

Design And Implementation Of An Improved Battery Charger For Two- Wheeler Electric Vehicle

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Abstract

This research presents the design, development, and hardware implementation of an improved battery charger system for electric two-wheelers (E2Ws), aimed at reducing charging time and enhancing energy efficiency. Traditional charging methods, especially the Constant Current–Constant Voltage (CC-CV) approach, though widely used, exhibit prolonged charging durations and thermal inefficiencies. To address these limitations, a novel fast-charging method is proposed that incorporates variable C-rate control while eliminating the constant voltage phase. The system utilizes real-time feedback from current, voltage, temperature, and State of Charge (SOC) sensors, managed by a microcontroller to ensure safe and optimal charging. MATLAB simulations and experimental hardware results confirm the superior performance of the improved method. It achieves faster charging, with 18% SOC reached in 600 seconds compared to 10% in 954 seconds using the CC-CV method. Full charging is accomplished in 1 hour 10 minutes, significantly quicker than the 1 hour 50 minutes required by the conventional system. Hardware implementation includes components such as a boost converter, EMI filter, PFC circuit, and LCD interface for real-time monitoring. The improved charger ensures voltage regulation, efficient thermal management, and protection against overcharging. The outcome demonstrates a robust, scalable solution for future EV infrastructure, addressing the growing demand for fast, efficient, and reliable battery charging systems for electric mobility.

Keywords: Electric Vehicles (EVs), Lithium-Ion Battery, Battery Charging, CC-CV Method, Fast Charging, Variable C-Rate, Microcontroller

1. INTRODUCTION

There are more and more electric cars (EVs). This is a big step forward in our recent efforts to make transportation better and more environmentally friendly [1]. People are more aware of the increases in greenhouse gases, climate change, and other alternatives to fossil fuels. Electric vehicles can replace a traditional gasoline-powered vehicle with a clean alternative. We accepted the fact that electric vehicles produce less exhaust, less noise, and less oil dependency, but electric vehicles still have significant implications in the environmental problems caused by internal combustion engines (ICEs).

Electric cars and trucks have grown since electricity become the first commonly utilized automotive fuel before the 20th century [2]. However, the global adoption of EVs is about to take off, with over thirty million EVs predicted to be on the roads by 2030, as consumers and government officials see EVs as a way to cut down on pollution. This will be aided by technologies that are becoming increasingly more effective, an increasing level of awareness among consumers, and the desire for more effective forms of transportation. Particularly since electric vehicles can lower carbon emissions, this mechanism is especially valuable in urban centers, contributing to an overall enhancement of environmental quality [3].

In order for electric cars (EVs) to become more popular, they need better places to charge. It includes everything except the DC-DC or AC-DC converters to charge an EV [4]. Power source AC is converted to battery-needed DC. This keeps the right number of power going. A bi-directional charger has more advantages than a unidirectional charger as the bi-directional charger can not only be used for grid support but also for energy storage in several sustainable benefits for the supporting EV systems. The increase in EVs means the need for the implementation of more reliable and quick charging stations/services to be integrated into today's urban environment. This paper aims to highlight and examine the existing EV charging infrastructure with respect to hardware components, software controls and the user interface. The objective is to produce a unique, future-ready EV charging system to ease the reliability, speed and convenience of charging and broaden the acceptance of EV's around the globe [5].

Since lithium-ion batteries replace lead-acid batteries, EVs are better for both the environment and business. Lead-acid batteries don't store energy as well or as quickly as lithium-ion batteries do. Batteries made with lithium ion are used all over the world for many things, such as power backup, in

uninterruptible sources of power (UPS), to store solar energy, and more [6]. They are not just used in electric cars. Transitioning to electric vehicles indicates a clear shift in how the world is managing, using, and consuming resources. Utilizing electric vehicles has multiple societal advantages, including lower emissions, less reliance on fossil fuels, and increased economic efficiency. On the downside, concerns about charging time and range are often cited as barriers to electric vehicle utilization, even with the environmental attributes [7]. Most EV batteries are charged in three steps: Constant Voltage (CV), Continuous Current (CC), and Constant Current-Constant Voltage (CC-CV) [8]. For these problems to be fixed, charging facilities and methods will need to be improved so that charging times are shorter and more efficient [9]. This study will look at the practical problems that electric vehicle (EV) charging infrastructure is facing right now, look for ways to make things better, and come up with ways to make charge networks better. The study's goal is to help EV technology improve and make the switch to a more environmentally friendly future easier. Moving towards electric mobility in transportation will require the creation of better charging systems that work well and are easy for users to use [10].

Table 1. Comparison of EV Battery Properties

Battery Chemistry	Specific Energy (Wh/kg)	Cycle Life	Safety	Cost
'Lead Acid'	30-40	500-800 cycles	Safe	Low
'NiMH'	60-120	2,000-3,000 cycles	Safe	Moderate
'Li-ion'	100-265	1,000-10,000 cycles	Thermal issues	High

2. LITERATURE REVIEW

In the literature review part, we look at the latest study and development in the design and use of chargers for batteries for electric two-wheeler vehicles (EVs). It describes relevant characteristics of charging such as charging technologies, charger architectures, fast-charging strategies, power factor correction, plus renewable energy storage and uses. This review covers challenges and potential for research in EV charging systems [11].

Alicia Triviño-Cabrera et al. (2021) explores how battery chargers have an impact on both the life and duration of performance of industrial batteries. The study explores the shift away from ferroresonant and SCR chargers to high frequency chargers, which are better because of their efficiency, size, and weight. The study stresses that high frequency chargers have a key role in future performance of conventional battery technologies, particularly in the industrial arena, and with regards to the rechargeable batteries gaining a larger share of the market [12]. **Joydeep Chandra et al. (2023)**, traces the history and advancements of battery charging technologies, from removable batteries, to the current wired and wireless charging technologies. The paper describes the historic path of DC battery charging technologies and the innovation of wireless charging gaining traction. Additionally, it notes the consistent demand for wired charging for consumer electronics (especially electric vehicles, EV), which will drive dramatic growth for the market and that wireless charging provides new opportunities with vertical resource sharing as well as replacing induction communication systems [13]. **Yuqi Li et al. (2023)**, studies lithium-ion battery charging using the multiple phase's constant current (MSCC) technique to find ways to make it more efficient, cut down on heat, and lengthen the life of the battery. It assesses the performance of batteries as a function of the design parameters design of systems, which include number of stages, stage transition requirements, and C-rate, while making recommendations for the design of fast charging approaches and for where future research and developments might be realized in the battery charging process. **Morris Brenna et al. (2020)**, concentrates on EV charging systems, in particular, the converter topologies, charging control methods, and the flow of power. It is important to pay attention to fast charge methods for lithium-ion batteries, especially the use of multiple processors in Level 3 chargers and the ability to connect EV charges to clean energy sources. The anticipated transfer to silicon carbide devices in the future stands to make chargers smaller and lighter while discussing future trends in EV charging [14]. **Sergio Saponara et al. (2024)**, concentrates on bidirectional electric vehicles (EVs) and the critical role to be played by On-Board Chargers (OBCs) in facilitating energy exchange between the EV and the grid.

The article explores a range of OBC topologies and the complexities associated with energy efficiency, thermal management, and voltage regulation. The authors advocate for a greater role for bidirectional systems to enable EVs to be channelled into smart energy infrastructure aiming to integrate our energy system, and welcome the idea of associated advanced filtering and control technologies in the charging circuits [15]. **Ahmed Zentani et al. (2024)**, analyzes fast-charging systems to charge EVs, with a comparison of methodologies such as battery swapping, ultra-fast charging (UFC), and direct current fast charging (DCFC). This paper discusses necessary DCFC infrastructure including communication protocols, power levels and supply, and safety standards. This paper addresses the issues of standardization and developing battery technology while also outlining possible avenues for future research in advancing fast-charging systems while integrating renewables for EV charging [11]. **Danilo Yu et al. (2019)**, examines the impact that electric vehicle operating and charging patterns have on the grid load profile. It recommends the application of a real-time scheduling approach for charging, to minimize grid energy usage by using renewable energy efficiently and anticipating EV demand. It concludes with a possibility that intelligent scheduling can flatten peak grid demand, and through application of solar and hybrid photovoltaic wind strategies could reduce grid use by commercial EV's by 24% annually [17]. **Md. Tanvir Shahed et al. (2024)**, talks about the evolution of technologies involved in EV charging, particularly the power converters and charging protocols. When looking at V2G (vehicle-to-grid) technology which involves bi-directional power transfer, this would be helpful to reliability of the grid and its efficiency, and many Government initiatives see this as a mechanism to integrate renewables better within the grid. It also examines the challenges addressed in the future evolution of EV charging research such as wireless charging, grid connections and optimising battery life and creates a development map to look forward to [18]. **Pierpaolo Dini et al. (2023)**, analyzes the functions of On-Board Chargers (OBCs) in bidirectional electric vehicles (EVs). It analyzes the effect of the various OBC circuit topologies with respect to the various types of rectifiers as well as switching converters with regard to energy efficiency, voltage regulation, and thermal management. The paper covers the evolution of charging systems from wired solutions to wireless options and describes observable trends in OBCs and possible future research areas including AI-based control algorithms and enhanced fast-charging infrastructure for EVs. An overview of recent developments in lithium-ion battery technology for electric vehicles is given by Dr. K.V. Vidyanandan et al. (2019). Topics covered include lithium-ion batteries' pros and cons, as well as their safety concerns and power and energy density. The article also reviews the varieties of EV's: PHEV's, FCEV's, and BEV's. It considers the future of EV batteries and the future innovation we need in battery technology to keep up with the increased demand for electric transportation [14].

G. Pérez et al. (2013), investigates the importance of proper State of Charge (SOC) and State of Health (SOH) diagnostics for lithium-ion batteries, which are the foundation for successful battery management. To study the battery proper, frequency domain and time domain characterization are considered as two different approaches of modeling the cell. The manuscript discusses the advantages and disadvantages of both types of approaches and provides the rationale for the introduction of a hybrid approach for improved battery diagnostics. The hybrid approach uses actual measurements of relevant operational domains to assess the model's ability to estimate the health of the cell. **A. Berrueta et al. (2016)**, focused on how important it is to get a good estimate of the State of Charge (SoC) of lithium-ion batteries that are used in fixed systems. The study looked at three different ways to watch SoCs and how well they worked at dealing with problems like inaccurate current measurements and old batteries. The best overall performer was a closed-loop method that used an adaptive filter and a state watcher. It provided a reliable or computationally efficient way to track SoCs in fixed systems in real time [20]. **Parveen Kumar et al. (2023)**, discusses the push for electric mobility initiated by the Indian government and its impact on acceptance of electric two-wheelers (e-2Ws) in urban areas. The study points out challenges to adoption, including high purchase costs, insufficient charging infrastructure, and long charging times. As a solution to the issue of charging times, battery swapping systems are proposed and examined. The study predicts significant growth for the e-2W market, providing an estimated range of up to 54.4 million units could exist by 2030 under optimistic expectations. The study also examined the estimated market size of the battery capacity requirement scope in relation to battery swap systems. In 2022, Sachin B. Shahapure et al. looked into how electric cars (EVs) might be used to clean up the air and make us less reliant on energy to fossil fuels. It reviews recent advancements in technology related to EVs, including motor drives, energy storage systems, and charging infrastructure. The study points to challenges related to battery technology,

which is critical to EVs, including safety, durability, and cost. It also looked at different ways to charge an electric vehicle, such as electrical charging, magnetic charging, and battery changing. Finally, it examined the development of EV infrastructure associated with the ongoing development of policies from the government of India aimed at promoting EV adoption [21].

3. METHODOLOGY

Electric cars (EVs) are a big part of making transportation more environmentally friendly by cutting down on greenhouse gas pollution and the use of fossil fuels. The number of EV charging points that are used and how useful, handy, and environmentally friendly they are all depend on how efficiently they are used. There are three different kinds of chargers: Level 1 (slow, home use), Level 2 (faster, home and public uses), and Level 3 (fast charging DC fast chargers, for quick recharge along highways). Standards, such as the J1772 standards and CCS (Combined Charging System), exist to ensure safe and compatible charging for standardized devices and stations across regions. Charging is reduced with charging efficiency, which decreases time of charging for EVs while taking a sustainable source like renewable energy sources; charging efficiency also increases grid stability. Charging efficiently lowers operational costs making EVs cheaper to operate, making them more accessible to consumers and leading to a broader adoption for a sustainable future.

3.1 Different charging methods of EVS

Electric cars can be charged in a number of ways, including:

- Float charging
- Trickle charging
- Constant current charging
- Constant voltage charging
- Pulse charging
- Negative Pulse Charging
- Random charging

3.1.1 Constant Voltage Charging Method

The connection current remains constant as CV charges the battery. However, battery charging reduces power. Full battery charging is possible using CV charging. The voltage regulation circuit uses a working amplifier and a voltage standard to keep the voltage fixed. The MATLAB simulation has a voltage source connected to the battery pack and a feedback loop to monitor the level of voltage. The battery model is designed for CV charging, and the profile of current, voltage, and SOC are documented.

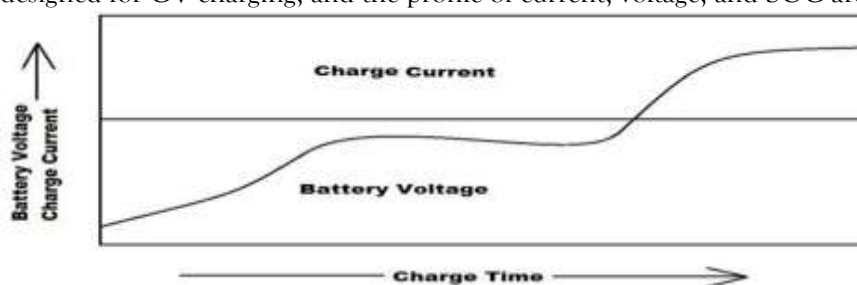


Figure 1: Constant Voltage Characteristics

3.1.2 Constant Current Charging Method

A steady current (CC) is sent to a battery until it reaches full power. This keeps a battery from getting too hot and the charge rate steady. To maintain current in CC, a current regulator circuit—a power transistor and feedback loop—regulates the current. In MATLAB simulations, current hits a battery pack and there is feedback from the element in the battery pack that governs the current. The simulation preserves current, voltage, and State of Charge (SOC) profiles over time.

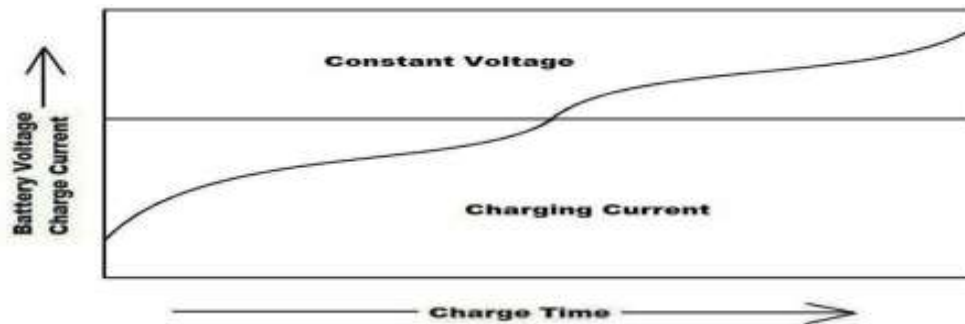


Figure 2: Constant Current Characteristics

3.2 Fast Charging Methods

Fast charging exposes batteries to a greater risk of overheating and overcharging than conventional charging, and that is why charger developers go through great lengths to demonstrate that damage will not occur. Each chemistry of a battery has its own charging profile, which is also why charges are made to fit the features of each battery. Fast charging does have provisions for safety including thermal fuses and temperature cut-offs. Fast charging also invariably utilizes a combination of charging methodologies, such as MCC-CV, or CC-CV-CC charging, etc., which enables greater charging speed without damaging the components.

3.2.1 IUI Charging (CC-CV-CC):

This method consists of three phases:

1. **Bulk Charge (I):** It is charged with a steady current until it reaches a certain level of power.
2. **Constant Voltage (U):** While the power drops, the battery's capacity stays at the same level.
3. **Constant Current Mode (I):** Makes ensuring every cell is charged equally, extending battery life.

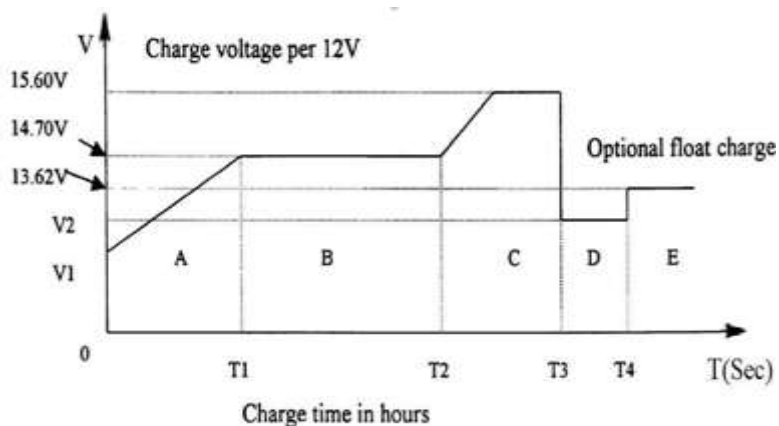


Figure 3: IUI charging profile

3.2.2 Multi-Constant Current-Constant Voltage (MCC-CV)

This method keeps the current steady until the battery is 70–80% charged. It then changes to a steady voltage to keep it from getting too hot. The process of charging is faster than the old way of doing it, cutting the time by 3–4 hours. Pulse charge and steady power can lower the temperature of the battery even more and make it work better.

3.3 System Design

The EV charging system consists of several key components:

- PSU: Converts AC in DC for charging.
- This part of the battery checks its health, temperature, and state of charge (SOC).
- Charge Controller: Keeps the charge current and power safe by controlling them.
- Charging Circuits: Use certain charging ways, such as CC, CV, and CC-CV.
- Battery Pack: A lithium-ion battery pack, typically 4.2V, 10Ah.
- Cooling System: This keeps the battery's temperature within safe ranges while it's being charged.

3.3.1 EV Fast Charging Characterization

Changing working factors like voltage and frequency describe how a fast-charging load acts. For power flow models in charging facilities, it is important to find a mathematical link between power supply and use.

3.3.2 Mathematical Modelling of EV Fast Charging

AC-DC front-end conversion as well as DC-DC buck/boost conversion are both part of the EV fast charge load. The battery's charge level affects current, power, or voltage exchange. Change AC for DC, DC to DC, and add the battery to see the effect.

3.3.3 Lithium-Ion Battery Modeling

Lithium-ion battery models relate voltage, current, SOC, and internal resistance. A performance model is made up of resistance, capacitance, or circuit elements. The SOC is determined based on charge/discharge rates and voltage changes, allowing accurate predictions of battery performance during charging. The relationship between SOC and battery terminal voltage is modeled using dynamic equations.

3.4 Boost Converter Design Calculations

The boost converter design is crucial for controlling voltage levels and improving charging efficiency. Specific calculations are made to ensure proper voltage regulation, ensuring the converter can handle the power needs during fast charging while maintaining safety and efficiency.

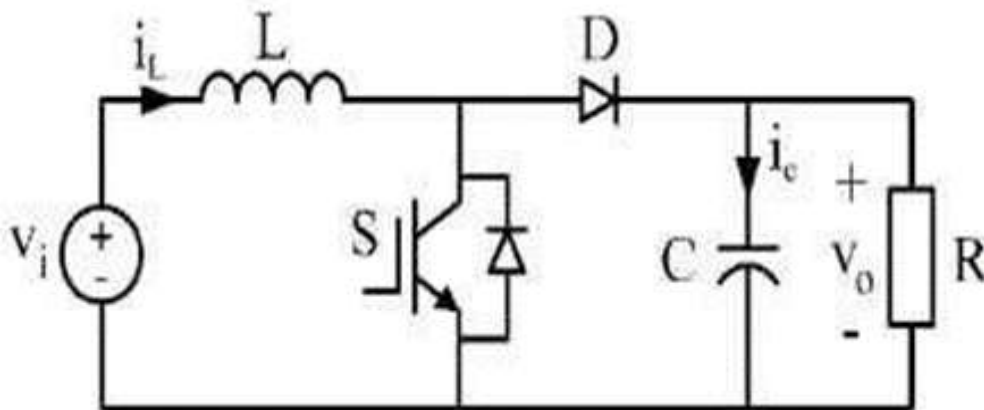


Figure 4: Boost converter

It's made up of an inductor, a diode, a capacitor, a MOSFET or IGBT semiconductor switch, and a load resistor. When the button is pressed, the inductor will pull power from the source. It gives back the energy it saved when the light is turned off. Both the input the frequency and the output the frequency go up because of this. And this is how the processor works.

3.5 Different topologies comparison of DC-to-DC converter used in EV charger

To compare some DC-DC converters, we can look at how much energy is put on the switch, how many switches are used, and how much power each one can handle:

Table 2: Different topologies- Comparison

Different Topology	Forward Converter	Fly-back Converter	Push-pull Converter	Half bridge converter	Full bridge Converter
Maximum voltage stress across switch	Twice the supply voltage	equal to the supplied voltage	twice the Supplied voltage	equal to the supplied voltage	equal to the supplied voltage
No. of switch used	1	1	2	2	4
Application range	Ideally, Use for 150-200W	Ideally, Use for below 100W	Ideally, Use up to 100-150W	Ideally, Use up to 400-500W	Ideally, Use for 1KW and above

Advantage/ Disadvantage	efficient, smaller in size than another converter	Proper transformer design required more cost, but efficient	For the same power rating, the size required for this converter is more than others	Costly and bulky equipment	Used for high- power applications, costly
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4. Improved new fast charging technique for two-wheeler

The standard CC-CV charging method doesn't always work because it takes too long to charge, especially when the battery is about 80% charged. This study suggests a new fast-charging method that changes the CC-CV method by adding a flexible C-rate and getting rid of the CV mode to make charge times shorter. This method uses information about the battery, like its temperature, maximum voltage, or state of charge (SOC), to make it safer, last longer, and charge faster while also lowering the temperature. The charging factors are controlled by a microprocessor, which makes the charging process more efficient.

4.1 Proposed Methodology and Mathematical Model for the New Improved Charging Method

This novel method charges EV batteries using temperature, charging time, shutdown voltage, and SOC. The process depends on battery temperature, voltage, and SOC time.

4.1.1 Variable C-Rate Charging in CC-CV Charging Topology:

It is hard to do CC-CV charging because you have to choose the right fixed numbers for each mode. The suggested variable C-rate system gradually lowers the current as the voltage at the terminals gets closer to the cutoff number. The computer controls everything, making sure the temperature stays safe and that the charging keeps going until the battery gets its full state of charge (SOC).

4.1.2 Variable C-Rate Charging Based on SOC:

With the SOC-based change between steps, it is possible to charge faster than with the regular CC-CV way. There are a variety of SOC steps in each study, and each one takes a unique amount of time. This way of measuring charge time, current, or temperature picks steps at random. The results show that charging takes less time and causes less temperature rise than CC-CV charging. This is very important when there is a long first-stage SOC gap.

4.1.3 Variable C-Rate Charging Based on Cut-Off Voltage:

In this method, the charging process goes on by lowering the current at each step until the battery hits a certain voltage, which for cobalt-based lithium-ion batteries is always 4.2V. This easy and direct way keeps going until the battery gets the set SOC or the set number of steps is finished.

4.1.4 Variable C-Rate Charging Based on Temperature:

A very important factor in the charging process is temperature. By setting different temperature limits based on battery data, this method makes sure the temperature stays safe. The charging will keep going until all of the factors, including the temperature, hit the amounts that were set. This helps keep the battery from getting too hot and keeps it in a safe working state.

4.2 MATLAB results for the new improved charging method:

I utilized an instance where the c-rate varied & looked at the battery's level of charge (%), output voltage, and current to find a better charging method.

Table 3 : improved fast charging method results of SOC (%), voltage, Charging time, and different C-RATE in the cc-mode of charging

SR NO	Current In (Amperes)	C-RATE	SOC (%)	Voltage in (volts)	Time in (seconds/hour)
1	24 Amperes	1C	87.50%	54.11 Volt	3150 SEC
2	18 amperes	0.75C	93.77%	54.15 Volt	3450 SEC
3	12 amperes	0.50C	97.60%	54.9 Volt	3750 SEC
4	6 amperes	0.25C	99.98%	55 Volt	4049 SEC

SOC (%) and charging time

Figure 6 shows that the CC-CV charge process works for between 10% and 80% of the time, or soc (%). Things get stronger over time, but the current stays at 10 amps. It tops at 54 volts at that point. It slowly goes up. Currents of 1C, 0.75C, 0.5C, and 0.25C, along with volts at each charging rate, were used to take the soc (%) in 0% to 90% in 4050 seconds.

4.4 MATLAB RESULTS of SOC, voltage, and current with different C-rate:

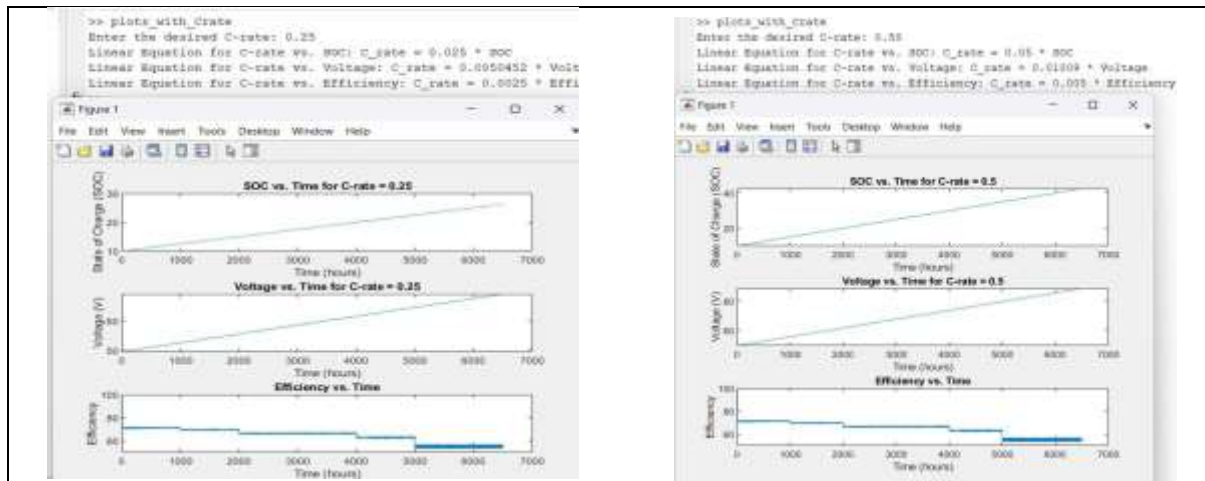


Figure 7 a, b: MATLAB results of voltage current and efficiency with 0.25C & 0.5C RATE

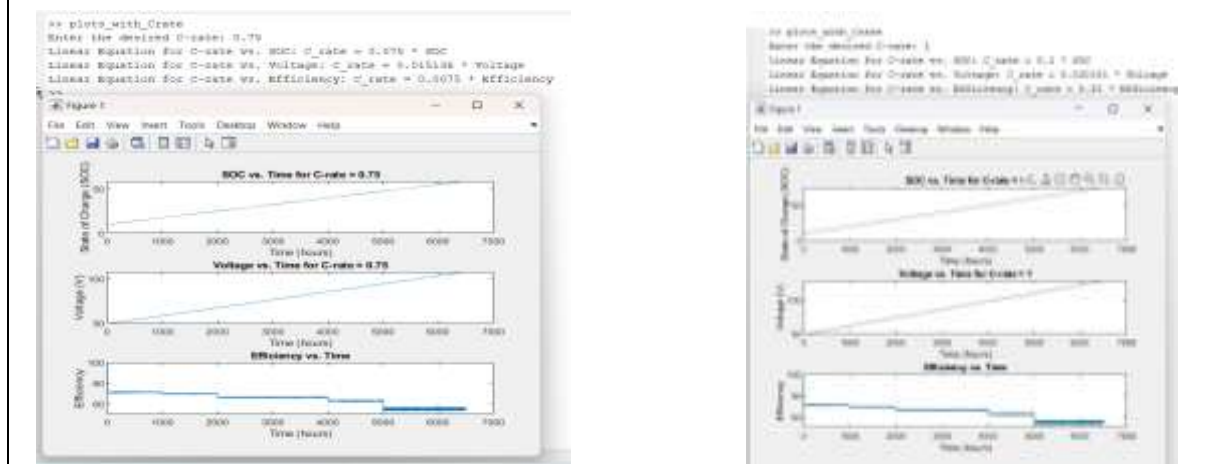


Figure 8 c, d: MATLAB results of voltage current and efficiency with 0.75C & 1C RATE

5. Simulation results of li-ion battery charger

A lithium-ion battery with a charger is demonstrated in MATLAB. It charges using constant current (CC), constant power (CV), and CC-CV. An off-board single-phase 230V battery, a full-bridge rectifiers, a converter for boost, an isolator transformer, as well as a buck/boost converter are all used to fix the voltage. A combined design that reduces charging time and increases battery life was proven by simulating and comparing the efficiency of various charge methods for EV batteries.

5.1 Simulation results of basic charging methods in MATLAB

5.1.1 Constant Voltage Charging Method (Cvcharging)

Table 5 (a): TWO-WHEELER LI-ION (NMC) BATTERY SPECIFICAITONS

Sr no	Specifications	Range
1	Battery capacity	56 volts,10 amp-hour
2	Range	122 km/charge
3	Maximum speed	42 km/hour
4	Motor power	550 watts
5	Maximum capacity	150 kg

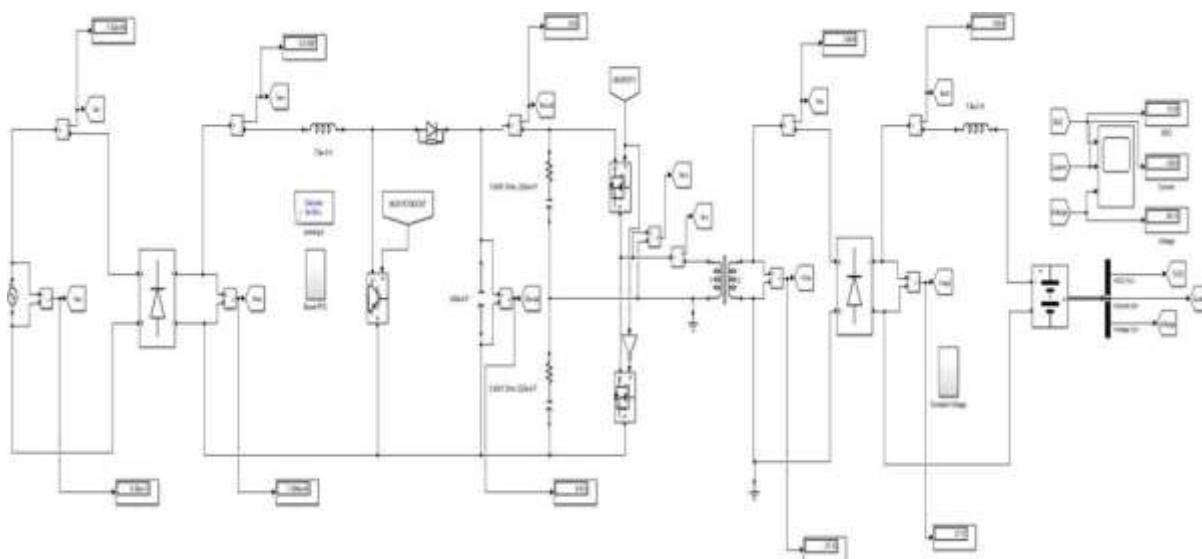


Figure 9: MATLAB circuit in constant voltage charging mode

Table 5 (b): MATLAB results of Charging Time in Constant Voltage Charging

SR NO	TIME OF BATTERY CHARGING(SECONDS)	STATE OF CHARGE (%)	VOLTAGE (VOLTS)
1	1000 seconds	65%	53.4 VOLTS
2	2000 seconds	78%	53.4 VOLTS
3	3000 Seconds (1 hour)	90 %	53.4 VOLTS

A MOSFET might indicate a battery with too much power. It has a diode and an inductance that lower the power so that charge is safe. Things that are important to keep an eye on are voltage, current, charge, or the State of Charge (SOC). To keep things safe, these monitors send information to a computer system that has return loops. Display modules show information in real time, which extends the battery's life and makes it work more efficiently. They also stop overcharging, deep draining, and burning, which makes the system safe and reliable.

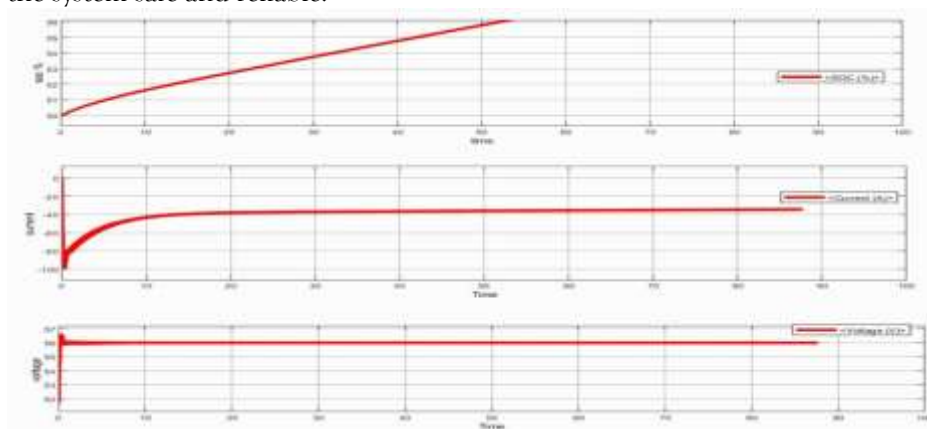


Figure 10 (a): MATLAB result of state of charge(%), current and voltage in constant voltage charging mode

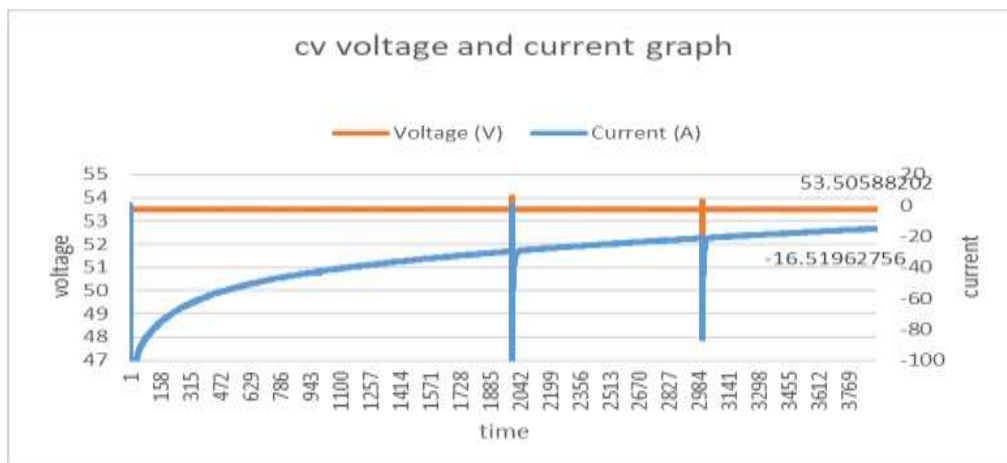


Figure 10 (b) : MATLAB result of constant voltage charging mode with state of charge, current and voltage variations

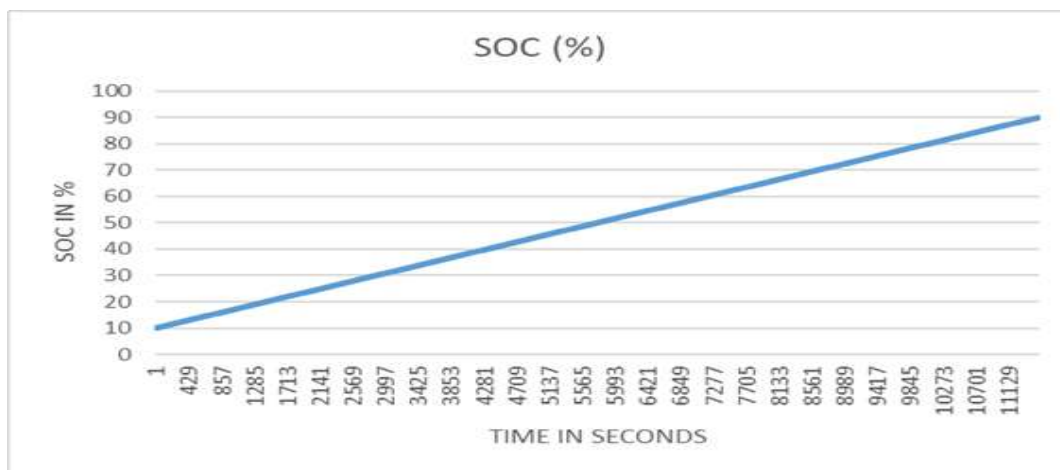


Figure. 11 (c): MATLAB result of SOC (%) in constant voltage charging method

5.1.2 Constant Current Charging Method

This technique charges a lithium-ion battery at a constant 10 amps. Charging happens when an AC plug is plugged in. A diode bridge changes the energy coming in from AC to DC. Up sampling of this DC voltage is done by a boost converter driven by an IGBT. CAPS keep the DC bus clean and steady. It is possible for power to run in both directions because of extra IGBT switches and an inductor. A 48V, 480Ah battery can be charged or drained with this. Monitors for current, voltage, and state-of-charge (SOC) are used to keep track of and control things in real time. Feedback loops keep the voltage and current in check so that charging works as well as it can.

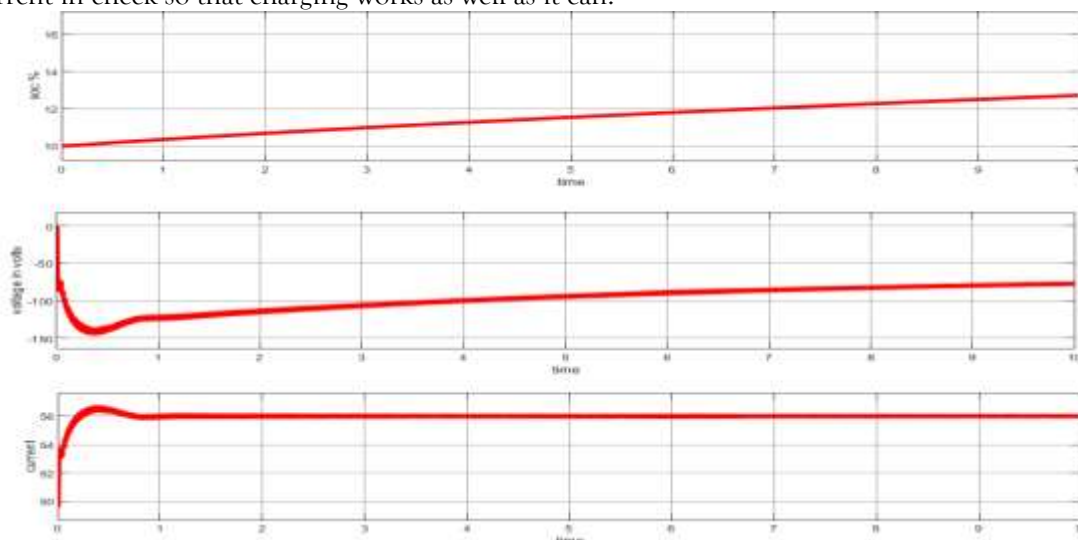


Figure 12 (a): MATLAB results of soc,voltage and current in CC charging method

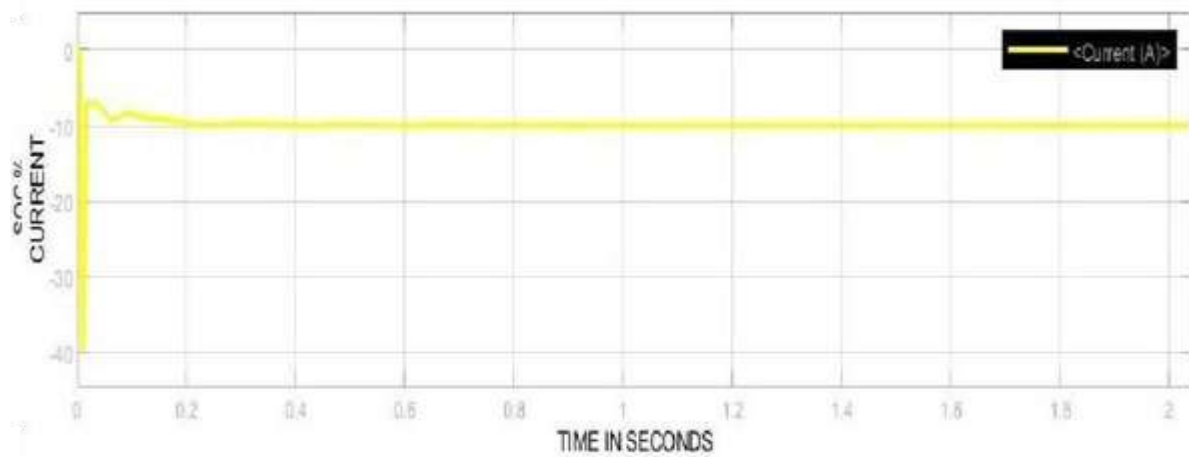


Figure 12 (b) : MATLAB constant current waveform in CC charging method

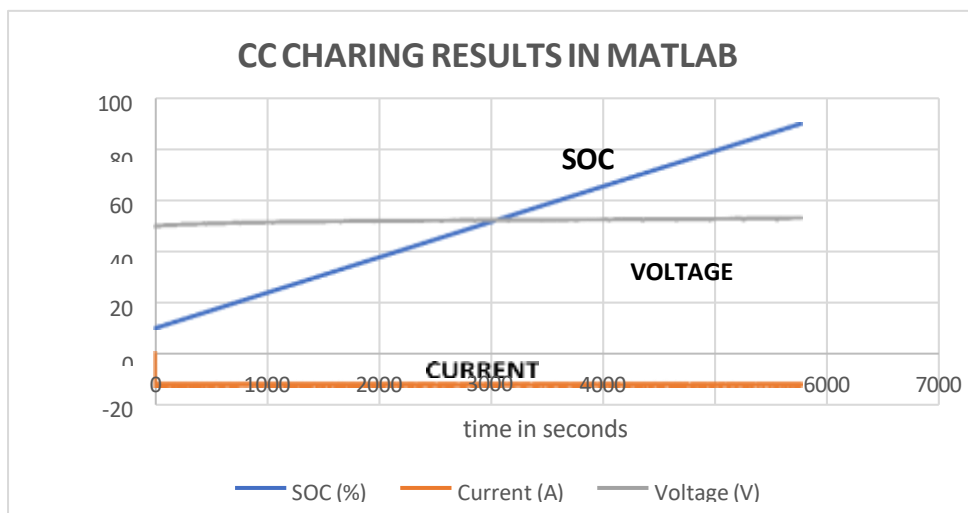
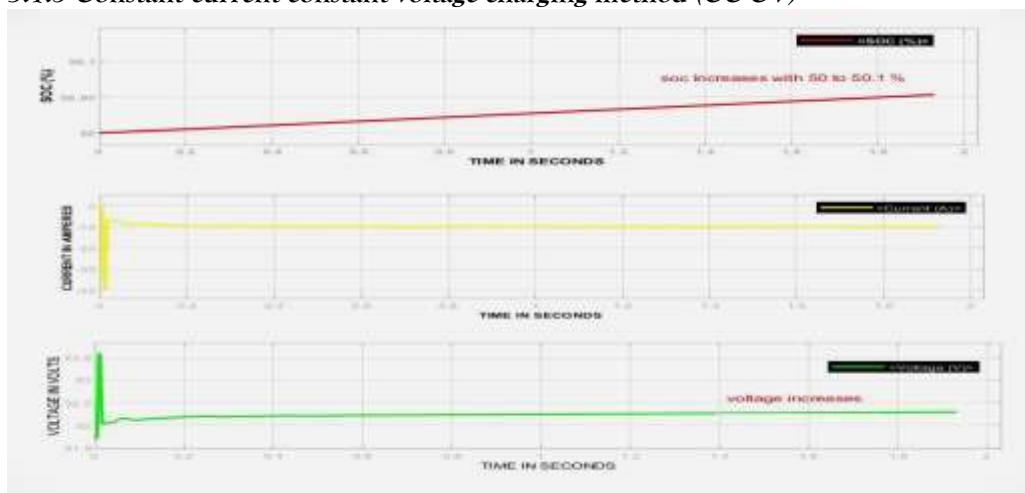


Figure 12 (c) : MATLAB result of combining all parameters of current and voltage constant current charging mode

5.1.3 Constant current constant voltage charging method (CC-CV)



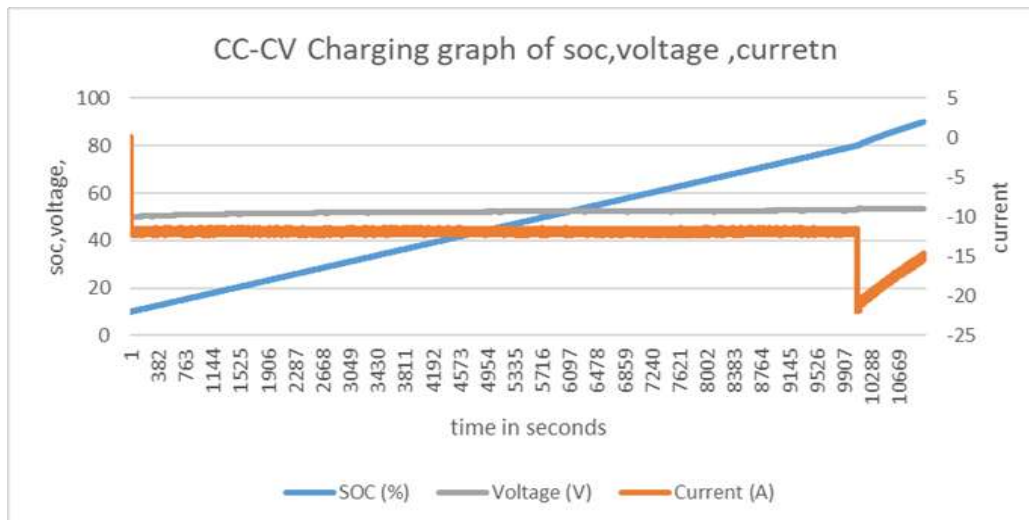


Figure 13(a), (b): MATLAB results state of charge, and charging time and voltage of combined charging method of CC-CV

6. Experimental Design of Li-ion battery charger circuit

This part talks about how the "DC-TO-DC converter," the "high frequency transformer," and the "LC-filter" are put together. Any "DC-DC converter" needs magnetic parts because high frequency transformers work better when they are properly designed. Both the voltage and current at the output are smoothed out by the "LC filter." This chapter talks about the design requirements for these parts.

6.1 Converter Specification

The "DC-DC converter" and battery parameters with the various characteristics taken into consideration in this project are as follows:

Table 7: Converter specifications

• V_{in} (Input Voltage; AC)	: 230V,50Hz
• V_s -(Step-down transformer Voltage)	: 450V
• VDC -(Rectified voltage of DC output)	: 339 V
• V_{smax} -(Inverter voltage; Max)	: 350 V
• V_o -(PFC Output DC Voltage Boost)	: 390-400V
• I_o -(Output current)	: 5 Amp
• Ah -(Battery rating)	: 48V,10Ah
• Charge voltage (full)	: 54.5V (2.25V/cell)
• Switching frequency	: 65khz

6.1.1 DC-DC Buck Converter Modelling:

During the "Constant Current" phase, the DC-DC buck converter keeps the current steady. When the battery hits a certain voltage, it changes to "Constant Voltage" mode to stop overcharging. It uses a feedback system to keep things stable and reduces ripple current to protect the battery [122].

6.1.2 Design of Boost Converter:

The boost converter boosts input voltage to charge the EV battery. This is accomplished by converting AC to DC, selecting an output capacitor that smooths out voltage fluctuations, and selecting an inductor to restrict ripple current. The duty cycle and switching frequency are set to their best levels to make sure that the voltage change for charging the battery works well.

- **Inductor & Capacitor Selection:**

Inductor value is chosen to minimize ripple current, and capacitors smooth voltage fluctuations. Typical values are $10\mu\text{H}$ to $100\mu\text{H}$ for inductors and $100\mu\text{F}$ to $470\mu\text{F}$ for capacitors.

- **Output Voltage Calculations:**

The boost converter adjusts the duty cycle to match the battery's voltage, or 14.4V for 4S lithium-ion batteries.

6.1.3 Control Strategy

Closed-loop control maintains voltage and current via CMC and VMC. Preventing spikes improves reaction time.

6.2 Mathematical Model of Full-Bridge DC-DC Converter

The full-bridge DC to DC converter effectively steps up or down DC voltage to charge the EV battery and maintain charging voltage and current.

6.3 Transformer Design (High Frequency)

High-frequency transformer design involves key factors such as a 3V voltage drop due to the full-bridge diode, a 10% output voltage decrease from winding resistance, and the use of ferrite material with a saturation flux density of 0.2T. Current density is selected between 2-5 amps/mm², and the maximum duty cycle is limited to 65% to prevent core saturation. Transformer efficiency is typically 90%, and window utilization factor accounts for insulation and wires. A flowchart illustrates the design process.

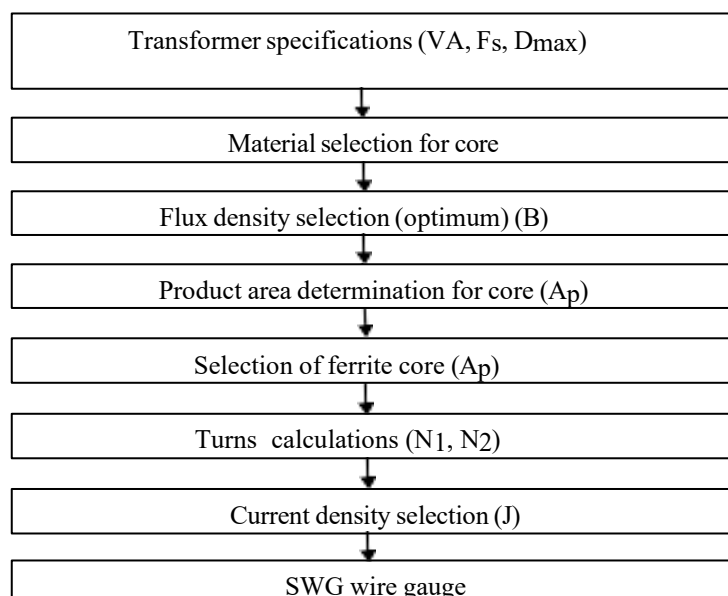


Figure 14: High-frequency transformer design flowchart

7. Design and Development of Smart Battery Charger for Two-Wheeler EVs

The planning and building of a high-tech battery charger for electric two-wheelers (E2Ws). The main parts it talks about are PCBs, transformers, rectifiers, and capacitors. It focusses on speed, heat reduction, and LCD user interface. The study shows that E2W charging methods are getting safer, more reliable, and more efficient.

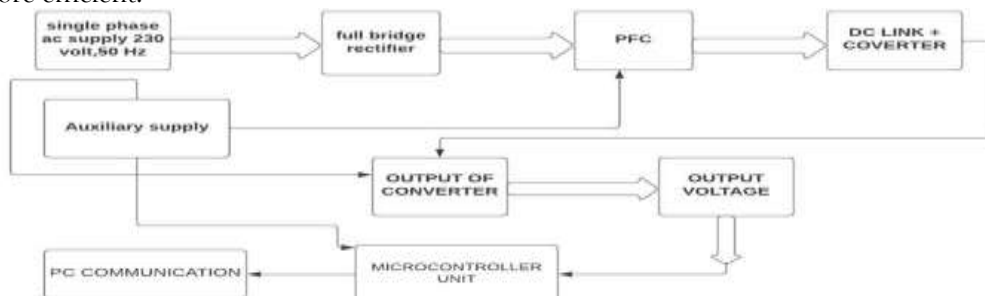


Figure 15: EV block diagram of TWO-WHEELER CHARGER

7. 1 Schematic Diagram of Ev Charging Circuit

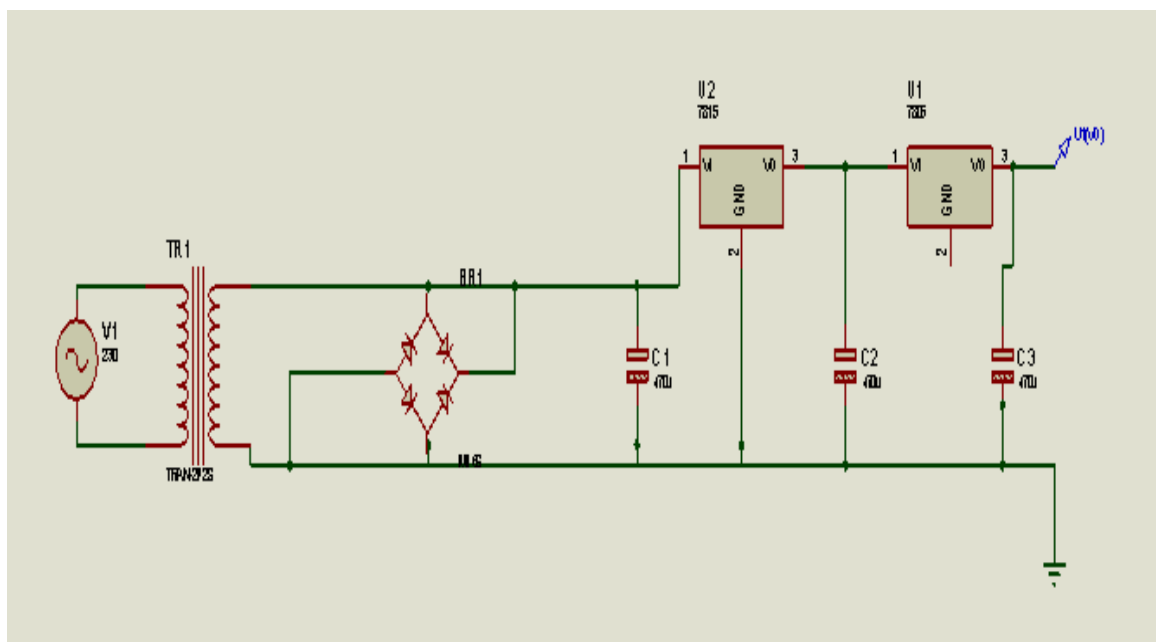


Figure 16: SMPS circuit

The input stage uses 230V, 50Hz AC. After an EMI filter removes noise, a bridge rectifier converts it to pulsed DC power.

7.1.1 Boost PFC converter

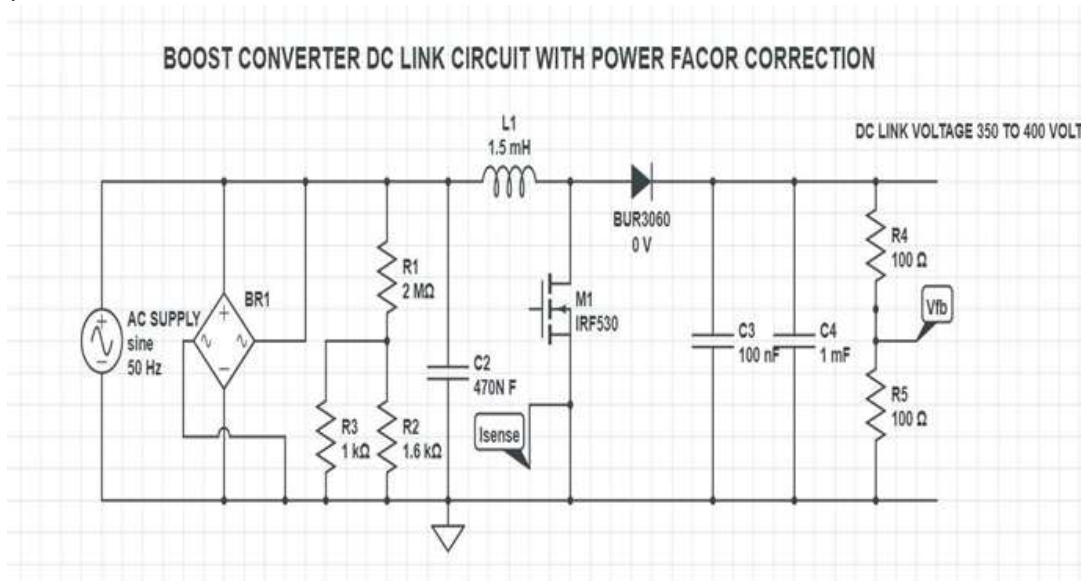


Figure 17: The schematic of a 400-volt DC link using a PFC circuit with the current

A bridge rectifiers, filter capacitors, as well as a feedback loop are used in the circuit to change 230V AC to controlled DC. It has a voltage feedback network, a transistor switch (Q1), and a current detecting resistor to keep the 400V DC output stable and protect it from spikes and swings.

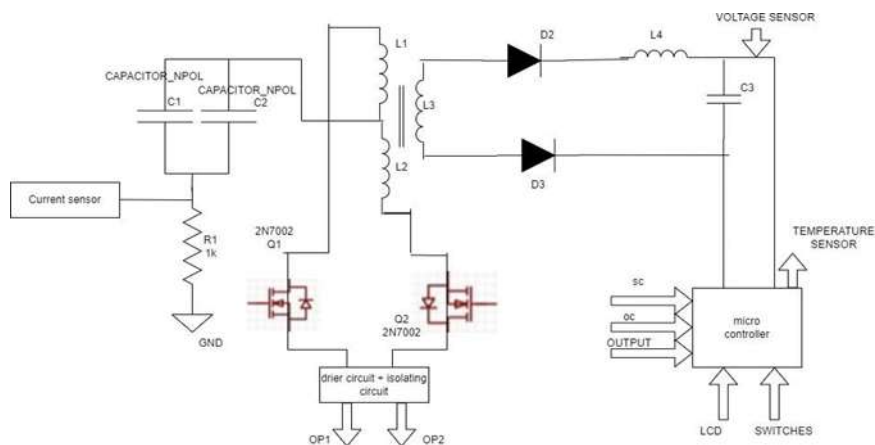


Figure 18: Schematic diagram of battery charger using a controller

7.2 TWO-WHEELER EV CHARGER HARDWARE CIRCUIT

The diagram shows an electric two-wheeler battery charger circuit. It has transformers, diodes, capacitors, voltage, current, and temperature monitors, transistors, and a computer. It has a boost converter design, and the microprocessor controls charging based on sensor input in real time. The circuit has a driver with separation, signal filtering with inductors and capacitors, and an LCD for tracking by the user. This shows what part it plays in smart power management.

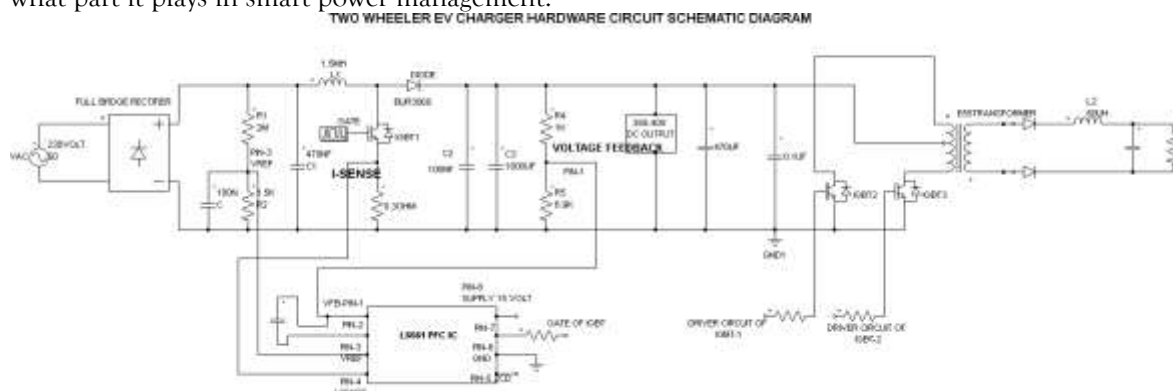


Figure 19: EV charger hardware circuit

7.3 Experimental (Hardware) control circuit of Two-wheeler charger using microcontroller DSPIC30F3011

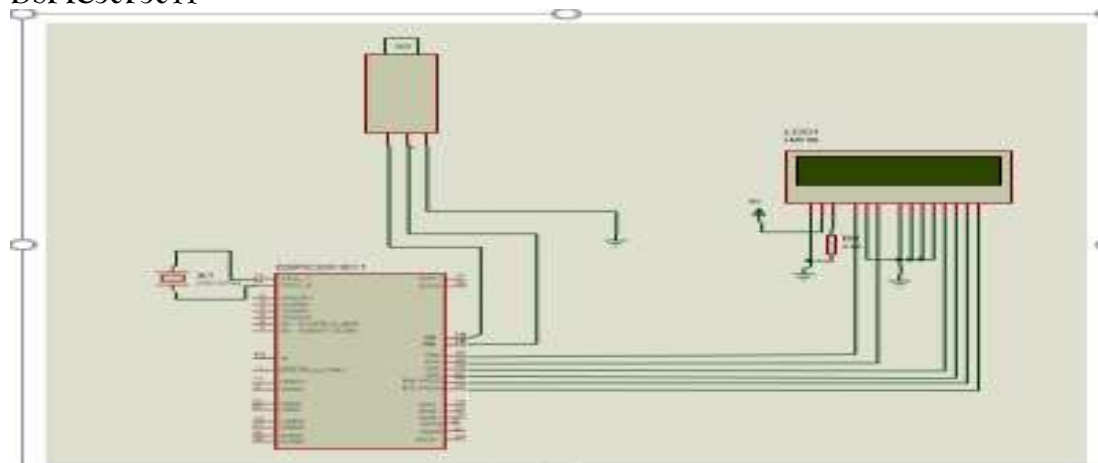


Figure 20: EV charger control circuit using microcontroller and LCD

The picture shows a specially constructed configuration with the modules "DRIVER," "PFC," and "CONTROLLER" labelled and linked by colored cables on a wooden board. These modules perform vital tasks for a sophisticated battery charger system used by electric two-wheelers, including power supply, power factor correction, or system management.

7.4 Experimental setup results of EV charger



Figure 21: Two-wheeler EV charger experimental set up (hardware prototype circuit)



Figure 22 (a) : Two-wheeler EV charger hardware circuit with pfc, controller driver circuit and Figure (b) Hardware assembly of experimental set up (prototype EV charger)

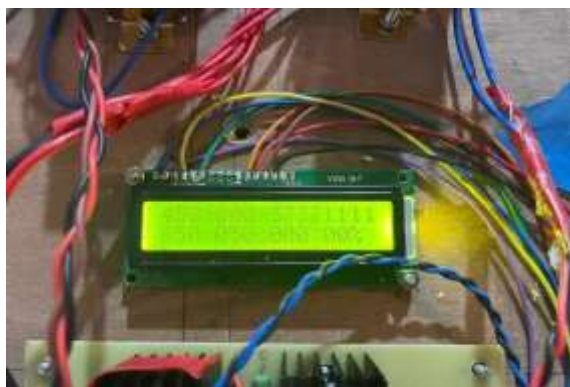


Figure 23 (c): LCD Display Module Showing Real-Time Charging Parameters for an Improved Two-Wheeler Electric Vehicle Battery Charger and Figure (d) Close-Up of LCD Display Showing Detailed Charging Metrics in Real-Time Parameters for a Two-Wheeler Electric Vehicle Battery Charger

7.5 Hardware results of EV charger



Figure 24: Switching waveforms of IGBT under off and on load conditions



Figure 25: (a) Input AC supply and output DC voltage waveforms



Figure 26: (a) IGBT waveforms at different loading conditions



Figure 27: (b) IGBT waveforms at different loading conditions from no load to full load condition

Table 8: experimental results of IGBT with different loading conditions EV battery

Sr no	Load current (amp)	Voltage (volts)	POWER (WATTS)
1	0.216	56.89 volts	12.32 W
2	0.309	56.93 volts	17.63W
3	0.407	56.89 volts	23.25W
4	0.408	56.93 volts	23.25 W
5	0.802	56.89 volts	45.65 W

8. RESULTS AND DISCUSSION

This research compares the Constant Current, which is Constant Voltage, or CC-CV approaches to analyse lithium-ion battery charge using MATLAB simulations. According to the results, CC-CV provides dynamic voltage as well as current management for safe, effective charging. Findings highlight the importance of precise modeling for developing reliable, high-performance EV battery chargers.

8.1 Experimental Hardware testing result of lithium-ion battery in open loop system

8.1.1 Experimental results of Constant current charging (hardware) testing result:

A constant current of 5 Amp is used to charge the battery in perpetual current mode. After that, the output voltage and filling time are noted. The battery takes almost two hours to reach its maximum 54.6-volt rating.



Figure 28: constant current charging experimental set up (hardware) testing of li-ion battery

Table 9: Experimental results of charging time, output voltage of lithium-ion battery in CC charging method in open loop

SR NO	TIME HOURS	IN	CURRENT(AMP)	VOLTAGE(VOLTS)
1	09:46		5A	46.2
2	10:00		5A	48.1
3	10:02		5A	48.2
4	10:04		5A	48.3
5	10:06		5A	48.4
6	10:20		5A	49.4
7	10:30		5A	50.2
8	10:40		5A	51.2
9	10:50		5A	52.3
10	10:58		5A	53.3
11	11:00(1hr 54min)		5A	54.6

8.1.2 Experimental results of Constant voltage charging (hardware) testing result

In this CC mode of battery charging, it starts in CV mode, and gradually current decreases with the increases or maintaining the constant voltage of the battery.

Table 10: Experimental Results of charging time, output voltage of lithium-ion battery in CV charging method in open loop

Sr No	Time In Hours	Current (Amp)	Voltage (Volts)
1	08:10	0	52.14
2	08:24	1.104	49.78
3	08:26	1.281	49.53
4	08:28	1.44	49.32
5	08:30	1.609	49.12
6	08:44	2.813	47.76
7	08:54	3.641	46.8
8	09:04	4.5	46.14
9	09:14	5.323	45.63

10	09:22	5.997	45.17
11	09:24	6.17	45.04
12	09:26	6.329	44.84
13	09:28	6.501	44.35
14	09:30(1hr 20min)	6.67	43.81

8.2 Experimental (Hardware) testing results of lithium-ion battery charging in closed loop using microcontroller

Table 11: Experimental results of CC charging of soc, charging time, current,voltage in closed loop

Sr No	Voltage In Volts	Current In Amperes	Time In Seconds	State Of Charge (%)
1	45	00	00	10%
2	46.8	4.4	600(10 min)	17%
3	48.1	4.5	1200(20 min)	19%
4	49.3	4.5	2400(40 min)	34%
5	50.2	4.5	3600(1 hr)	48%
6	51.5	4.4	4800	63%
7	51.9	4.5	6000	67%
8	52	4.5	7200(2 hr)	72%
9	52.5	4.5	8400(2 hr 20 min)	80%

8.2.1 Experimental testing of Constant current charging (hardware)results in closed loop

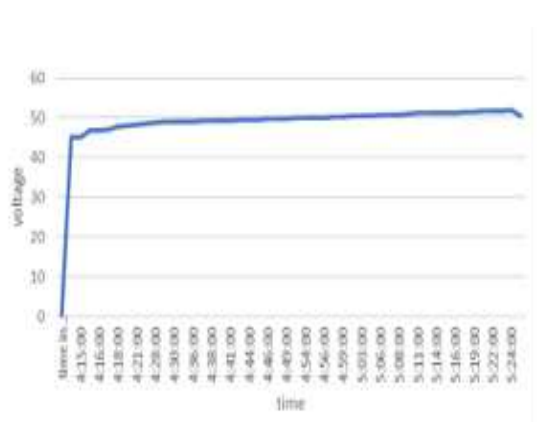


Figure 29 (a): Voltage vs time in cc method

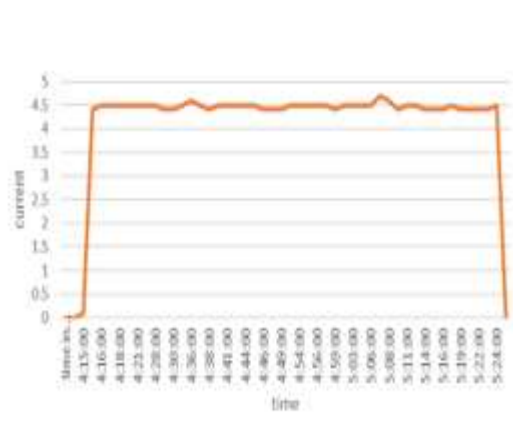


Figure 27 (b): Current vs time in cc method

The voltage reaction is shown in Figure 27(a). It starts at 0 volts and quickly rises to around 45-50 volts, which shows that the system started up quickly. After that, the voltage stays stable with only small changes, showing that the control worked well and the performance was consistent. Figure 27(b) shows

the current reaction. The peak current was around 4.6 to 5 amps at first because of the high demand at starting. Over time, the current slowly drops in steps until it reaches a steady level of 1.2 amperes. This decrease means that things are moving towards a more efficient operating state. The lines show that the charger keeps the voltage stable while changing the current so that the battery can be charged safely and quickly.

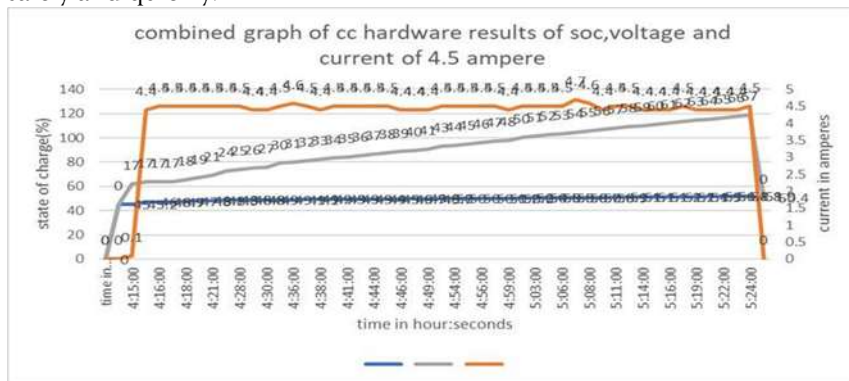


Figure 30: combined results of soc, voltage, current vs time of cc charging method

8.2.2 Constant Voltage charging hardware results in closed loop

In closed-loop constant voltage charging mode, the voltage quickly levels off at 50.5V, and the current starts at 4.5A and slowly drops as the battery charges. Around the hour mark, the current drops even more, hitting 1.2A and then zero, which means the battery is fully charged. This keeps the charging safe and effective and stops the battery from being overcharged, which extends its life.

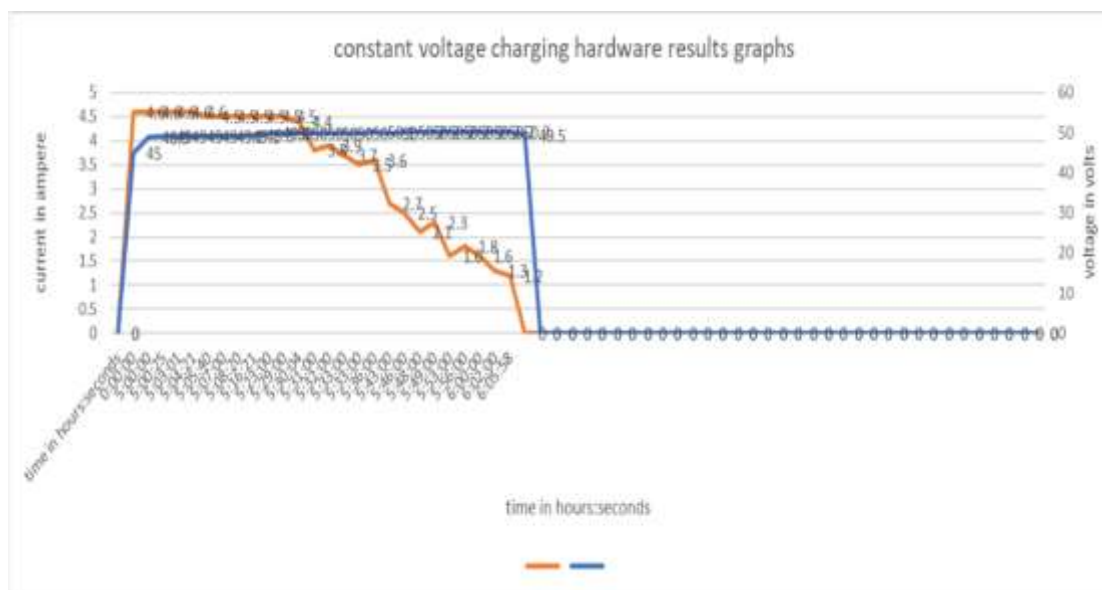


Figure 31: constant voltage charging experimental (hardware) results of soc, output voltage, current

All of the output parameters—voltage, current, and charge state—that vary over time are shown in this image.

8.3 Comparison of existing CC-CV charging method and new improved charging method of lithium-ion battery for EV

The new charging method works much better than the old CC-CV method; it gets to 18% SOC in 600 seconds instead of 954 seconds for 10% SOC. It stays this efficient the whole time; it takes 2,580 seconds to hit 50% SOC instead of 3,657 seconds. Overall, it cuts down on the total time needed to charge while keeping efficiency high and SOC levels high.

Table 12: Experimental Results Comparison of Existing and New Charger Time

SR NO	SOC (%)	CCCVMETHOD (CHARGING TIME)		NEW IMPROVED CHARGING METHOD (CHARGING TIME)	
		REFERENCE DATA TIME (SEC)	REFERENCE DATA SOC (%)	CHARGING TIME (SEC)	MEASURED DATA SOC (%)
1	10	954	15	600	18
2	20	1849	25	1200	29
3	30	2800	40	2100	47
4	40	3657	50	2580	53
5	50	5478	60	4080	64
6	60	6237	70	4740	72
7	70	7183	80	5700	85
8	80	8875	90	7425	94
9	90	10,079	91	8620	100

8.4 Comparison of Hardware Experimental Results: Existing vs. Improved EV Charger

That's how long it took the CC-CV charger to charge the battery from 10% SOC to 67-70% SOC using a controlled way of constant current and then constant voltage. This keeps you safe and makes the battery last longer. In contrast, the improved fast-charging method completed the same charge in just 1 hour and 10 minutes, significantly reducing charging time. While speedier, it needs careful thermal control to avoid overheating and save battery life. This comparison shows how the new charger reduces charging time without sacrificing safety when handled appropriately.

Table 13: Experimental results of charging time of li-ion battery of ev with, comparison of existing two-wheeler charging method and new improved charging method

Sr No	Charging Methods	Experimental (Hardware) Results Time In Hours/Seconds	MATLAB results of charging time in hour/seconds
1	CONSTANT CURRENT CONSTANT VOLTAGE CHARGING METHOD (CCCV)	1 Hour 50 Minutes	1 Hour 52 Minutes
2	FAST CHARGING METHOD	1 Hour 10 Minutes	1 hour 20 minutes

CONCLUSION

Improving the present battery charging mechanism for electric two-wheelers, or E2Ws, is the main goal of this study. We are looking for a method to get around the problems with the current charging system. Constant Current-Constant Voltage is a popular and trustworthy technique (CC-CV). However, since it

takes longer to charge, customers can find it inconvenient. According to MATLAB models and experiments, the standard CC-CV method takes around 10,079 seconds to charge the battery to 67–70% SOC and about 1 hour & 50 minutes to fully charge it. In contrast, the newly developed fast-charging technique incorporates a variable C-rate and eliminates the constant voltage phase, significantly reducing the total charging time. The improved method achieves 18% SOC in just 600 seconds compared to 10% in 954 seconds using CC-CV. It reaches 100% SOC in only 8620 seconds, which is 1459 seconds faster than the conventional approach. Hardware testing further validates the system's efficiency, where the charging time is reduced to 1 hour and 10 minutes for the same SOC level. A microprocessor dynamically adjusts the charging current based on real-time SOC, temperature, or voltage feedback. This provides safe, efficient, thermally optimised charging. Additionally, the integration of components such as boost converters, LCD modules, PFC circuits, and sensor-based feedback loops ensures regulated voltage output and protection against overcharging or overheating. This design increases battery life, operational safety, and user experience via real-time monitoring. The study confirms that the new charging approach is more efficient, practical, and adaptable for the evolving electric vehicle ecosystem. It provides a scalable and intelligent solution to meet future demands of fast and sustainable E2W charging systems.

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