

UGANDA INSTITUTE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY



PROJECT TITLE: AUTOMATIC LEAD ACID BATTERY CHARGING STATION

PREPARED BY: GROUP 16

NAME	REGISTRATION NUMBER	SIGNATURE
OLENY TONNY	2022/DEE/DAY/0646/G	
BWANIKA GEOFRY	2022/DEE/DAY/0680/G	
WAFULA STEPHEN NGOLOBE	2022/DEE/DAY/0636/G	
GAVOOLA EDRISA	2022/DEE/DAY/0676/G	
NATSAMI JOEL	2022/DEE/DAY/0967/G	
DDAMBA CHARLES	2022/DEE/DAY/0678/G	

A PROJECT PROPOSAL SUBMITTED TO UGANDA INSTITUTE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY(UICT) IN A PARTIAL FULLFILMENT FOR THE REQUIREMENT OF THE AWARD OF DIPLOMA IN ELECTRICAL AND ELECTRONICS ENGINEERING.

ACADEMIC SUPERVISOR:

NAME: MR. OCHOM EMMANUEL

TEL: 0775305193

SIGNATURE:.....

DECLARATION

We hereby declare that the information in this proposal is entirely our own piece and its content are based on the events and facts that we are personally going to be involved in, observe and perform during project activities.

This proposal is purely our own compilation and any collaborative contributions have been clearly indicated and acknowledged.

The work in this proposal is original and has been done by under general supervision of our supervisor Therefore, this project proposal has not been submitted to any other institution for any kind of award besides Uganda Institute of Information and Communication Technology (UICT).

PROJECT MEMBERS	REGISTRATION NUMBER	SIGNATURE
OLENY TONNY	2022/DEE/DAY/0646/G	
BWANIKA GEOFRY	2022/DEE/DAY/0680/G	
WAFULA STEPHEN NGOLOBE	2022/DEE/DAY/0636/G	
GAVOOLA EDRISA	2022/DEE/DAY/0676/G	
NATSAMI JOEL	2022/DEE/DAY/0967/G	
DDAMBA CHARLES	2022/DEE/DAY/0678/G	

APPROVAL

This is to certify that this project proposal has been done **by** the student of the above registration numbers. The proposal has been presented in accordance with the guide lines governing award of diploma in electrical and electronics engineering at Uganda institute of information and communication technology (UICT)

The information in this proposal is the students own work and is a true record of the work that will be done during project activities.

This proposal therefore has been approved for submission to the Department of ICT and Engineering at UICT.

ACADEMIC SUPERVISOR:

NAME: **MR. OCHOM EMMANUEL**

SIGNATURE:.....

DEDICATION

We dedicate this proposal to our families, relatives and friends for the financial assistance, social support and any other form of support they have rendered to us from the start of the entire course.

We also dedicate this proposal to our loving Principal **Dr. Fredrick E. Kitoogo (PHD)** and the entire institution of **UICT**. All the developments and research conducted in effect of this particular project was aimed at enabling us excel in our education and equip us with the skills necessary to complete in the technology market and industry at large.

ACKNOWLEDGEMENT

First and foremost, we thank Almighty God for the knowledge, wisdom and provision analysis, we would like to express our special thanks of gratitude to our lecture **MR. OCHOM EMMANUEL** who gave us the golden opportunity to do this wonderful proposal, which provided us at Uganda institute of information and communication technology (UICT) an opportunity to explore the new horizons and potentials in the field, more so engineering in particular. We sincerely express our gratitude towards our fellow students. **MAY GOD REWARD ALL OF YOU IN ABOUND**

TABLE OF CONTENTS

DECLARATION.....	II
APPROVAL	III
DEDICATION.....	IV
ACKNOWLEDGEMENT	V
LIST OF FIGURES	VIII
LIST OF TABLES	IX
LIST OF ACRNYOMS.....	X
CHAPTER ONE	1
1.1 INTRODUCTION.	1
1.2 BACKGROUND OF THE PROJECT	1
1.3 PROBLEM STATEMENT.....	1
1.4 GENERAL OBJECTIVE	1
1.5 OBJECTIVES OF THE PROJECT	1
1.6 RESEARCH QUESTIONS	1
1.7 SCOPE OF THE PROJECT.....	2
1.8 SIGNIFICANCE OF THE PROJECT.	2
1.9 JUSTIFICATION	2
CHAPTER TWO: LITERATURE REVIEW	3
2.1 INTRODUCTION	3
2.2 REVIEWS	3
2.3 COMPARATIVE EVALUATION	7
CHAPTER THREE: METHODOLOGY	8
3.1 INTRODUCTION	8
3.2 Data Collection Methods:	8
3.21 Literature Review	8
3.22 Online surveys.....	8
3.23 Observation.....	8
3.24 Interviews.....	8
3.3 Data Collection Tools:	8
3.31 Literature review checklist.....	8
3.32 Online survey platform	8
3.33 Questionnaires	8

3.4 FINDINGS.	9
3.41 9	
3.42 In terms of security	9
3.43 INTERACTIONS WITH THE USERS	9
4. SYSTEM STUDY, ANALYSIS AND DESIGN	10
4.1 SYSTEM STUDY	10
4.2 SYSTEM ANALYSIS	10
4.3 FLOW CHART FOR THE STEP AND STEP MOVEMENT OF THE SYSTEM	11
4.3 SYSTEM CONSTRUCTION	14
4.4 PSEUDO FLOW OF THE COMMANDS AND LISTS FOR OUR SYSTEM	15
4.5 CIRCUIT DIAGRAM	17
4.6 MATERIALS AND METHODS USED.	18
5.0 SYSTEM DEVELOPMENT, TESTING AND VALIDATION	27
5.1 SYSTEM INTERFACES	27
5.2 SYSTEM TESTING AND VALIDATION	29
6.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS	32
6.1 DISCUSSION	32
6.2 CONCLUSION	32
6.3 33	
6.4 FUTURE MODIFICATIONS	33
REFERENCES	34
APPENDICES.....	36

LIST OF FIGURES

Figure 1: Case diagram	Error! Bookmark not defined.
Figure 2- CIRCUIT DIAGRAM	17
Figure 3: Micro-controller ESP32	19
Figure 4: Coin Acceptor	21
Figure 5: SD CARD MODULE	21
Figure 6: DISPLAY UNIT	22
Figure 7: VERRO-BOARD	22
Figure 8: PUSH BUTTONS	23
Figure 9: Relay unit	24
Figure 10: DC voltage sensor	25
Figure 11: DC CURRENT SENSOR	25
Figure 12: GSM MODULE	26
Figure 13- pilot lamps	27
Figure 14-solenoid lock	27
Figure 15-FAN	28
Figure 16-Vero board(with components)	28
Figure 17- Component testing intergrated	29
Figure 18-GSM Module	30
Figure 19-Pilot lamps	30
Figure 20-Solenoid lock	31
Figure 21-Payment system	31
Figure 22: Questionnaire	36

LIST OF TABLES

Table 1: Specifications for Microcontroller ESP32	19
Table 2: Relay specifications	24
Table 3: Dc current sensor specifications	26

LIST OF ACRNYOMS

GSM	Global System For Mobile Communication
DC	Direct Current
IEC	International Electro-Technical Commission
Mhz	Mega Hertz
OSHA	Occupational Safety And Health Administration
Ghz	Giga Hertz
BLE	Bluetooth Low Energy
GPIOs	General Purpose Input Output Pins
SOC	State Of Charge
IOT	Internet Of Things
LCD	Liquid Crystal Display
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver Transmitter
RNG	Random Number Generator
PWM	Pulse Width Modulation
Ah	Ampere hours
OTP	One Time Password

CHAPTER ONE

1.1 INTRODUCTION.

Our project was an innovative solution to address the challenges in existing public battery charging stations for **(lead acid battery)** in Uganda. We designed an automatic battery charging station for lead acid batteries. Leveraged microcontroller technology (Arduino), our system detects when a battery is fully charged, it disconnects it from the charger, notify the user via a notification system (GSM). This efficient and user-friendly approach aims to optimize charging processes, reduce labor, saves time and enhance user experience.

1.2 BACKGROUND OF THE PROJECT

In many rural and urban areas, the availability of reliable and accessible battery charging infrastructure is limited. This lack of infrastructure poses significant challenges, particularly for users of electric vehicles, portable electronic devices, and backup power systems. The inability to charge batteries efficiently can lead to reduced mobility, increased downtime, and dependency on traditional power sources, which may not be sustainable or environmentally friendly.

Lead acid batteries are widely used in various applications in Uganda, including automotive, renewable energy, and consumer electronics. Current charging stations in Uganda often require manual monitoring and disconnection, leading to inefficiencies and potential safety hazards. Overcharging is a common issue in Uganda, resulting in reduced battery lifespan, safety risks, and economic losses. Microcontrollers have been successfully used in various projects, demonstrating their reliability and versatility. Uganda has a growing need for sustainable energy solutions, and our project will contribute to that goal.

1.3 PROBLEM STATEMENT.

In Uganda current lead acid charging stations face various challenges such as; overcharging, leading to reduced battery lifespan and safety risks. Inefficient manual monitoring, resulting in wasted time and labor. Limited charging capacity, causing long wait times for users and so on. which needs to be solved with more advanced technology as it is going to be solved in our project.

1.4 GENERAL OBJECTIVE

To develop and implement an efficient, user friendly and environmentally sustainable automated battery charging station to provide convenient and reliable charging services to the public.

1.5 OBJECTIVES OF THE PROJECT

1. To design and develop an automatic battery charging station for lead acid and lithium-ion batteries.
- 2.To implement a micro controller-based system to fully charge and disconnect batteries.
3. Develop a notification system to alert users when their battery is fully charged.
- 4.To conduct testing and validation to ensure safety, efficiency, and reliability.

1.6 RESEARCH QUESTIONS

- i. What will be the reasons of automatic public battery charging station?
- ii. What will be the impact of automatic public battery charging station.

1.7 SCOPE OF THE PROJECT

Design and develop an automatic battery charging station for lead acid batteries, utilizing Microcontroller technology. Implemented a notification system to alert users when their battery is fully charged, ensuring safe and efficient charging. Conduct thorough testing and validation of the system in a real-world setting to ensure reliability and performance. Evaluate user experience and system performance, gathering feedback to inform future improvements and expansion.

1.8 SIGNIFICANCE OF THE PROJECT.

The project will be able to provide valuable information to the general public, as it will contribute to the development of an innovative automatic battery charging station for lead acid and lithium-ion batteries, utilizing advanced technology (Micro controller) to enhance efficiency, safety, and user experience, Reduction of overcharging and associated risks, such as battery damage and safety hazards, Improvement of charging speed and convenience, saving time for users, Contribution to the growth of Uganda's battery charging infrastructure and promotion of sustainable energy solutions, Potential for scalability and replication in other regions.

1.9 JUSTIFICATION

Current manual charging processes are time-consuming, prone to errors, and lead to overcharging, reducing battery lifespan and posing safety risks, Uganda's growing demand for efficient battery charging solutions necessitates innovative and automated systems.

Advanced technology, such as Arduino microcontrollers, offers a reliable and programmable solution for automation. The project addresses a significant gap in the market, providing a unique and valuable solution for users. Uganda's government initiatives to promote renewable energy and reduce carbon emissions align with the project's objectives.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

Our project is about designing an automated battery charging station which leverages the Internet of things technology and automation which is user friendly and efficiency.

In this chapter we are going to research about the existing research on automated charging systems, user needs in the public spaces and lead acid battery management, We will be able to identify the gaps in existing or already done literatures in order to copy up with the user prefaces

2.2 REVIEWS

Charging system.

In various existing installations, batteries are kept floating on the line and are so connected that they are being charged when load demands are light and automatically discharged during peak periods when load demands are heavy or when the usual power supply fails is disconnected. In some other installations, The battery is connected to the feeder circuit as and when desired, allowed to discharge to a certain point, then removed and recharged for further requirements [1].

For batteries other than the floating and system governed type, following two general methods (though there are some variations of these) are employed (David and Thomas, 2010) [2]. i.e The constant current system and constant voltage system

Battery Monitoring

It is useful to know the state of charge of a battery since charging a battery continually when they are already charged as this would degrade the batteries. [3]

The solid-state voltmeter described in the article/project allows continuous monitoring of the battery voltage so that incipient failure can be spotted at an early stage. The circuit will also indicate any fault in the car voltage regulator which may lead to overcharging and damage to the battery. Battery voltage can of course be measured using a conventional moving coil voltmeter.

However, as only the voltage range from about 9 to 15v is of interest only the top third of the scale of a 15v meter would be used, unless a suppressed zero facility was added. Moving coil meters are also fairly delicate mechanically and not so efficient.

Existing Current charging infrastructure primarily focusses on level 2 and DC Fast charging for lithium-ion batteries in larger vehicles. While these systems are crucial for long-distance travel, they are not suitable for the smaller EVs and lead-acid batteries this project targets. Additionally, research by [Wang et., 2022] highlights the limitations of current public charging infrastructure for smaller Gas vehicles, emphasizing the need for dedicated solution. A dedicated single- or three-phase 208-240V AC circuit is generally used for Level 2 charging. The charging station is protected by a circuit breaker and GFI. Again, PFC, AC/DC conversion, DC/DC boost conversion, battery management, and various filtering functions are carried out within the charger. A safety interlock and communication interface between the charging station and the on-board EV charger is established via the coupler. With a peak current of 80A (since 2009), the maximum delivered power can be up to 20kW. The charging cables are permanently fixed to the charging station.

[4].

About the existing battery chargers:

A battery charger is an electrical device employed in charging batteries that are usually charged by battery charger. These are storage batteries also known as “accumulators”.

The charger is made up of various electrical and electronics component which are for the purpose of charging are grouped into your basic unit, they are:

The power supply units

The smoothing circuits

The regulating unit and

Regulated D.C charging units

A Battery charger comes in various designs and voltage. The choice of a particular charger depends largely in Ah size of battery or batteries which charge the mini battery charger could be used to charge batteries whose voltage ranges from 6 – 12 volts. The bigger battery changes are for batteries with voltage ranging from 12 – 48 volts. These are the heavy duty batteries.

The battery charge is built in such a way that it delivers a constant value of DC current into the battery it is charging in the opposite direction from which current flows on the batteries during discharge one cannot successfully design a battery charge without a fundamental understanding of the accumulator because it also makes up the operation .

Charger Types

- Unregulated Transformer-Based Charger

These are the absolute cheapest chargers around. They consist of a wall mount transformer and a diode. The transformer is designed to deliver 13 to 14 volts over a reasonable current range. The biggest problem with this approach is that when the current tapers off, the voltage raises to 15, 16, 17, even 18 volts. At these high voltages electrolysis of the water in the battery starts in. These must not be left to trickle or float charge a battery, they must be disconnected when the battery is fully charged. This is not a problem with flooded batteries as long as you check the water periodically and refresh it. Sealed lead acid batteries can recycle the generated gasses as long as they are being overcharged at less than $C/3$. However, leaving the battery to be overcharged even at $C/10$ will corrode the plates if left on for weeks at a time. The transformer is so designed as to limit the current while the battery is in absorption mode. As the battery voltage rises the current decreases to top off the battery. Because the transformer is used to control the current and voltage these chargers are typically heavy and get hot [5].

- Constant Voltage Chargers

A circuit that is set for the maximum allowable charge voltage, but has a current limit to control the initial absorption current can produce a very nice charger. This type of charger can both charge at a reasonable rate and maintain the battery at full charge without damage.

Not all constant voltage chargers are made equal, however, because the maximum voltage is a function of temperature. A temperature compensated charger is a little more expensive, and should be used where the temperature varies significantly from room temperature [6].

- Constant current chargers

A more sophisticated and not much more expensive charger uses an electric circuit to control the charging current. This method is useful for recovering batteries that have suffered from extensive storage without charging, but is capable of overcharging a battery if there is not some voltage limiting function, usually from the transformer. For this reason these chargers are limited to slow charging [6]

- Taper chargers

Another cheap way to charge a sealed lead acid battery is called a taper charge.

Either constant voltage or constant current is applied to the battery through a combination of transformer, diode, and resistance. The unregulated chargers mentioned above are taper chargers. A better, and not very expensive, alternative is a regulated taper charger. These do not let the voltage climb higher than the trickle charge voltage, so they can be also be used to maintain a battery. They won't damage the battery if left on charge too long, and they do not change their charging characteristics if the line voltage should change [5].

- Regulated taper chargers are very useful when you need a 12V or 24V battery backup.

A taper charger in parallel with the battery, in parallel with the load makes an effective battery back-up. You should take care to ensure that the taper charger is designed to give continuous current equal to the load plus some left over for battery charging. It is also important that the current limit of the taper charger is the voltage-cut-back method, and not the hiccough method or other PWM methods.

There are two ways to make a regulated charger. The first is to use a transformer and a simple voltage regulation circuit. This has the disadvantages of weight and heat, but it is still inexpensive. The second uses a modern switching power supply in a wall mount or desk mount package. These low power high frequency switchers are surprisingly cheap, efficient, and small. They are rapidly taking over the overnight charging requirement in consumer equipment (Ali and John, 2010) [6],

Method of Charging the Lead Acid Battery

There are a few methods that are existing or known to be able to charge a lead acid(car) battery but in this case, we are focusing the constant current-constant voltage charging method where it uses a voltage based algorithm that is the same with the lithium ion battery charging method too where a usual charge time for a sealed lead acid battery can be up to 16 hours. There is a faster way to charge the battery which is known as the fast battery charging method where it uses a high current pulse that is pumped into the battery at a faster rate with high capacity of current which will cut down on the charging time but at the same time, if it is not under close supervision, it might damage the battery due to its high current pumping into the battery. The constant current-constant voltage charging method will be explained and further discussed in 3 sections which is the constant current charge, constant voltage (topping charge) and the float (trickle charge) [7].

- Constant Current Charging

This constant current charging is the first phase of the recharging of the batteries where it usually takes up 50% of the charging period. Usually a battery that has just been discharge have a voltage of 11.50V approximately and when it undergoes the charging process, this constant current charging will ensure that the voltage of the battery rises to a voltage that is determine by the characteristics of the battery itself which will be approximately 13V with a relatively uniform current flow charging the battery.

This helps to eliminate the imbalances of cells and batteries that are connected in series which is the most appropriate for cyclic operation where a battery is required to obtain a full charge overnight. In this phase, the battery will be charged up to 70% approximately in the range of 4-7 hours and the other 30% is charged using the trickle charging method. The change of phase from the constant current charging to the next phase occurs when the battery reaches its voltage limit. This method is widely used for most battery chargers. [8].

- Topping (Constant) Charging

This charging takes place when the lead acid battery voltage increases and stays constant at its voltage limit which will be in the range of 12V to 13V. For every standard lead acid battery, the approximate pre-determined battery is 12.6V. Once it reaches its saturated voltage, the current that is applied into the battery will start to decrease where it leads to a full charge condition once it reaches 3% of the rated current. This process is mainly to ensure that the battery cells remains at the same voltage in the battery pack. During the charging and discharging process, each cell in the lead acid battery might react differently to other cells that are in the battery due to certain factors such as the quantity of charge in each cell is different. [9]. Hence during the charging process, this topping charge will help to give a slight overcharge to bring the other cells up to full charge. Topping charge should be applied every six months to avoid voltage drop below 2.10V per cell. (Anu, 2007) [8].

The stronger cells in the battery will absorb the overcharge through the dissipation of heat from the boiling and gassing while the weaker cells will absorb the current from the overcharge until it is sufficient. This topping charge period should be long enough to help pull the cells in the battery up to a fully charged condition.

This topping charge is also used to complete the process of fast charging where it is left to charge for at least 30 minutes with a low current. If the battery is used regularly, it will tend to have high leakage current which means when it is left on shelf, the process of self discharging happens rapidly. This high rate of leakage might not attain this low saturation current.

A precautionary step should be taken to ensure that overcharging doesn't take place for too long of a time because once the lead acid battery is being overcharged, the electrochemical process will cause it to heat up and boil. The phenomenon of hydrogen gas been let off at the negative cathode plate and oxygen gas being let off at the positive anode takes place due to any charging current beyond that required to liberate the small amount of sulphate radicals from the plates, ionizes the water in the electrolyte. Hence, triggering the process of electrolysis where it separates the water into hydrogen and oxygen gas. While this process occurs to form water vapor, the presence of flammable and potentially explosive hydrogen gas will encourage charging to be done in a well ventilated area. If this is not conducted properly, it will result in a battery explosion due to the hydrogen gas that is being released by the boiling acid. This brings more bad news for sealed lead acid battery where it have a higher chance of an explosion to happen as it has nowhere for the gas to exit hence indirectly building up the pressure in the case leading to an

explosion. On the other hand, at low temperature, the electrolyte might freeze up, affecting the performance of the battery. The safe operating temperature for a battery pack is usually 80 Fahrenheit or 26.37 degree Celsius (Anu, 2007) [8]

- Float (Trickle) Charge

The float charging is also known as the trickle charging method where its definition is a charging current that can be applied to the battery without damaging it or simply defined as slow charge. This process keeps the voltage at a constant where else the current will be operating at a very low level. The float charge compensates for the self discharging process that happens when the battery is put on shelf where it will self discharge at a rate of 2% - 3% every month. Aging batteries will be an issue when the float charge is set due to the different age condition that each of the cells have. This can be seen where % float current that is too high for the aging cell will starve the stronger cells in the same battery causing sulfation due to undercharging. The figure below shows the characteristics of the constant current constant voltage charging [10] voltage.

2.3 COMPARATIVE EVALUATION

	SYSTEM FUNCTIONALITY				
EXISTING SYSTEMS STUDIED	Floating online	Efficient monitoring	Temperature regulation charging methods	Charging methods	Notification Alert
CHARGERS	NO	GOOD	POOR	GOOD	NO
SEMBO STATION (NAKAWA)	NO	Poor	Poor	Good	NO
SYSTEM B	YES	Poor	POOR	Unidentified	NO
OUR SYSTEM	NO	Very Good	Very Good	Very Good (combined)	YES

CHAPTER THREE: METHODOLOGY

3.1 INTRODUCTION

This chapter will deal with the techniques and tools used to execute and develop an automated charging station. It will be able to demonstrate the feasibilities through outlining the steps to be followed to achieve the project goals. Also provide **transparency by** revealing the methods and tools to be used to collect data, analyze findings, and design the project

3.2 Data Collection Methods:

3.21 Literature Review: Reviewed existing research papers, industry reports, and product manuals on automated battery charging systems and lead-acid battery charging best practices and prices

3.22 Online surveys: Conducted online surveys targeting potential users (e.g. mostly rural areas with no back up means of electricity) the urgent need for low cost power in order to run there business infrastructures like mini Saloons.

3.23 Observation: We used our naked eyes to assess the already available battery charging stations, analyzing it and then determining the areas of innovation.

3.24 Interviews: Here we interacted with the owners of the already existing battery charging stations, in this way we got exposed with most of the challenges they face during battery charging.

3.3 Data Collection Tools:

3.31 Literature review checklist: Ensured consistent evaluation of relevant literature sources.

3.32 Online survey platform (e.g., Google Forms, SurveyMonkey, Online): Facilitated survey creation, distribution, and data collection.

3.33 Questionnaires: We wrote down questions to be used during the interviews, where we organized questions in there order.

We used our own **naked eyes** for observation and noted the results on the paper.

Procedure:

- Conducted a comprehensive literature review to identify existing technologies, design considerations, and user needs.
- Distributed the survey through communication with community and social media groups relevant to the target audience that charge there batteries to the already existing stations.
- During the interview we first introduced our selves, then asked questions while noting the answers somewhere.

Consultation

- We shall schedule a consultation meeting with our project supervisor to discuss and get help
- In case of any inconveniences during the project execution. We will also get more innovative
- criteria to add through also continued consulting the existing local technology.

3.4 FINDINGS.

We interacted with the existing charging structures and the users:

3.41 Existing Structures.

The methods used for checking of fully charged batteries in these structures:

- Some use meters which are sometimes inaccurate and most of the users don't know how to use them hence it is easy to cheat the customers.
- Others use bare hands to feel the battery temperature and if its warm, they conclude that the battery is full and if the temperature is found to be cold it said that the battery is not readily full. Without a full awareness of the real percentage, this can lead to risks of overcharging.
- Most of the existing stations have a poor charging spaces for the batteries with no proper temperature regulating features in case when the batteries heat up which reduces the battery health.

3.42 In terms of security

- We found out that customers can unknowingly swap batteries if the batteries resemble in appearance, this sometimes lead to quarrels between the owners and customers.
- We also found out that sometimes the attendants they accidentally connect the positive and negative terminals of the charger in a wrong way to the batteries causing short circuits which leads to damaging of the battery.
- There is also data insecurity. This is mainly found with smart charging systems where by there is a risk of data breaches where personal and payment information can be compromised for example a lady can take her battery for charging and leaves her contact with the attendants to call her back when her battery is full and instead he shares her contact to other people who in sometimes starts to stalking her.
- We also found out that some technicians do not adhere to the industry standards and regulations e.g (OSHA, IEC) to ensure safe and legal operations.

3.43 INTERACTIONS WITH THE USERS

The following are the finding we got from the users.

- The users lack proper ways to of getting notified for when the battery is full which causes an insufficiency in case when the user depend solely on the power obtained from the batteries.
- Some users do not follow the manufacturers guidelines for charging intervals and maintenance routines. This is mainly because they do not know whether their batteries need to be charged or not. Awareness of potential hazards, such as hydrogen gas emission is crucial.

4. SYSTEM STUDY, ANALYSIS AND DESIGN

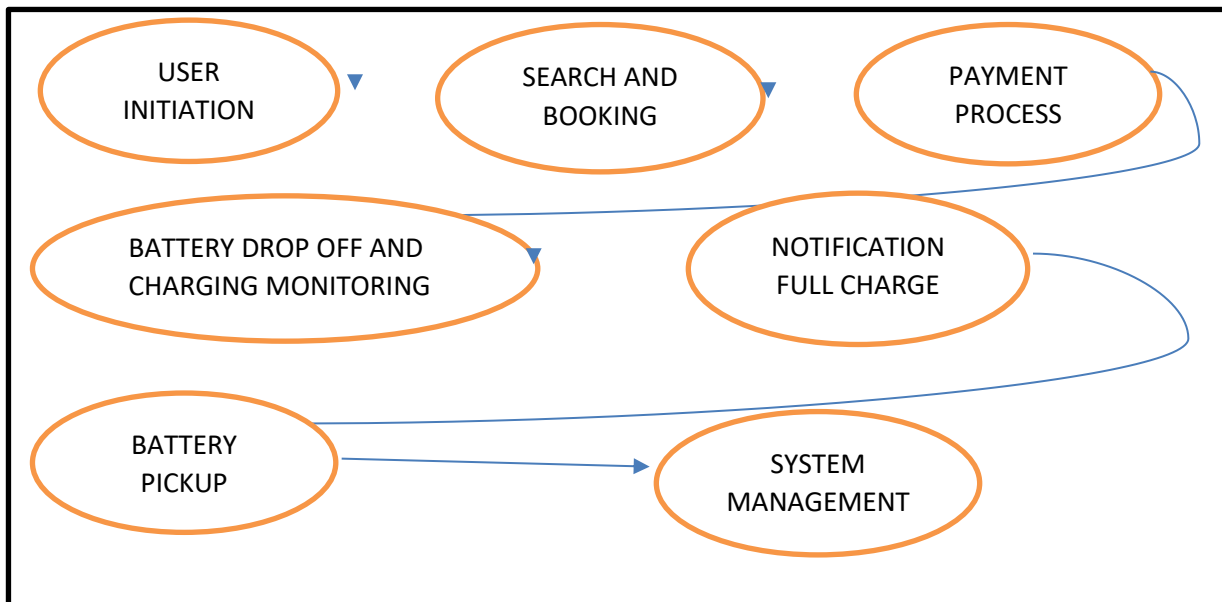
4.1 SYSTEM STUDY

We analyzed the existing infrastructure obtained the following information. The areas for innovation as stated below.

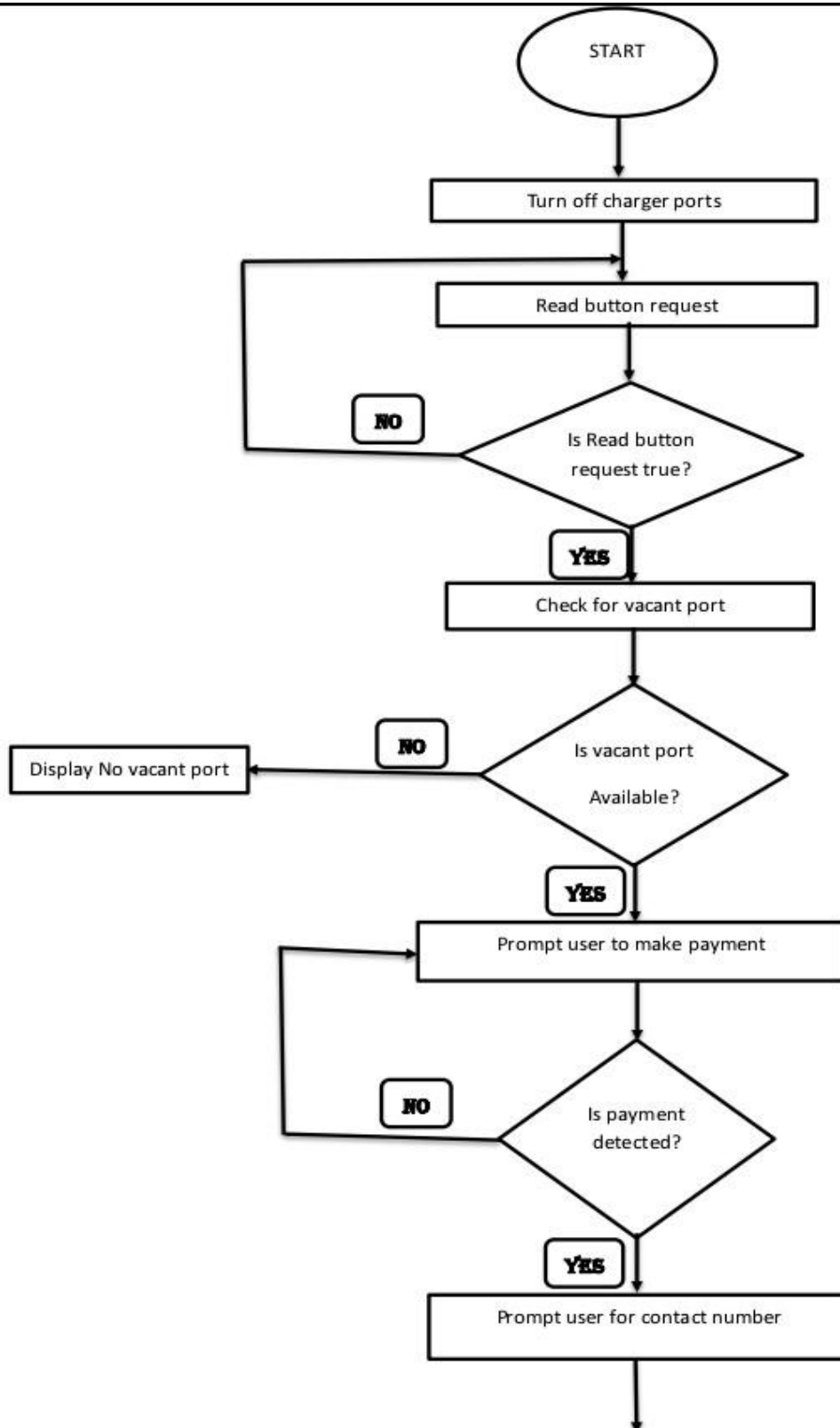
- Poor charging environments: The existing local charging stations environments for the batteries. Are insignificant in away they lack proper air conditioning or ventilation, crowding of batteries with proper spacing which can lead to short circuits.
- Untimely full charge predictions: The existing stations lack efficient ways for monitoring and detecting the already full charged batteries. In away they keep regular monitoring the battery with the use of a multimeter and some use there hands to feel if the battery is warm, then its full.
- In terms of safety: Due to a lack of proper organized structure for collecting the users data and then allocating it to his/her battery, batteries are easily misplaced and exchanged with different customers.

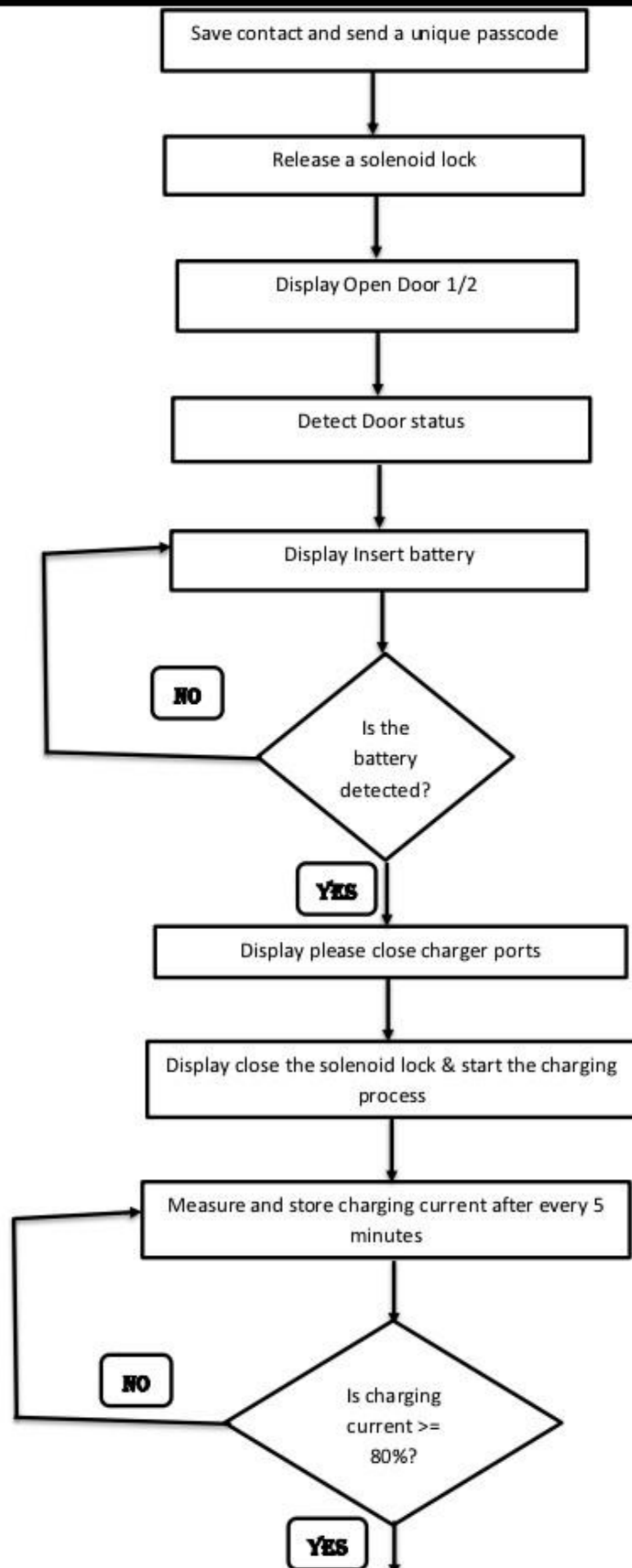
4.2 SYSTEM ANALYSIS

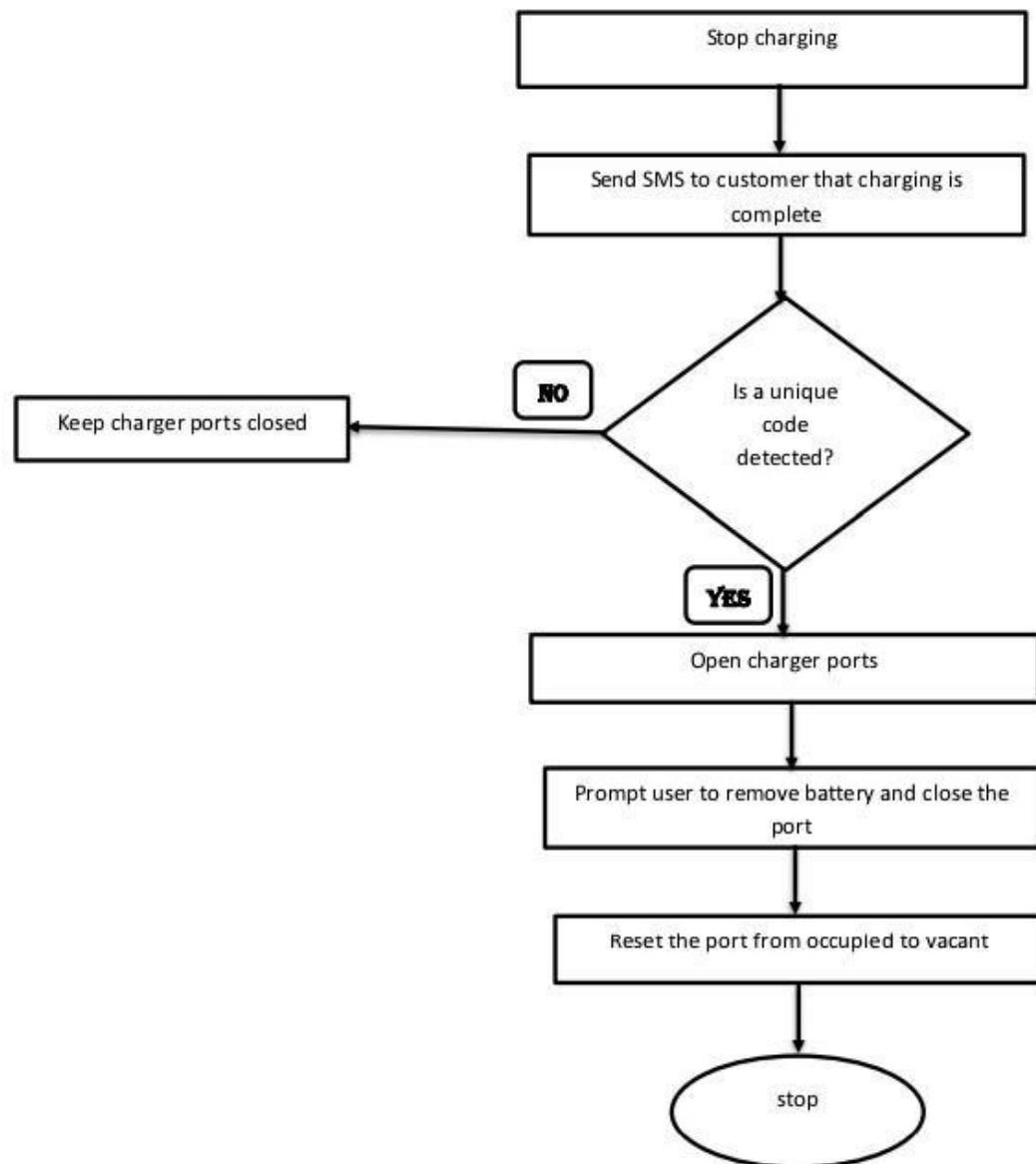
Case flow diagram



4.3 FLOW CHART FOR THE STEP AND STEP MOVEMENT OF THE SYSTEM

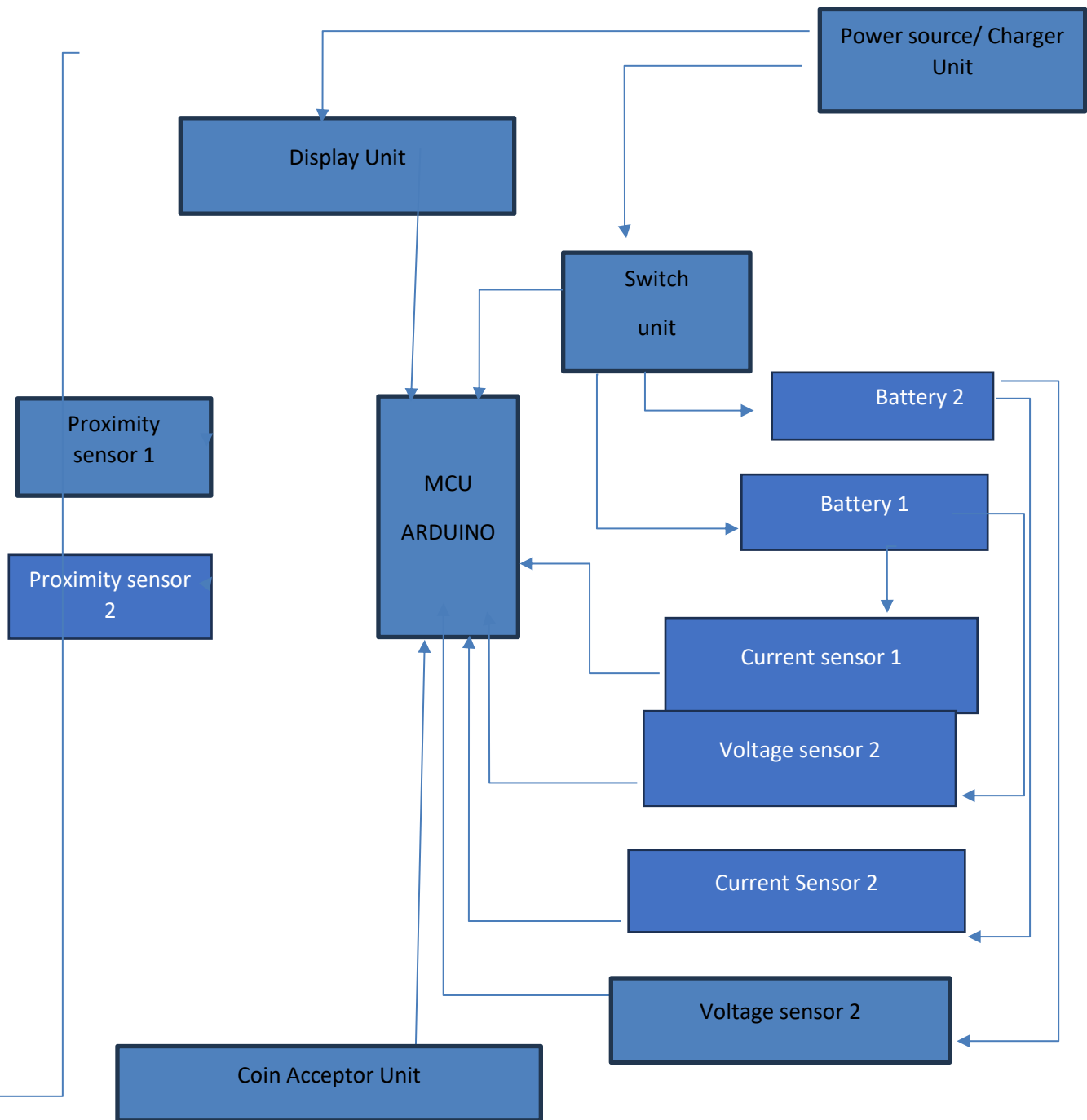






4.3 SYSTEM CONSTRUCTION

4.3.1 Block diagram for automated public charging station



4.4 PSEUDO FLOW OF THE COMMANDS AND LISTS FOR OUR SYSTEM

1. detect payment request from payments request button.
2. from the voltage sensors (comparator out puts to the microcontroller).
3. if battery presence is detected on both charging ports? then the coin unit must stay off
4. display "Charge ports not available".
5. the solenoid locks must stay closed, (hence their control pins are kept low)
6. But if payment request is detected and at least one of the voltage sensors indicate absence of a battery.
7. record in EEPROM the specific vacant charge port number either one or port 2.
8. prompt the user to insert the coin into the coin acceptor.
9. if no coin signal is not detected in a duration of 30seconds, the system just defaults to no payments request.
10. if payment is made with in the 30second duration.
11. the system prompts the user to type his/her phone number using the keypad.
12. this is an 8digit number sequence which is scanned to check for the following:
 - a. the numbers(characters) are exactly 8 in counting.
 - b. no alphabetic letters must be allowed (A, B, C, D)
13. the display must show the first two digits "07" on the LCD to enable the user type in correctly the remaining digits of his/her contact number.
14. the " * " key will act as the backspace key. and the " # " key will act as the ENTER (confirmation) key.
15. the phone number is displayed as its being typed on the screen.
16. display to screen "Inserted correctly please wait...."
17. if all is inserted correctly, the phone number is saved in EEPROM to be used later on in the process.
18. display "please wait for OTP code".
19. then using the gsm800c the system sends an SMS to the previously type phone number with a randomly generated OTP code (3 characters are alphabetic and 3 are numbers saved in EEPROM too), to be used when retrieving the battery after full charge.
20. from the voltage sensors (comparator out puts to the microcontroller) we must have detected and saved which charge port is vacant.
21. then on the display prompt the user to open that specific vacant charger port's door, right after activating its solenoid lock to open up.

22. with the door contact sensor of that charge port we detect opening of the door for the charge port, if opened, prompt the user to insert the battery correctly.
23. if the battery is detected from the voltage sensor, user is prompted to close the charge port door very well.
24. this can be confirmed by the door sensor.
25. the solenoid lock is deactivated (pulled low) to lock the charge port.
27. activate the charging relay for that specific charge port.
28. using the current sensor measure and save to EEPROM the initial charging current.
29. this current is to be periodically checked (1minute interval) to see whether the charging current has dropped by 1% of the initial saved current.
30. deactivate the charging relay, and send an SMS to the user's phone number that " dear customer your battery is fully charged to 100%, please pick it from the charging station"
31. periodically check the temperature from the ds18b20sensor and turn on the fan when it exceeds 30 degrees Celsius and off if lower than 30 degrees.
32. using the same payment button, we detect a 5-second-long press, where if its detected
33. prompt the user to type n his/her previously received OTP code into the key pad with in a duration of not more than 40seconds.
34. if the OTP is correct, Activate the solenoid lock to open the lock and prompt him/her to remove the battery.
35. if the battery is removed, which is confirmed by the door sensor and voltage sensor, we prompt him/her to close the door and we deactivate the solenoid lock to lock the door again.
36. for the pilot lamps, each char port has two. red for still charging, and green for full charged. both will remain off is there is no battery at all.

4.5 CIRCUIT DIAGRAM

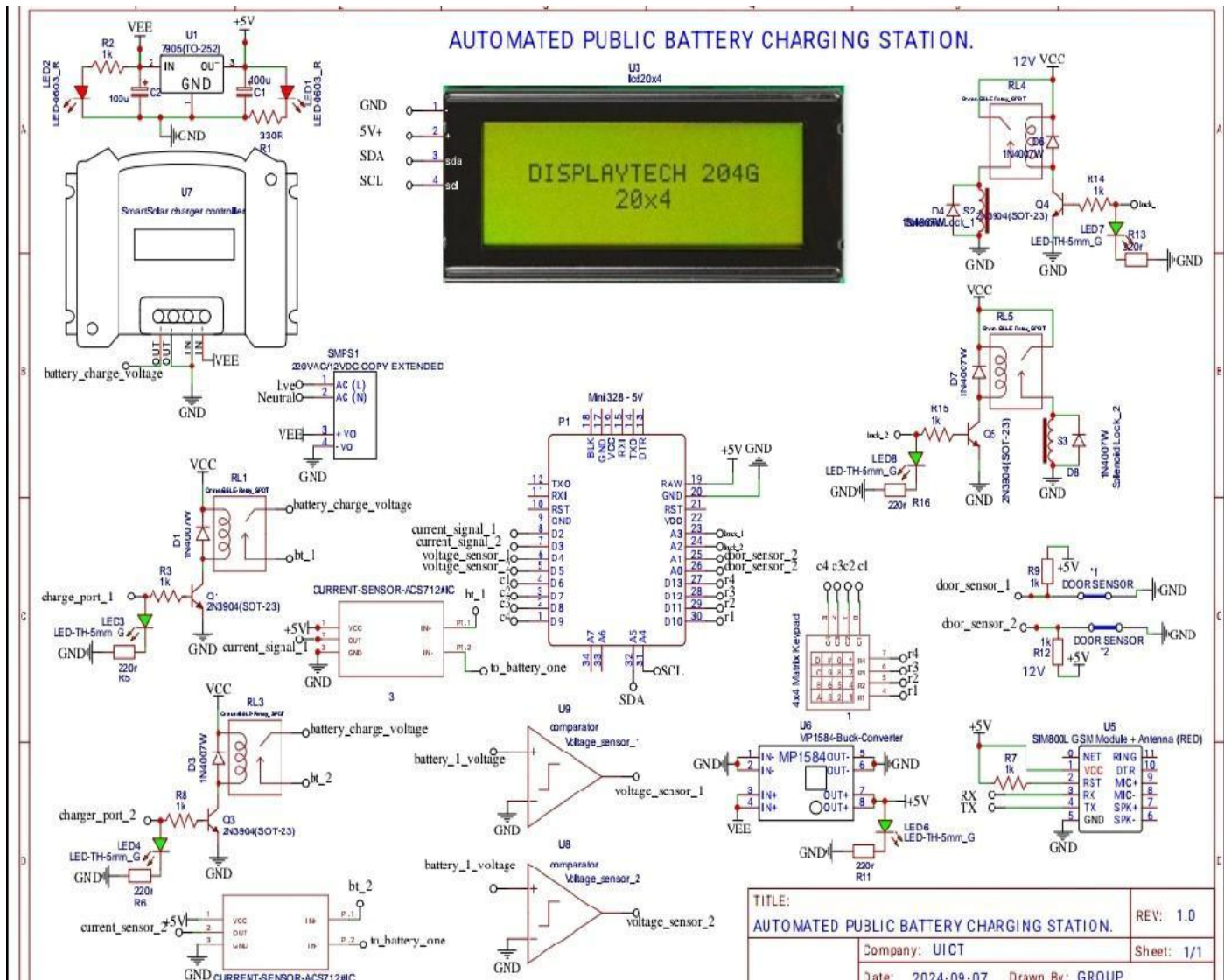


Figure 2- CIRCUIT DIAGRAM

The purpose of wiring diagram was to illustrate the visual representation of the connection interaction for given hardware to the micro-controller. This helped us in easy trouble shooting, reduce errors, increase efficiency

4.6 MATERIALS AND METHODS USED.

MATERIALS

1. Micro-controller ESP32
2. AC to DC converter
3. Relay Unit
4. Coin Acceptor
5. Display Unit
6. Indicator Leds
7. Cabling
8. Vero Board
9. GSM module
10. SD card module
11. Push button
12. Temperature sensor
13. DC current sensor
14. DC voltage Sensor
15. Male Header Pin
16. Female Header Pin
17. Capacitors
18. Solder Wire
19. Milliscenous

4.61 Micro-controller (ESP32)

The ESP32 is a versatile and widely-used microcontroller and Wi-Fi/Bluetooth system on-chip (SoC) produced by Espressif Systems. SoC, is essentially an integrated circuit that takes a single platform and integrates an entire electronic system onto it, for an specific application. Contrary to a simple microcontroller (like Atmega324p Arduino Uno), that offers several general usage peripherals instead of a specific set of tools for one application.

In the case of ESP32, this was designed to be an IoT SoC with already integrated Wifi, Bluetooth, and Cryptographic hardware acceleration to allow the user to access the internet.

This micro-controller will be the brain of our system through receiving sensor values from for example current sensors, voltage sensors, temperature sensors and responds to them accordingly. [11]



Figure 3: Micro-controller ESP32

SPECIFICATIONS OF MICRO-CONTROLLER ESP32

Table 1: Specifications for Microcontroller ESP32

PROPERTY	SPECIFICATION
Processor:	- Dual-core Tensilica LX6 microprocessor (up to 240 MHz) - Single-core Tensilica LX6 microprocessor (up to 160 MHz) for low-power applications
Memory:	- 4 MB flash memory (embedded) - 520 KB SRAM (embedded) - External flash memory support (up to 16 MB) - External PSRAM support (up to 8 MB)
Wireless Connectivity:	- Wi-Fi: 802.11 b/g/n/e/i (2.4 GHz) - Bluetooth: 4.2 BR/EDR and BLE standards - Bluetooth Low Energy (BLE) support
Peripherals:	- 34 GPIOs (multiplexed with other functions) - 12-bit SAR ADC (up to 18 channels) - 8-bit DAC (2 channels) - I2S (2 channels) - I2C (2 channels) - SPI (4 channels) - UART (4 channels)

	- RMT (Remote Control) module - Pulse Counter module - LED PWM module
Security:	- Secure boot and flash encryption - 1024-bit RSA/ECC acceleration - Random Number Generator (RNG)
Power Management:	- Power consumption: 50 mA (average), 5 mA (sleep mode) - Operating voltage: 2.2-3.6 V - Power-saving features: sleep modes, dynamic voltage regulation
- Temperature range	40°C to 125°C

4.62 COIN ACCEPTOR

coin acceptor is a device that allows a machine to accept coins as a form of payment. The coin acceptor will serve the purpose of **collecting payment from users for the battery charging service**.

Here's a breakdown of its role:

- **Accepts coins:** The coin acceptor is designed to recognize and accept valid coins inserted by users.
- **Processes payment:** It verifies the coin's denomination (e.g., quarter, dollar) and translates it into a credit for the charging service.
- **Potentially integrates with the system:** Depending on the chosen coin acceptor model, then communicate with the system's microcontroller to signal a successful payment and initiate charging. [12]



Figure 4: Coin Acceptor

4.63 SD CARD MODULE

The SD card module will be specially used for require data logging.

The Arduino will create a file in an SD card to write and save data using the **SD** library. There are different models from different suppliers, but they all work in a similar way, using the SPI communication protocol. The module used in this tutorial is the one shown in figure below (front and back view). [13]



Figure 5: SD CARD MODULE

4.64 DISPLAY UNIT

The Liquid Crystal library allows you to control LCD displays that are compatible with the Micro-controller. This display unit will be used for the following. [14]

Displaying charging status: The display can show users the current charging status of their battery, including percentage charged, estimated time remaining, and any error messages.

☐ **Booking confirmation:** It can visually confirm a user's booking, displaying the assigned charging bay and estimated completion time.

□ **Payment processing:** The display can guide users through the payment process, showing the amount due and confirmation upon successful payment.

Battery information: It can display details about connected batteries, such as battery type, voltage level, and charging history.



Figure 6: DISPLAY UNIT

4.65 VERO BOARD

Veroboard is a brand of stripboard, a pre-formed circuit board material of copper strips on an insulating bonded paper board used to make electronic circuits, where some of the electrical connections are formed by strips of copper on the underside of the board. Veroboard is a printed circuit board that's designed with rows of copper tracks with holes drilled in then for electronic components to be soldered to construct electronic circuits. It is characterized by a 0.1 inch regular grid of holes, with wide parallel strips of copper cladding running in one direction all the way across one side of the board.

We will use it to create our own circuit for intergration of the micro-controller and other gadgets. [15]

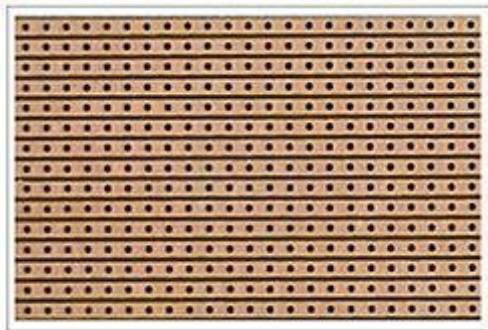


Figure 7: VERRO-BOARD

4.66 PUSH BUTTON

Push button switches (also referred to as pushbutton switches) are electrical actuators that, when pressed, either close or open the electrical circuits to which they are attached. They are capable of controlling a wide range of electronic gadgets.



Figure 8: PUSH BUTTONS

4.67 RELAY UNIT

A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals.

It is normally open and one normally closed contact. It can control DC or AC signal. It will be used for some of the following importance.

- **Connecting and disconnecting batteries:** The relay acts as a switch, controlling the flow of high current between the power source and the battery being charged. When a user initiates charging, the control system activates the relay, allowing current to flow and begin charging. Once the battery is fully charged, the relay disconnects the battery, preventing overcharging.
- **Safety measures:** Relays can be integrated with safety features to protect the batteries and the charging station. For example:
 - **Overcurrent protection:** The relay can be triggered to cut off power if the charging current exceeds a safe limit, preventing damage to the battery or the station.
 - **Short circuit protection:** In case of a short circuit, the relay can rapidly disconnect the battery, minimizing the risk of fire or overheating.
- **Power management:** If your station has multiple charging bays, relays can be used to manage the overall power distribution. The control system can sequence the activation of relays to prevent overloading the power supply when multiple batteries are charging simultaneously. [16]



Figure 9: Relay unit

Specifications for the Relay unit

Table 2: Relay specifications

Property	Specification
Connector Type	Quick Connect
Contact Material	Brass
Contact Type	Normally Closed
Current Rating	10 Amps
Mounting Type	Screw Mount

4.68 DC VOLTAGE SENSOR.

The voltage sensor module is a conventional method used to determine, monitor, and measure the supply of voltage in a device. DC Voltage sensors can sense DC voltages. ADIY DC voltage sensors are highly precise sensors that work on the principle of the potential divider rule. As a result, it reduces the input voltage by a factor of 5. This allows us to use the analog input pin of microcontrollers to observe the voltage above the threshold level. With a small compact device, both voltage and current measurements are combined into a single physical device. For 0-5v analog input, the output measured up to 25v. ADIY dc voltage sensor consists of 5 pins in which two of which are on the two-pin screw terminal and three are male header pins.

The dc voltage sensor will be used for;

- ☐ **Monitoring battery voltage:** The sensor continuously measures the DC voltage level of the connected battery. This information is crucial for the control system to regulate the charging process.
- ☐ **Automatic charging control:** Based on the voltage reading from the sensor, the control system can:
 - **Initiate charging:** When a battery is placed in the station and the user confirms charging, the control system checks the voltage. If it's below the discharge threshold (typical for lead-acid batteries), the system activates the relay to connect the battery and begin charging.
 - **Regulate charging current:** The control system can adjust the charging current based on the measured voltage. As the battery approaches full charge, the voltage will rise. The control system can then reduce the charging current to prevent overcharging, which can damage the battery.

- **Terminate charging:** Once the voltage reaches the fully charged level (specific for lead-acid batteries), the control system detects it through the sensor and disconnects the battery using the relay. This prevents overcharging and ensures optimal battery life.



Figure 10: DC voltage sensor

4.69 DC CURRENT SENSOR

A DC current sensor is a device used to measure the flow of direct current (DC) in an electrical circuit.

It will be used the following.

- ☐ **Monitoring charging current:** The DC current sensor measures the actual current flowing into the battery during the charging process. This information complements the voltage data for a more comprehensive picture of the battery's state.
- ☐ **Enhanced charging control:** By combining voltage and current data, the control system can achieve finer control over charging:
 - **Adaptive charging:** The system can adjust the charging current not just based on voltage but also on the actual current being drawn by the battery. This allows for more efficient charging, especially for batteries with varying capacities or initial charge levels.
 - **Faster charging (with caution):** In some scenarios, the control system might be able to safely increase the charging current if both voltage and current readings indicate the battery can handle it. However, implementing faster charging strategies requires careful consideration and safety measures to prevent overheating or damage.
- ☐ **Improved diagnostics:** Analyzing both voltage and current data can provide valuable insights into battery health. [17]

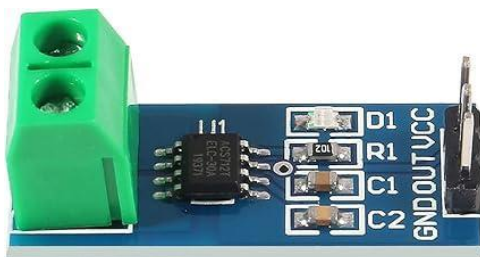


Figure 11: DC CURRENT SENSOR

SPECIFICATIONS OF DC CURRENT SENSOR.

Table 3: Dc current sensor specifications

PROPERTY	SPECIFICATION
Supply Power	5V
Measuring range	5A / 20A / 30A
Analog output	200 mv/A
PCB board dimension	31x13 mm

4.70 GSM MODULE

A GSM (Global System for Mobile Communications) module is a versatile component used for cellular connectivity and wireless communication.

With a GSM module and a cellular subscription, the station will be able to connect to a mobile network. Allowing monitoring and control capabilities:

- **Real-time status updates:** Users can receive SMS or mobile app notifications on their phone regarding their battery's charging status (percentage charged, estimated completion time).
- **Station monitoring:** Can remotely monitor the overall station health, including the number of available charging bays, occupied bays, and any potential error alerts.



Figure 12: GSM MODULE

5.0 SYSTEM DEVELOPMENT, TESTING AND VALIDATION

5.1 SYSTEM INTERFACES

A. Pilot lamps



Figure 13- pilot lamps

The pilot lamps as described before from the prseduo code the red one is for vacant port and the green one is to show the port is occupied.

B. SOLENOID LOCKS

These uses electromechanical locking mechanism which uses electromagnet coil to open and close.



Figure 14-solenoid lock

We used the solenoid lock to automatically lock and unlock the ports by the signal from the micro-controller after switching

C. FAN (12DC BRUSHLESS)

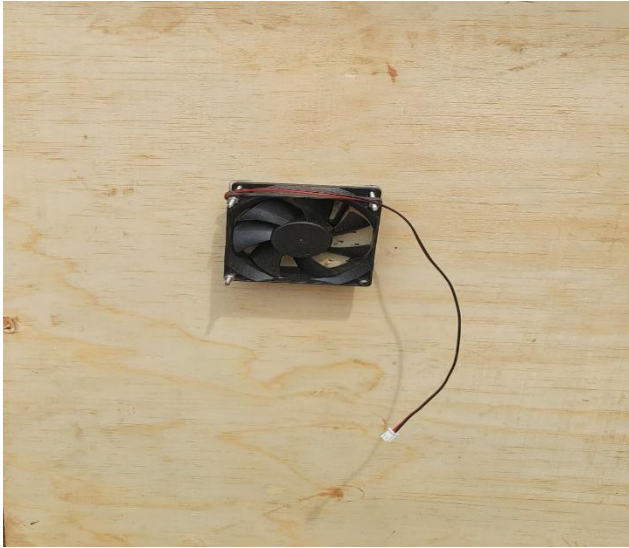


Figure 15-FAN

The DC fan purpose is to automatically switch on when the temperature exceeds 30°C

D. VERO BOARD (with some of the components)

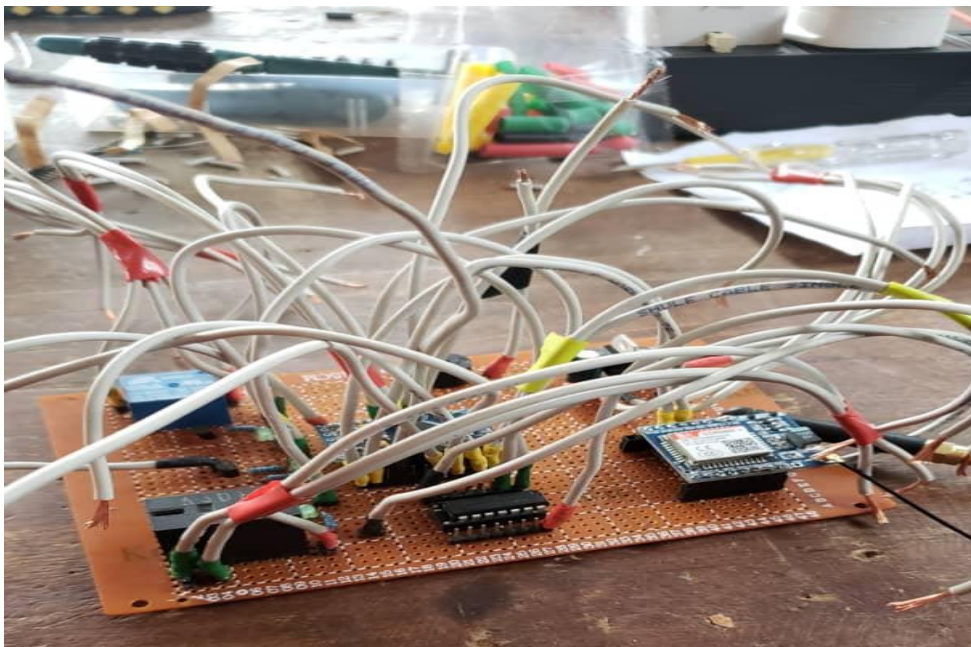


Figure 16-Vero board(with components)

We used the vero board as a circuit board where we soldered and interconnected the hardware components for example (relays, transistors, integrated circuits,) to each other for better communication.

E. SCREEN, COIN ACCEPTOR AND THE KEYPAD



- i. Screen was used as a communication interface which gave display output to the user of the system that is to say to show the ports available for the user, to show the user the OTP during sign in and also to indicate that the battery is charging
- ii. Coin acceptor machine: This is the payment module for the system which accepts only coins of 500/= only to give access to the charging ports.
- iii. Keypad: This is used to select vacant port , enter users contact and OTP code.

5.2 SYSTEM TESTING AND VALIDATION

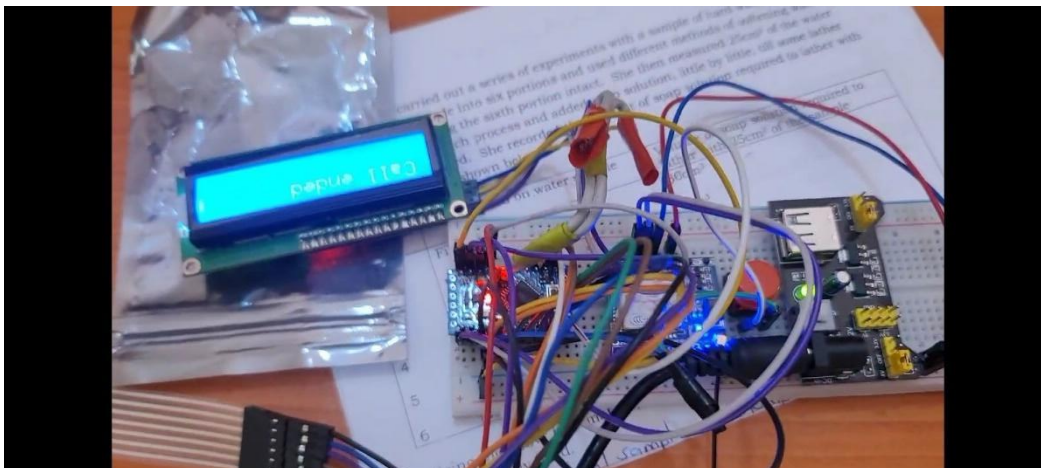


Figure 17- Component testing intergrated

5.21 COMPONENT TESTING`

Microcontroller (Arduino Atmega 328p): We tested input and output operations, communication with other components for example LCD, GSM

GSM Module (SIM800C): We tested this component by supplying it with 4.4V DC and then placing a sim card (airtel) then we called on it, it was found out the it call went through and rang.

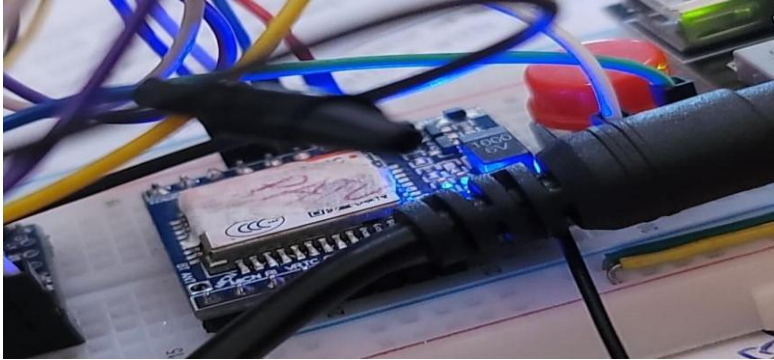


Figure 18-GSM Module

Door contact Sensor: The operation of this sensor was like, it acted as a switch when we brought the two pieces together and tested for the continuity using the multimeter. The multimeter produced a buzzing sound meaning that its continuous and when separating them, then it doesnot

LCD Display: We tested the clarity of the characters and symbols on how they were displayed on the screen this was archived by building a small hardware on breadboard with the micro-controller and then wrote a small code.

Pilot lamps: Since these where rated 12V DC, we supplied them with their rated voltage and they were working well.

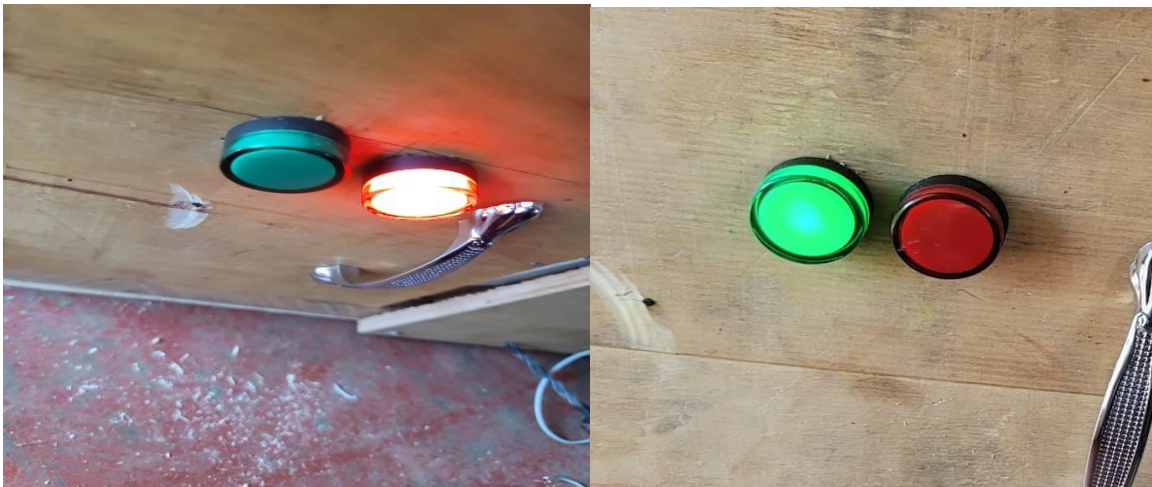


Figure 19-Pilot lamps

Solenoid Locks: These were active high (they are active high). We supplied each separately by a 12V DC as per there rating and they could lock and unlock well.



Figure 20-Solenoid lock

5.22 BLOCK TESTING

Payment System: This included coin detection, OTP verification and SMS communication.



Figure 21-Payment system

Door Control System: To Ensure proper door locking and unlocking based on the sensor inputs and system state.

Notification System: Tested SMS delivery, content accuracy, and timely notifications.

In this way we used one our colleagues contact and the system sent a one time password to his contact.

5.23 INTERGRATED SYSTEM FUNCTIONALITY.

We did end to end scenario where we simulated the user interaction, payment, charging and retrieval process to verify the system's overall performance.



6.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1 DISCUSSION

In discussion, the existing station most of them imitated the idea from the online web journals, you tube research videos as obtained in the findings. These stations, however they are good at charging batteries their efficiency is not guaranteed because of the poor handling of batteries and monitoring even more as discussed previously.

Therefore, we are designing this lead acid battery station to solve the insufficiencies.

6.2 CONCLUSION

Our charging station prototype represents a significant step towards providing a suitable and convenient solution for the battery charging needs. With further development and refinement, it's the future for charging automations in Uganda

6.3 RECOMMENDATIONS

6.31 Business and operational recommendation

Develop pricing strategies i.e prices that are competitive with the existing local charging station.
Exploring partnership; This includes collaborating with businesses, government agencies and organizations to expand the network of charging station

6.32 Policy and regulatory Recommendations

- **Support research and development;** Through investing in research and concentrating on the best experiences for the user.

6.33 Hardware and infrastructure improvements

- Expand charging capacity through increasing the number of charging stations to meet growing demand and reduce waiting lines.
- Consider solar integration to reduce reliance on the grid power and potentially offer free charging costs during sunny hours.

6.4 FUTURE MODIFICATIONS

1. Hardware enhancements i.e Wireless Charging, Solar panel integration, Multiple battery type, Fast charging mechanism (coming new on market)
2. Software Enhancement i.e Remote monitoring and control, Enhanced payment option like using mobile money, Credit cards and more.
3. Developing an app with a database to keep user information and clear monitoring the battery health, efficiency which is readable by the user

References

- [1] S. Dogget, "Renault Nissan Alliance Getting Recharging stations in Place," 10 JUL 2008. [Online]. Available: <https://www.cnbc.com/2023/02/06/nissan-to-buy-up-to-15percent-stake-in-renault-ev-unit-under-reshaped-alliance.html>.
- [2] "Handbook of Batteries," in *Handbook of Batteries*, New York, McGraw-Hill, 2010, p. 59.
- [3] M. p. systems, "The importance of state of charge () SOC," 24 July 2024. [Online]. Available: <https://www.monolithicpower.com/en/support/videos/evaluating-battery-management-systems-state-of-charge-and-state-of-health.html>.
- [4] S. Sepasi, "Journal of Power Sources," *Journal of Power Sources*, pp. 368-378, 2014.
- [5] R. Jackey, "A simple, effective lead acid battery modeling process for electrical system component selection," *Journal of passenger cars: Electronic and electrical systems*, pp. pp 219-227, 2007.
- [6] M. w. J. M. M. Ali Emadi, Vehicular electrical electric power system, New York: Dekker, Inc, 2010.
- [7] H. E. Andreas Nyman, Modeling the Lithium-Ion Battery, New York: Comsol, 2012.
- [8] A. Maria, "Introduction to Modeling and Simulation," Washington DC, USA, 2007.
- [9] M. H. H. G. M. K. Ahmad Darabi¹, "International journal of Emerging Technology And Advanced engineering Vol 3," *Modeling of Lead acid battery in energy storage system*, pp. pp 932-937, 2013.
- [10] "Learn about Batteries," 24 November 2006. [Online]. Available: <https://batteryuniversity.com/articles> .
- [11] WIKIPEDIA, "ESP32," 21 July 2024. [Online]. Available: <https://en.wikipedia.org/wiki/ESP32>.
- [12] S. Electronics, "Amazon.com," 12 January 2024. [Online]. Available: <https://www.amazon.com/Operated-Selector-Acceptor-Programmable-Shipping/dp/B081CWXBQ3> .
- [13] R. n. tutorials, "Guide to sd card Module," 25 June 2024. [Online]. Available: <https://randomnerdtutorials.com/guide-to-sd-card-module-with-arduino/>.
- [14] Arduino, "Liquid Crystal Displays," [Online]. Available: <https://docs.arduino.cc/learn/electronics/lcd-displays/> .
- [15] Adebule, "Tech:What is VEROBOARD," 06 June 2018. [Online]. Available: <https://steemit.com/technology/@adebule/tech-what-is-veroboard>.
- [16] M. Bazaar, "Single channel Relay Module," [Online]. Available: <https://makerbazar.in/products/single-channel-relay-module> .
- [17] ADIY, "DC voltage Module," [Online]. Available: <https://adiy.in/shop/dc-voltage-sensor-module-0v-25v/>.

APPENDICES

Appendix 1: QUESTIONNAIRE

User Information

1. What is your primary use for batteries (automotive, renewable energy, consumer electronics, etc.)?
2. How many batteries do you typically charge at one time?
3. What is your current method of monitoring battery charge levels (manual, voltage meter, etc.)

Charging Experience

1. Have you ever experienced battery damage or reduced lifespan due to overcharging or undercharging?
2. How much time do you estimate is spent on battery charging and maintenance per week?
3. Have you encountered any safety issues or concerns while charging batteries (e.g., overheating, explosions, etc.)?

Automatic Charging Station_

1. Would you be interested in using an automatic battery charging station, and why or why not?
2. What features do you consider essential in an automatic charging station (e.g., automatic disconnection, timer, notification system, etc.)?
3. How important is the ability to charge multiple batteries simultaneously to you?

Notification System

1. Which notification method do you prefer (SMS, email, mobile app, or a combination)?
2. What specific notifications would you like to receive (e.g., full charge, low charge, charging complete, etc.)?
3. Would you like to receive notifications for each individual battery or a summary notification for all batteries?

Additional Comments

1. Are there any specific pain points or challenges you face with your current battery charging process?
2. How do you think an automatic battery charging station could improve your overall experience?
3. Are there any additional features or functionalities you'd like to see in the automatic charging station?

Figure 22: Questionnaire