion and Future Recommendations

7.1 Conclusion

Lahore, Pakistan experienced a significant rise in air pollution levels, leading to its ranking as the city with the highest air pollution n in the world in 2022, primarily due to increased carbon emissions. The electricity generation sector is the greatest cause of carbon emission.co2 emission from gasoline powered car vehicles is increasing rapidly. Our project's solar-based hybrid charging terminal for electric vehicles serves as a groundbreaking solution to address environmental challenges and promote sustainable transportation. By incorporating solar power generation and leveraging advanced technologies, we have successfully created an innovative infrastructure that mitigates carbon emissions, reduces air pollution, and diminishes reliance on traditional fossil fuels. This integration of renewable energy sources not only contributes to a cleaner and healthier environment but also sets a path towards a greener future.

Furthermore, the implementation of cutting-edge technologies such as IoT, GSM, and real-time data monitoring plays a pivotal role in optimizing energy management and enabling remote control capabilities. Through IoT connectivity, we can effectively monitor the power status of the reservoir battery, receive real-time alerts, and remotely switch between power sources based on availability and efficiency. This level of control enhances the system's performance, promotes efficient utilization of resources, and ensures a seamless charging experience for electric vehicle owners. By embracing these technological advancements, we +take significant strides towards a more sustainable transportation ecosystem that prioritizes energy efficiency, reduces environmental impact, and paves the way for a brighter future.

7.2 Future Recommendations

Looking ahead, there are several potential recommendations for the future development and enhancement of our solar-based hybrid charging terminal for electric vehicles. Firstly, incorporating advanced energy storage solutions such as lithium-ion batteries or other emerging technologies can improve the efficiency and reliability of the system. Energy storage enables better utilization of solar power by storing excess energy during the day and utilizing it during periods of low solar availability, ensuring a continuous power supply for charging.

Secondly, exploring the integration of smart grid technologies can further optimize the charging process and grid interaction. Smart grid capabilities can enable intelligent load management, demand-response mechanisms, and bi-directional power flow between the charging terminal and the grid. This would not only enhance grid stability but also enable vehicle-to-grid (V2G) capabilities, where electric vehicles can feed energy back into the grid during peak demand periods, contributing to grid flexibility and balancing.

Furthermore, in the future, there is potential to make our solar-based hybrid charging terminal even smarter by incorporating location-based services. By integrating GPS technology and developing a dedicated mobile application, electric vehicle users could easily locate nearby charging terminals and access real-time information about their availability, charging rates, and other relevant details. This would enhance the convenience and accessibility of charging facilities, making it more convenient for EV owners to plan their journeys and locate charging options along their routes.

Additionally, the integration of smart payment systems, such as RFID or mobile payment platforms, could simplify the billing and payment process for charging services. Users could seamlessly authorize and pay for their charging sessions, eliminating the need for physical payment methods and providing a seamless user experience.

Moreover, leveraging advanced data analytics and machine learning algorithms, we can analyze the charging patterns, user behaviors, and energy consumption trends to optimize the operation and management of the charging terminal. This data-driven approach would enable predictive maintenance, load forecasting, and dynamic load management, ensuring efficient utilization of energy resources and optimal charging performance.

By incorporating these advancements and continuously innovating, our solar-based hybrid charging terminal can evolve into a comprehensive, intelligent charging ecosystem that not only addresses the current challenges but also anticipates the future needs of electric vehicle users. It would provide a seamless and user-friendly charging experience, promote the wider adoption of electric vehicles, and contribute to a greener and more sustainable transportation landscape.

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Annexure ‘A’

Codes used in project

1.Interfacing Current and Voltage Sensors with Arduino Mega 2560

```
// voltage and current sensor interfacing
#include "LiquidCrystal.h"
LiquidCrystal lcd(7, 6, 5, 4, 3, 2);
const int currentPin = A0;
int sensitivity = 185;
int adcValue= 0;
int offsetVoltage = 2500;
double adcVoltage = 0;
double currentValue =0;
const int voltageSensor = A3;
float vOUT = 0.0;
float vIN = 0.0;
float R1 = 30000.0;
float R2 = 7500.0;
int Volt = 0;
void setup()
{
Serial.begin(9600);
lcd.begin(16, 2);
}
```

```
void loop()
{int offset=0;
// current sensing
adcValue = analogRead(currentPin);
adcVoltage = (adcValue /1024.0)*5000;
currentValue = ((adcVoltage - offsetVoltage) / sensitivity);
// voltage sensing
Volt = analogRead(voltageSensor);
double vo=map(Volt,0,1024,0,2500)+offset;
vo/=100;
//vOUT = (value * 5.0) / 1023.0;
//delay(1000);
//vIN = vOUT / (R2/(R1+R2));
//displaying voltage
lcd.setCursor(0,1);
lcd.print("voltage = ");
lcd.setCursor(9,1);
lcd.print(vo);
delay(3000);
// displaying current
lcd.setCursor(0,0);
lcd.print("Current = ");
lcd.setCursor(10,0);
lcd.print(currentValue);
delay(5000);
}
```

2. Sensing Alert SMS through GSM for Power Shortage and Backflow Detection

```
#include<SoftwareSerial.h>

SoftwareSerial gsm(7,8);//rx tx

//voltage sensor1

const int voltageSensor1 = A3;

float value1;

// current sensor1

const int currentPin1 = A0;

float currentValue1;

//voltage sensor 2

const int voltageSensor2 = A4;

float value2;

// current sensor2

const int currentPin2 = A1;

float currentValue2;

void setup()

{

delay(1000);

Serial.begin(115200);

gsm.begin(115200);

}

void loop()

{

//voltage1 sensing(reservoir)

int Volt1 = analogRead(voltageSensor1);
```

```
int v1=map(Volt1,0,1024,0,2500);
value1=v1/100;
Serial.println("reservoir volatge is");
Serial.println(value1);
delay(3000);
// current1 sensing
int adcValue1 = analogRead(currentPin1);
//Serial.println(adcValue);
delay(1000);
float adcVoltage1 = (adcValue1 /1024.0)*5;
float c1 = ((adcVoltage1 - 2.5) / 0.066);
currentValue1=c1;
// printing current
Serial.println("reservoir battery current is");
Serial.println(currentValue1);
delay(3000);
float power1=value1*currentValue1;
Serial.println("power1 in watt is =");
Serial.println(power1);
delay(3000);
//power2 incoming car battery
//voltage2 sensing
//voltage1 sensing(reservoir)
int Volt2 = analogRead(voltageSensor2);
int v2=map(Volt2,0,1024,0,2500);
value2=v2/100;
```

```
Serial.println("incoming car battery volatge is");

Serial.println(value2);

delay(3000);

// current2 sensing

int adcValue2 = analogRead(currentPin2);

//Serial.println(adcValue);

delay(1000);

float adcVoltage2 = (adcValue2 /1024.0)*5;

float c2 = ((adcVoltage2 - 2.5) / 0.066);

currentValue2=c2;

// printing current

Serial.println("car battery current is");

Serial.println(currentValue2);

delay(3000);


float power2=value2*currentValue2;

Serial.println("power2(car battery) in watt is =");

Serial.println(power2);

delay(3000);

//float totalpower_W=120;

//float threshold=0.20*120;

//power shortage condition in reservoir

if(power1<3.0)

{

SendMessage1();

}
```

```
//power backflow condition
if(power2<power1)
{
gsm.println("AT+CMGF=1");
delay(1000);
gsm.println("AT+CMGS=\"+923405254094\"\r"); //replace x by your number
delay(1000);
gsm.println("Car battery power is greater than that of reservoir");
delay(100);
gsm.println((char)26);
delay(5000);
}
}
void SendMessage1()
{
gsm.println("AT+CMGF=1");
delay(1000);
gsm.println("AT+CMGS=\"+923405254094\"\r"); //replace x by your number
delay(1000);
gsm.println("reservoir battery power has fallen below threshod value. power shortage!");
delay(100);
gsm.println((char)26);
delay(5000);
}
```

3.Remote System Management: Efficient Control and Monitoring with MIT App Inventor

3.1 Arduino Code

```
//arduino code

#include <SoftwareSerial.h>

//SoftwareSerial abc(0,1);

const int voltageSensor1 = A3;

int value1;

int power1;

int power2;

// current sensor initialization

// sensitivit=66mv/A for 30A current sensor

const int currentPin1 = A0;

int currentValue1;

const int voltageSensor2 = A1;

int value2;

// current sensor initialization

const int currentPin2 = A2;

int currentValue2;

int led=13;

void setup() {

pinMode(13,OUTPUT);

Serial.begin(9600);

//abc.begin(9600);

while(!Serial);

Serial.println("input 1 to turn on led");
```

```
// put your setup code here, to run once:
}
void loop() {
// current sensing
int adcValue = analogRead(currentPin1);
Serial.println(adcValue);
float adcVoltage = (adcValue /1024.0)*5;
float c1 = ((adcVoltage - 2.5) / 0.066);
currentValue1=c1*1000;
// votage sensing
int Volt = analogRead(voltageSensor1);
int v=map(Volt,0,1024,0,2500);
value1=v/100;
//value1=v1*1000;
//power1 calculation
power1=value1*currentValue1;
//delay(100);
// voltage displaying
Serial.println(".....sourse#1 current &voltage....");
//delay(100);
Serial.println("voltage1=");
//delay(100);
Serial.println(value1);
//delay(100);
Serial.write(value1);
// current diaplaying
```

```
Serial.println("current1=");
//delay(100);
Serial.println(currentValue1);
////delay(100);
Serial.write(currentValue1);
//displaying power1
Serial.println("power1 is = ");
Serial.println(power1);
//delay(300);
Serial.write(power1);
int adcValue2 = analogRead(currentPin2);
//Serial.println(adcValue);
float adcVoltage2 = (adcValue2 /1024.0)*5;
float c2 = ((adcVoltage2 - 2.5) / 0.066);
currentValue2=c2*1000;
// votage sensing
int Volt2 = analogRead(voltageSensor2);
int v2=map(Volt,0,1024,0,2500);
value2=v2/100;
//value2=voltage2*1000;
//power2 calculation
power2=value2*currentValue2;
//delay(100);
// voltage displaying
Serial.println(".....sourse#2 current &voltage....");
delay(100);
```

```
Serial.println("voltage2=");
delay(100);
Serial.println(value2);
//delay(100);
Serial.write(value2);
// current diaplaying
Serial.println("current2=");
delay(100);
Serial.println(c2);
//delay(200);
Serial.write(currentValue2);
// power2 displaying
Serial.println("power2=");
delay(100);
Serial.println(power2);
//delay(200);
Serial.write(power2);
if (Serial.available()){
int state=Serial.parseInt();
Serial.println(state);
//delay(1000);
// if not working then write if((state-(state-1))==1) another condition is if(state==1)
if(((state)-(state-1))==1){
digitalWrite(13,HIGH);
}
if(state==0){
```

```
digitalWrite(13,LOW);

}

}

//int data=150;

//Serial.write(data);

//Serial.println(data);

//delay(3000);

//Serial.println("command recieved:1 led on ");

}
```

3.2 Nodemcu Esp8266 Code

```
#include <ESP8266WiFi.h>

#include <ThingSpeak.h>

#include <SoftwareSerial.h>

// node mcu code

//two communication code for nodemcu . it is working properly.we have added all data excep
thingspeak.

//#include<SoftwareSerial.h>

SoftwareSerial abc(13,15);//RX=D7 TX=D8

WiFiClient client;

long myChannelNumber= 2148281 ;

const char myWriteAPIKey[]="1IBRU5LIHBIC499G";// write api key

const char * myCounterReadAPIKey = "843MF6E6X3LTJN1H";// read api key

int value1;

int currentValue1;

int value2;

int currentValue2;
```

```
int power1;
int power2;
void setup() {
abc.begin(9600);
Serial.begin(9600);
WiFi.mode(WIFI_STA);
Serial.begin(9600);
WiFi.begin("Spark2","Aasar@ahmad45");
while(WiFi.status() !=WL_CONNECTED){
Serial.println("..");
}
Serial.println("");
Serial.println("NodeMCU is connected!");
//Serial.println(WiFi.localIP());
ThingSpeak.begin(client);
}
// put your setup code here, to run once:
void loop() {
int A = ThingSpeak.readLongField(myChannelNumber, 1, myCounterReadAPIKey);
Serial.println(A);
if(A==1){
abc.write("1");
delay(1000);
}
if(A==0){
abc.write("0");
```

```
delay(1000);
}
//abc.write("0");
//delay(1000);
//abc.write("1");
//delay(1000);
if(abc.available()){
value1=abc.parseInt();
//value=Serial.read();
Serial.println("voltage1=");
Serial.println(value1);
//delay(100);
ThingSpeak.writeField(myChannelNumber,7,value1,myWriteAPIKey);
currentValue1=abc.parseInt();
//currentValue=Serial.read();
Serial.println("current1=");
Serial.println(currentValue1);
//delay(100);
ThingSpeak.writeField(myChannelNumber,2,currentValue1,myWriteAPIKey);
//power1
power1=abc.parseInt();
//currentValue=Serial.read();
Serial.println("power1=");
Serial.println(power1);
//delay(100);
```

```
ThingSpeak.writeField(myChannelNumber,3,power1,myWriteAPIKey);

// battery 2 reading
value2=Serial.parseInt();
//value=Serial.read();
Serial.println("voltage2=");
Serial.println(value2);
//delay(100);
ThingSpeak.writeField(myChannelNumber,4,value2,myWriteAPIKey);
currentValue2=Serial.parseInt();
//currentValue=Serial.read();
Serial.println("current2=");
Serial.println(currentValue2);
//delay(100);
ThingSpeak.writeField(myChannelNumber,5,currentValue2,myWriteAPIKey);
//power2
power2=Serial.parseInt();
//currentValue=Serial.read();
Serial.println("power2=");
Serial.println(power2);
//delay(100);
ThingSpeak.writeField(myChannelNumber,6,power2,myWriteAPIKey);
//int a=abc.parseInt();
//Serial.println(a);
}
}
```

3.3 MIT Screen1 Code for Data Monitoring

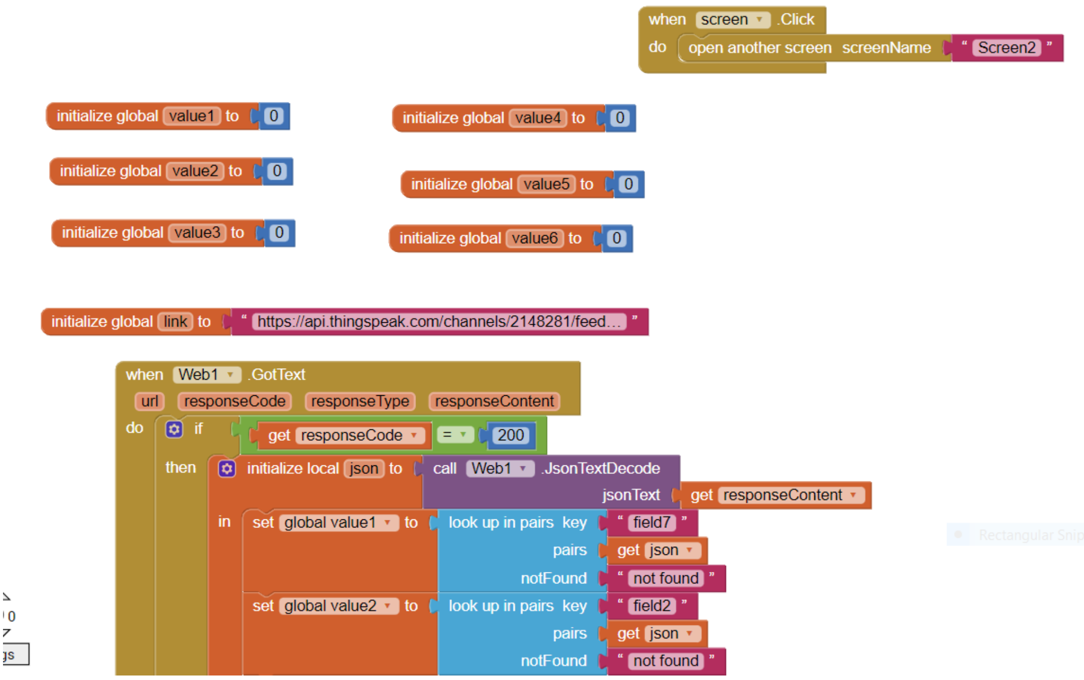


Figure 3 MIT screen code for data monitoring 1

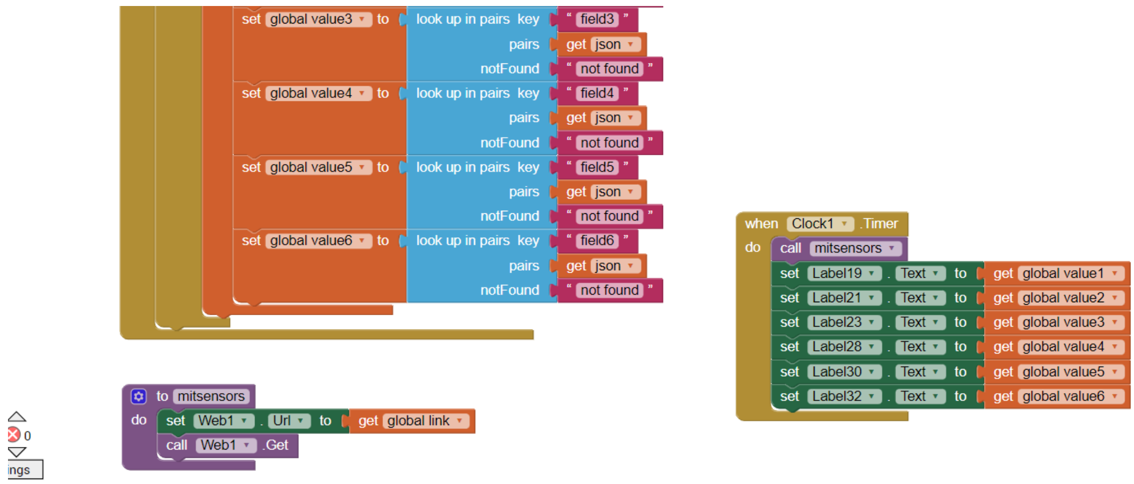
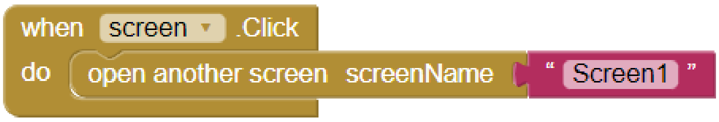
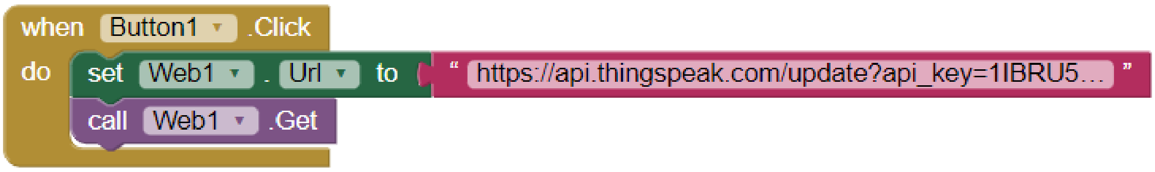
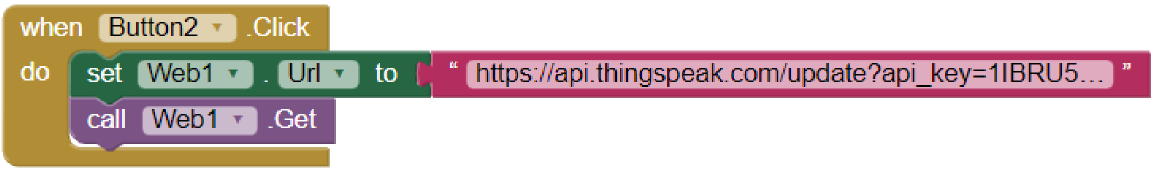


Figure 4MIT screen code for data monitoring 2

3.4 MIT Screen 2 Code for Controlling







4.Source Selection Code

```
#include <Wire.h>

#include "RTClib.h"

RTC_DS3231 rtc;

int relayPin = 13;

int relayPin2 = 2;

int Volt2;

int v2;

float threshold_kwh=0.14;

//voltage sensor1 PV

const int voltageSensor1 = A3;

float value1;

// current sensor1

const int currentPin1 = A2;

float currentValue1;
```

```
// RECTIFIER VOLTAGE
const int voltageSensor2 = A0;
float value2;
// RESERVOIR VOLTAGE
const int voltageSensor3 = A1;
float value3;
// current sensor2
//const int currentPin2 = A4;
//float currentValue2;
void setup () {
Serial.begin(9600);
rtc.begin();
rtc.adjust(DateTime(2023,5,20,8,14,30));//set current time and date uncomment
pinMode(relayPin, OUTPUT);
//digitalWrite(relayPin , HIGH);
pinMode(relayPin2, OUTPUT);
//digitalWrite(relayPin2,HIGH);
}
void loop () {
DateTime now = rtc.now();
int hour = now.hour();
int minute = now.minute();
int second = now.second();
//bool is_pm = hour >= 12;
//char ampm;
// Convert 24-hour format to 12-hour format
```

```
//if (hour > 12) {
//hour -= 12;
//} else if (hour == 0) {
//hour = 12;
//}
Serial.print(hour);
Serial.print(":");
Serial.print(minute);
Serial.print(":");
Serial.print(second);
Serial.print(" ");
//if (is_pm) {
//char ampm='p';
//Serial.print(ampm);
//}
//else
//{
//char ampm='a';
//Serial.print(ampm);
//}
Serial.println();
delay(1000);
// RESERVOIR BATTERY VOLTAGE
int Volt3 = analogRead(voltageSensor3);
int v3=map(Volt3,0,1024,0,2500);
value3=v3/100;
```

```
Serial.println("reservoir volatge is");
Serial.println(value3);
delay(3000);
// between 7amto 6pm battery will charge from solar panel
if((hour>=7 && minute>=0) && hour<18)
{
//check power of solar pannel(check for cloudy day)
//voltage1 sensing(solar pannel)
int Volt1 = analogRead(voltageSensor1);
int v1=map(Volt1,0,1024,0,2500);
value1=v1/100;
Serial.println("Pannel volatge is");
Serial.println(value1);
delay(3000);
if(value1<13) {// when cloudy day
// check if wapda is availabe or not
Volt2 = analogRead(voltageSensor2);
v2=map(Volt2,0,1024,0,2500);
value2=v2/100;
Serial.println("rectifier volatge is");
Serial.println(value2);
delay(3000);
if(value2<12){
// turn off whloe charging station
digitalWrite(relayPin2, LOW);
Serial.println("no sourse avilable ,turn of charging terminal");
```

```
}
else{ // WHEN WAPDA AVAILABLE
if(value3<13){
// CHECK BATTERY STATUS FIRST
// relay will turn on and charging will start from rectigier
digitalWrite(relayPin, LOW);
Serial.println("relay on");
}
else{
Serial.println("battery is full");
digitalWrite(relayPin ,HIGH);
}
}
}
else
{
// charging from solar pannel
digitalWrite(relayPin ,HIGH);
Serial.println("charging from solar pannel");
}
}
// if to trigger between 630 am and 7pm the write ((hour>=6&& minute>=30)&& hour<19)
if(hour>=18 || hour<7){
// check whwher wapda is available or not
int Volt2 = analogRead(voltageSensor;
int v2=map(Volt2,0,1024,0,2500);
```

```
value2=v2/100;
Serial.println("rectifier volatge is");
Serial.println(value2);
delay(3000);
if(value2<12){
// turn off whloe charging station
digitalWrite(relayPin2, LOW);
Serial.println("NO power sourse is avaible, Turn off whole charging terminat");
}
else{
// charge from rectifier
if(value3<13){
digitalWrite(relayPin, LOW);
Serial.println("charging from rectifier");
}
else{
Serial.println("bsttery is full");
digitalWrite(relayPin, HIGH);
}
}
}
}
```