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Design and Implementation of Improved Battery Charger for Two-Wheeler Electric Vehicle

Sheetal Parmar, Pritesh R Mankad

Abstract*: *Lithium-ion batteries are essential for the development of electric vehicles (EVs). Two-wheeler EVs can be charged using a wide variety of EV charging systems. In this research, existing and prospective EV charging technologies' topologies, power levels, and charging control mechanisms are analyzed. In this study, a new fast-charging approach is investigated to decrease battery temperature variance, shorten charging time, and improve charging efficiency. In contrast to constant current (CC) charging, CC-CV Charging (CC-CV) separates the charging process into multiple parts based on its C-rate for lithium-ion battery rapid charging. A 24Ah Li-ion battery, charging voltage of the battery is 54 volts of two-wheeler EV are considered for MATLAB experimental data are utilized to validate the suggested approach. The proposed technique is distinctive in that it may fully charge the battery

Keywords*: *Electric Vehicle, Lithium-Ion Battery, Battery Charger for Two-Wheeler, Dc-Dc Converter, Half Bridge Inverter.

I. INTRODUCTION

Electric vehicle development requires lithium-ion batteries (EVs). There are numerous EV charging systems available for two-wheeler EVs. This study examines the topologies, power levels, and charging control mechanisms of current and future EV charging solutions. To reduce battery temperature variance, cut down on charging time, and boost charging efficiency, a new rapid charging method is examined in this study. CC-CV Charging (CC-CV) breaks the charging procedure into many sections based on its C-rate for lithium-ion battery quick charging, in contrast to constant current (CC) charging [Morris Brenna,2020[2]]. The suggested method is tested using experimental data from MATLAB and a 24Ah Li-ion battery. The proposed method stands out because it has the potential to fully charge the battery.

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*Correspondence Author(s)

Sheetal Parmar*, PhD Research Scholar, Gujarat Technological University, Ahmedabad (Gujarat), India. E-mail: setudeep@yahoo.co.in, ORCID ID: 0009-0006-9022-7779

Dr. Pritesh R Mankad, Associate Professor, Mahatma Gandhi Institute of Technical Education and Research Center, Vadodara (Gujarat), India. E-mail: mailto:sheetal140981@gmail.com

Maximum battery charge capacity, a shorter charge time (CT), and increased battery cycle life are all characteristics of the perfect charger. The goal of charger development strategies has always been to provide quick battery charging without compromising the battery's electrochemistry. CC-CV techniques are typically used to charge Li-ion batteries (Morris Brenna,2020, [2]). While charging a battery in CC mode, a higher constant current is used until the battery reaches its predetermined cut-off voltage, which is commonly 4.2V.

During CV mode, the same cut-off voltage is provided continuously until the current reaches its cut-off value (usually 0.01 C), at which point charging is stopped. When charging in CC mode, the charging time is prolonged, and the charging efficiency and capacity are reduced. As a result, the quick CC-CV charge approach is impractical.

II. DIFFERENT CHARGING METHODS FOR THE LITHIUM-ION BATTERY FOR TWO-WHEELER EV

A. Constant Current Charging Method:

With this technique, a continuous, uniform current is used to charge the battery. This technique of charging should not be used if there are more cells in the battery since certain cells may reach full charge before others. This approach is ineffective and puts too much strain on the cells. Longer charging times result from maintaining a low charge current. This approach requires a greater charging current in order to quickly charge Li-ion batteries [Mihir Gaglani,2020 [3][5]]. Although the rate of Li-ion travel is faster than the rate of insertion into the device, this is due to a high charging current. graphite layer (Morris Brenna, 2020, [2]).

This prevents some lithium ions from entering the electrode layer and causes them to be deposited instead. Lithium plating is the process involved. Li-ions need enough time to penetrate open graphite electrode sites in order to prevent lithium plating (Mihir Gaglani, 2020 [7]). As shown in figure.1 it shows the MATLAB simulation of constant current charging circuit.

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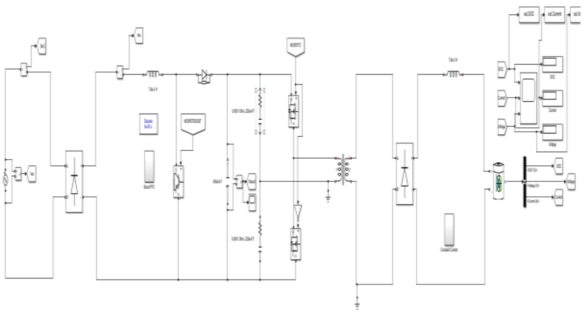


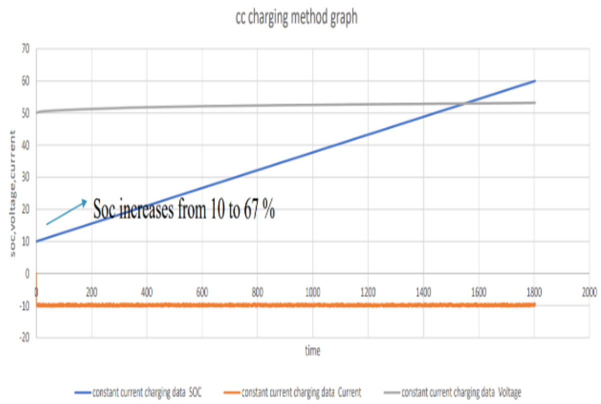
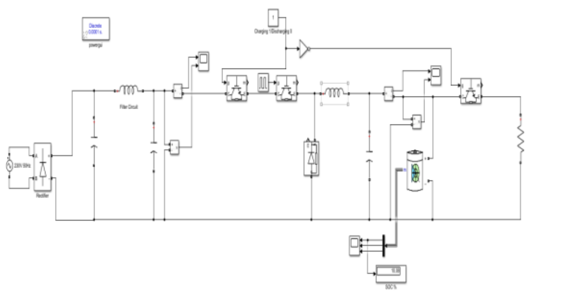
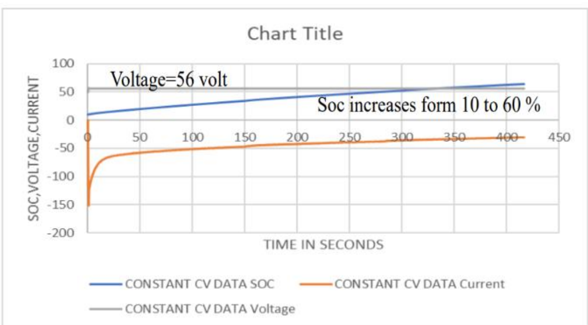


Figure.1 Matlab Circuit in Cc Charging Method and Results of Cc Charging Soc (%) And Current with the Constant Value of 24 Ampere

B. Constant Voltage Charging Method:

With this technique, a battery is charged to the desired voltage using a DC power source. The nominal set-point voltage for lithium-ion batteries is 4.2 +/- 50 mV, and the maximum charging current is 1 C (J. Thomson,2018[10]). This approach is recommended in Pb-acid batteries because it equalizes the charge of each cell. The battery doesn't get fully charged with this approach, and it takes the battery more than two hours to get fully charged. This is a significant disadvantage (Xia song Hu,2020, [4]).





Here figure.2 shows the MATLAB simulation of constant voltage charging method of lithium-ion battery with 54 volts constant and soc increases from 10% to 60%.

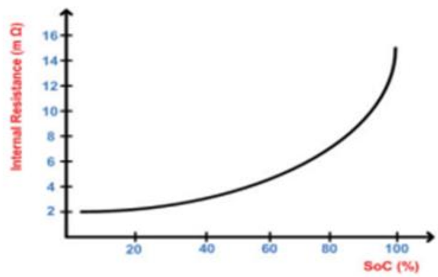
C. Constant Current, Constant Voltage Charging Method:

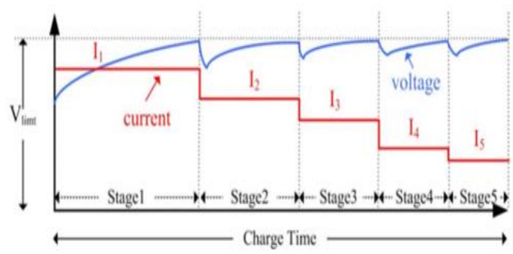
Because it is simple to use, effective, and has its own benefits, constant current constant voltage (CCCV) charging is the standard method for charging Li-ion batteries [Mihir Gaglani,2020]. In most commercial chargers for lithium-ion batteries, the straightforward and typical constant current constant voltage (CCCV) charging approach is employed. There are two phases of charging. The first constant current (CC) stage involves charging the battery at a constant current until a certain voltage is reached at the battery terminals. In the second constant voltage (CV) stage, a predetermined voltage is maintained until the charging current progressively decreases to the predetermined value, such as 0.01 C, where C rate is defined as the ratio of the charging current to the nominal current capacity (C) of a battery. Our study used a cut-off current of 0.01 C to stop the CCCV charging process (Tarun Parmar,2020, [6]).

D. Fast Improved Charging Method:

All of the aforementioned charging plans have issues with lengthy charging times. According to Fig. 2, the battery is charged using this manner at five different current levels. If the battery hits its threshold voltage limit, each level will end once (Romain Mathieu,2021, [8][1]).

High charging currents are required to implement fast charging in Li-ion batteries, although doing so has disadvantages such as lithium plating and joule heating [Romain Mathieu,2021 [15][16][17]. Hence, in order to charge a battery quickly, the charging current must be increased when the internal resistance of the battery is low and decreased when the internal resistance of the battery is high, as illustrated in figure 3(a).





As shown in Fig.3(a) internal resistance of battery is less when SoC is low and it is high when SoC is high.

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Hence, it is advised to charge the battery with high charging currents during low SoC level and with low charging currents during high SoC level (Tarun Parmar,2020, [6]).

Figure 3(b) illustrates a step charging scheme where the charging rate can be controlled by varying the width of pulses. According to this method, charging can be sped up, polarization can be slowed down, and life can be increased. As shown in Figure 3(b) Every pulse charge current applied to a battery includes three factors: peak amplitude Ipk, duty cycle D=ton/Tp, and frequency [Romain Mathieu, 2021[12]]. In this method of charging each stage are 1C, 0.75C, 0.50C, 0.25C respectively [Romain Mathieu,2021]. Two steps, three step, four step of charging with different C-rate is also preferable. As the charging current is controlled till the battery is fully charged, the total time gets reduced.

It is seen that the charging current at final stage of the charging cycle is 0.25C, which is very large compared to the same at CCCV scheme [Xia song Hu, 2020 [14]].

Terminating the battery charging with charge current of 0.25C does not damage the battery and step charging of current charge method is efficient and prolongs battery life as well [Xia song Hu 2020 [14]][18][19][20]. To implement step charging scheme a battery charger circuit using a closed loop current controlled DC-DC converter as shown in Figure.4 is proposed in this paper.

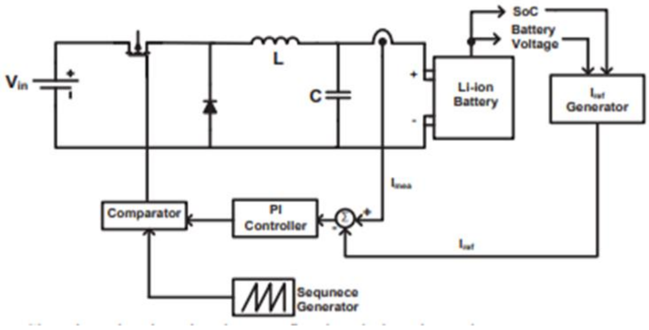

Figure 4. Simulation Results of all Charging Methods in MATLAB

The CCCV method is the traditional and well-established method for battery charging among the several charging procedures described in the literature, as was explained earlier. For the quick charging approach suggested in this research, study step charging currents [Tarun Parmar,2020, [10]]

The results of simulating both charging techniques in MATLAB simulation software are displayed in Figs. 5 and 6, respectively. During the simulation study, a Li-ion cell with a 24 Ah capacity, a nominal voltage of 3.7 V, and a full charge voltage of 4.2 V is taken into consideration [11].

In the figure above. Figure 5 illustrates the results of the CCCV charging technique for soc (%) up to 10 to 80% in 5000 seconds, constant current of 12 ampere, and steady voltage rise to its threshold value of 54 volts. In Figure 4, the results of the enhanced charging technique are shown for soc(%) from 0 to 90% in 4050 seconds, (J. Eichler.2019, [7]) currents at various C-rates (1C, 0.75C, 0.50C, and 0.25C), and voltage at various C-rates.

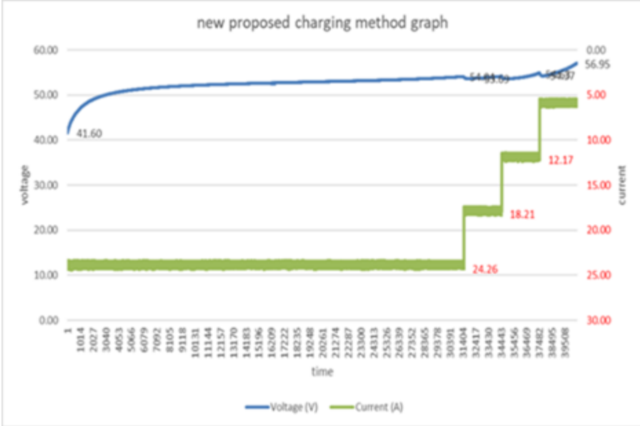

Figure 5. CCCV Soc graph

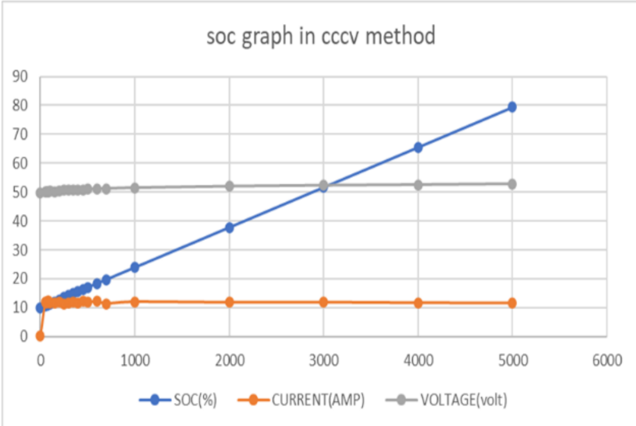

Figure 6. CCCV V/I graph

In this figure.5 and figure.6 shows the CCCV charging method results for soc (%) up to 10 to 80% in 5000 seconds, current constant 12 ampere, and the voltage rises gradually up to its threshold value of 54 volts.

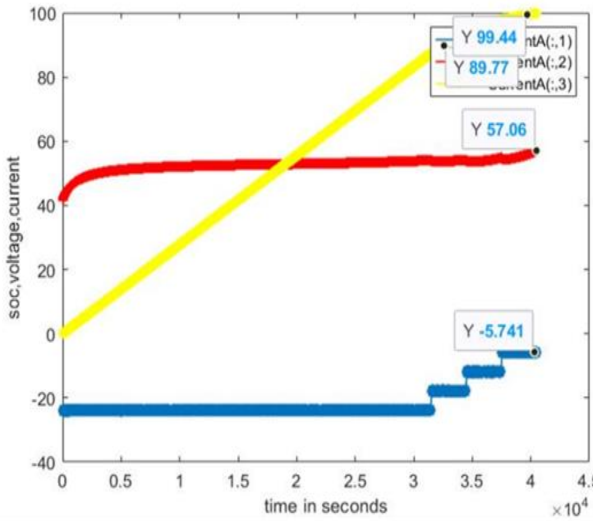

Figure 7. Step Charging Soc, Voltage, Current Graph

This figure.7(b) shows the improved charging method results for soc (%) from 0 to 90% in 4050 seconds, currents in different C-rates like 1C,0.75C,0.5C,0.25C, and voltage in every different C-rate of charging.

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In this Paper Comparison of Times of Different Charging Methods are Given in TABLE.I

Sr no	Charging method	Time(seconds)	SOC (%)
1	CC Method	6000second	10 to 90%
		(2 hour)	
2	CV Method	3000seconds	10 to 90%
		(1 hour)	
3	CC-CV Method	5508 seconds	10 to 90%
		(1hr 52minutes)	

Table 2: Charging Time of CCCV and Step Charging Method in Matlab

Sr no	Charging Method	Time (Seconds)	SOC (%)
1	CCCV Method	6000second	10 to 90%
		(2 hour)	
2	New fast charging method	4000 seconds	10 to 90%
		hour 12 minutes)	

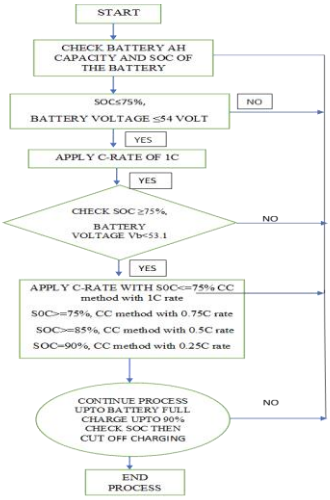


Figure 8. Flow Chart of the Proposed Step Charging Method of EV Two-Wheeler

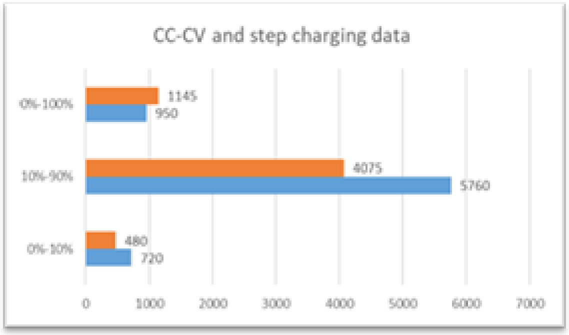
This figure.8 new proposed charging scheme was explained in steps, first we check the battery initial state such as Ampere hour capacity of battery and state of charge(SOC) of the battery which is less than or equal to 75 percent and battery voltage is also less than its threshold value of voltage in this EV two wheeler its 54 volts, If both of the conditions are met, implement our suggested new fast charging topology in steps as follows: first, apply a charging rate of current of 1C, and then again check the SOC (%) and threshold value of voltage 54 volts. Similarly, in each step, check the SOC (%) and threshold value of voltage after applying C-rate with different values and measure the time of charging lithium-ion battery. Repeat the process for the li-ion battery with a different rate charging up to the soc reached 90 to 100%. There are numerous

III. RESULTS AND DISCUSSIONS

There are numerous charge methods described in the literature. The CCCV technique is widely used and accepted. The ideal charging currents to use for the step charging approach are constantly being studied (Romain Mathieu,2021 [15]. Both charging techniques are simulated using MATLAB simulation software, with the outcomes displayed in Figs. 3 and 4. During the simulation study, a Li-ion cell with a 24 Ah capacity, a nominal voltage of 3.7 V, and a full charge voltage of 4.2 V is taken into consideration, Charing voltage of battery module for two-wheeler is 54 volts.

The CCCV technique, as seen in Fig. 6, requires over two hours for SoC to reach 80%. The main reason for the long duration is the exponentially falling current in the constant voltage stage [Nitin Trivedi,2018 [13]]. In this scenario, the charging current is uncontrolled and keeps decreasing exponentially.

According to Fig. 6, a battery can be fully charged using a step charging method in around one and a half hours. The overall duration is shortened as the charging current is managed until the battery is fully charged. It can be seen that the charging current at the charging cycle's final stage is 0.1C, which is significantly higher than the same value under the CCCV system. The battery is not damaged if the battery charging is stopped at 0.1C; therefore, this step current charge approach is effective and increases battery life [Mihir Gaglani,2020 [9]. In Table II, specifics of charging time with relation to SoC are provided.



Over 90% SoC, it is also noted that the CCCV method takes a long time to inject charge into the battery, whereas the step charging approach takes less time as seen in Table. II

IV. CONCLUSION

A battery charger that uses a step charging technique was suggested in this study. The suggested charger circuit is simulated and validated using MATLAB simulation tools. There are tabulated findings from simulations contrasting the charging times of the CCCV and step charging techniques as shown in figure.9. In order to implement a charging method in the future, a charger circuit prototype is being developed. It has been observed that simulation and experiment findings frequently correlate. According to simulation results, the step charging strategy takes less time to charge than the CCCV method.

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DECLARATION STATEMENT

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
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Authors Contributions	All authors having equal contribution for this article.

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AUTHORS PROFILE

Sheetal Parmar, Phd research scholar from Gujarat technological university Ahmedabad. I have completed my ME in electrical from the faculty of technology and technology MS UNIVERSITY With 14 years of teaching experience.

Dr. Pritesh R Mankad, Associate Professor, Mahatma Gandhhi Research and Technical Education, Navsari. Working as Head of Electrical engineering Department of BIT from 2017. Worked at various positions like Chairman of Board of Examiners –VNSGU, PG faculty at GTU, Paper setter at GTU, Life member of ISTE, Fellow of Institution of Engineers (India), Life member of Society of Power Engineers, Coordinator of e-Yantra lab BIT, Coordinator of e-YIC of IITB at BIT He is expert in induction motor drive and power electronics and he has 22 years of experience of industry and teaching also.