



Application of the Constant Current Method in Lead-Acid Battery Charging

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Abstract

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Air pollution caused by fossil fuel-powered vehicles has a significant impact on public health and the environment, encouraging the transition to electric vehicles in accordance with Presidential Regulation No. 55 of 2019. Electric vehicles use batteries as their main energy source, making a safe charging system essential to prevent overcharging. This study designs a lead-acid battery fast charging system based on the Constant Current (CC) method with a constant current of 2.7 A, equipped with an automatic cut-off. Testing was conducted through field observation, interviews, and literature review. Results show that the charging time is only ± 3 hours 13 minutes, significantly faster than the conventional method (10 hours), with component measurements within tolerance limits. The PZEM-017 and voltage divider sensors accurately read voltage according to the datasheet. This system proves to be efficient, safe, and capable of preventing battery damage due to overcharging.

Keywords: Lead-Acid Battery, Fast Charging, Constant Current.

Abstrak

Polusi udara akibat kendaraan berbahan bakar fosil berdampak signifikan terhadap kesehatan dan lingkungan, mendorong transisi menuju kendaraan listrik sesuai Perpres No. 55 Tahun 2019. Kendaraan listrik menggunakan baterai sebagai sumber energi utama, sehingga sistem pengisian daya yang aman menjadi penting untuk mencegah overcharging. Penelitian ini merancang sistem fast charging baterai lead acid berbasis metode Constant Current (CC) dengan arus konstan 2,7 A yang dilengkapi pemutus otomatis. Pengujian dilakukan melalui observasi lapangan, wawancara, dan studi literatur. Hasil menunjukkan waktu pengisian hanya ± 3 jam 13 menit, jauh lebih cepat dibanding metode konvensional (10 jam), dengan nilai pengukuran komponen dalam batas toleransi. Sensor PZEM-017 dan voltage divider mampu membaca tegangan secara akurat sesuai data sheet. Sistem ini terbukti efisien, aman, dan mampu mencegah kerusakan baterai akibat overcharging.

Kata kunci: Baterai Lead-Acid, Fast Charging, Arus Konstan.



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1. Introduction

Air pollution caused by fossil-fueled vehicles has long been recognized as a form of environmental degradation. According to Indonesian law (Law No. 32/2009 and Government Regulation No. 41/1999), this environmental issue reduces the quality of life, leads to serious health problems, and contributes to global climate change[1].

Based on data from Clean Air Asia (CREA) and the "Ayo Sehat" portal of the Indonesian Ministry of Health in 2024, more than 29 million residents in the Greater Jakarta area (Jabodetabek) were exposed to unhealthy levels of air pollution that resulted in premature deaths[2]. This alarming figure indicates the high risk of air pollution caused by fossil-fueled vehicles, thereby reinforcing the urgency of transitioning toward electric vehicles (EVs). Such a transition is strongly supported by Presidential Regulation (Perpres) No. 55 of 2019 concerning the Acceleration of the Battery Electric Vehicle Program for Road Transportation [3].

Electric vehicles are motorized vehicles powered by electricity stored in batteries as the primary energy source, operating without exhaust gas emissions. The battery functions as the main energy storage system required to drive the electric motor [4]. To utilize the battery effectively, a charging system is required. However, charging that continues after the battery reaches full capacity, without automatic cut-off, may cause overcharging, which leads to damage or reduced battery performance.

Previous studies by Chee Hiun Lee, Jianhui Wong, Yun Seng Lim (2023), and Arif Hariyadi, Awan Nugroho, and Suwarno (2021) have shown that fast charging of lead-acid batteries using a constant voltage method without automatic disconnection may result in overcharging, excessive heat generation, and accelerated battery degradation [5][6]. To prevent such issues, an optimized fast charging system is required, one that can automatically stop the charging process once the battery is fully charged.

In this study, the fast charging system applied is based on the Constant Current (CC) method, which includes an automatic cut-off mechanism [7]. In this method, the battery is charged with a stable and constant current of 2.7 A[8]. This approach not only allows faster charging but also prevents overcharging, which could otherwise accelerate the aging process of the battery. By optimizing the use of the CC method, this research aims to improve the performance of lead-acid battery charging by enabling rapid charging while protecting the

battery from overcharging. The evaluation focuses on charging time, current, and battery voltage [9][10].

2. Method

This research was conducted experimentally to design and implement a fast charging system for lead-acid batteries using the Constant Current (CC) method with an automatic cut-off mechanism. The system is designed to ensure that the battery can be charged with a constant and stable current while avoiding overcharging, which could degrade the battery performance. The methodology applied in this study consists of several stages, as described below.

2.1 System Planning

The design process began with selecting components based on functional requirements, cost efficiency, and compatibility. Components such as the Arduino Mega 2560 microcontroller, voltage divider, PZEM sensor, MOSFET, Max485 transceiver, and Human Machine Interface (HMI) were prepared and assembled on a PCB board according to the circuit schematic. After the assembly, the system was programmed using Arduino IDE to control charging operations automatically.

2.2 Block Diagram

The block diagram illustrates a microcontroller-based system with Arduino Mega as the central processing unit. The system receives input from two types of sensors: a PZEM sensor for current measurement and a voltage divider sensor for battery voltage measurement. The data collected from these sensors are processed by the Arduino, which then controls two output devices: the MOSFET for regulating the charging process and the HMI display for real-time monitoring.

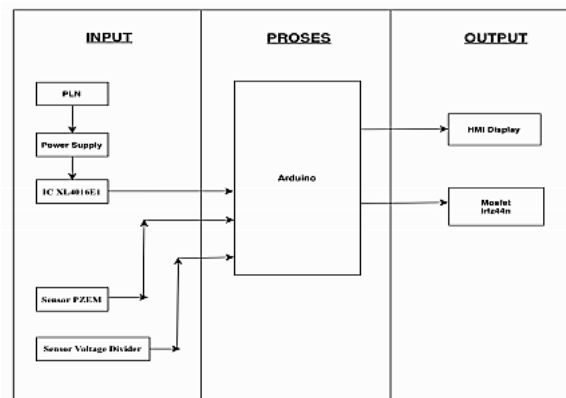


Figure 1. Block Diagram

2.3 Circuit Schematic

The circuit schematic represents the connection between electronic components within the system. A regulated DC power supply provides input voltage, which is then conditioned before being fed into the Arduino Mega. The microcontroller manages input from sensors (voltage divider and PZEM) and controls the MOSFET for current regulation. The system also communicates with the HMI display via serial communication to provide real-time monitoring of charging parameters.

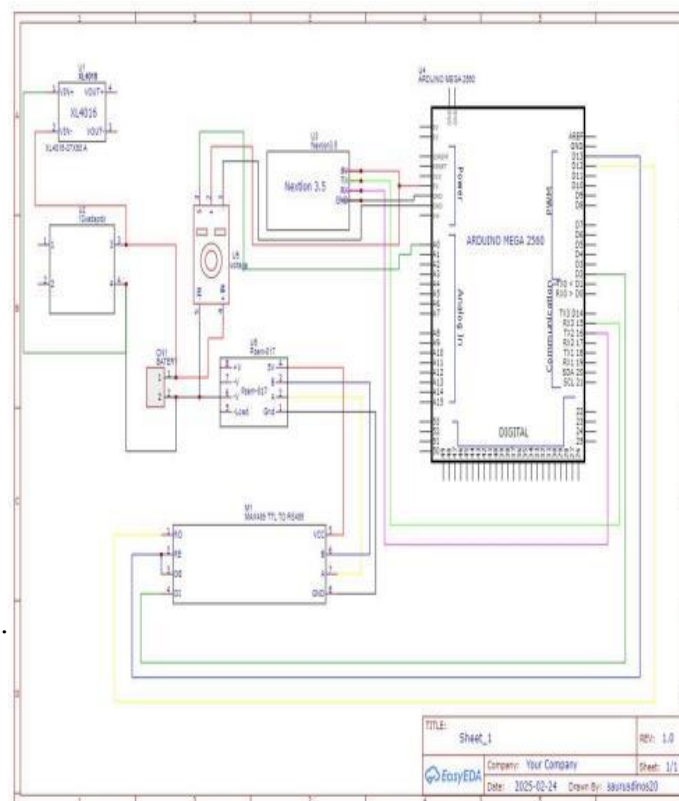


Figure 2. Circuit Schematic

2.4 Device Design

At the device design stage, the main objective is to ensure that the assembly process runs smoothly and produces a system that meets expectations and can be utilized optimally. This design stage serves as an essential foundation to develop a device that not only functions properly but also has a well-structured and efficient component arrangement.

One of the key activities in this stage is to prepare a comprehensive design of the device, focusing on the accurate and systematic placement of components. This approach minimizes installation errors and ensures a seamless assembly process. In addition, workflow planning in the form of a flowchart is required. Generally, a flowchart is a visual representation of a process

that outlines sequential steps or workflows using standard symbols such as arrows, process blocks, and decision nodes. Flowcharts simplify the understanding of the designed process by presenting information in a concise, structured, and easy-to-follow manner.

The flowchart in this study functions to map the sequence of processes or working steps of the device from start to finish. With this representation, each stage in the system can be designed more systematically and logically, thereby facilitating implementation and evaluation. Furthermore, the use of a flowchart helps to identify potential obstacles and ensures that the overall system operates in accordance with the predetermined design.

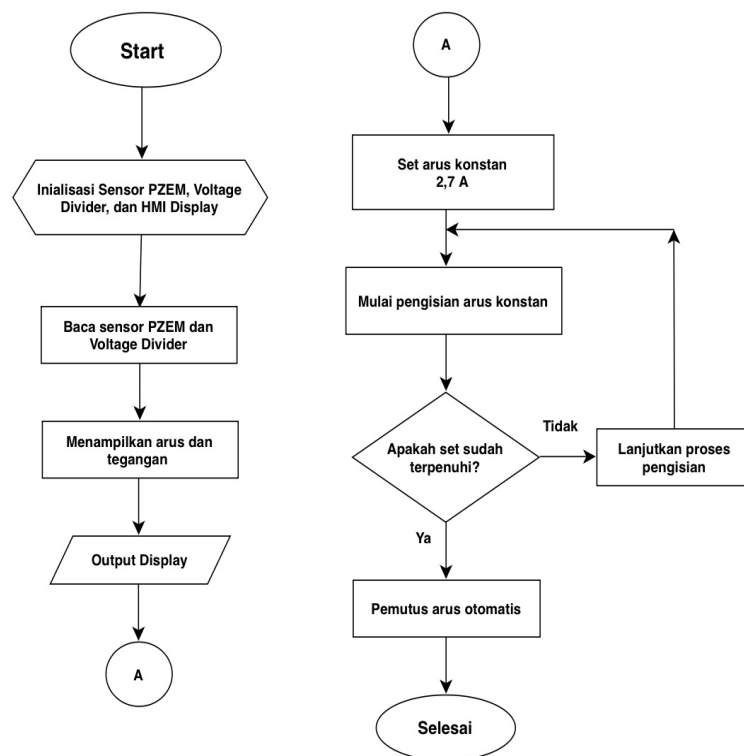


Figure 3. Flowchart Description

2.5 Working Principle of the Device

The working principle of the device can be described as follows:

1. When the system is powered on, the Arduino Mega begins reading signals from the Voltage Divider sensor and the PZEM sensor.
2. The signals from the sensors are transmitted to the Arduino via the Max485 transceiver. Based on the received data, the Arduino controls the MOSFET, which regulates the current flow to the load.
3. Once the battery reaches full capacity, the system automatically cuts off the charging process to prevent overcharging.

4. In addition, the Arduino is connected to the HMI via serial communication, allowing the HMI to display real-time charging data.
5. The user only needs to monitor the process through the HMI, while other functions operate automatically under the Arduino control system.

3. Results and Discussion

This chapter presents the results obtained from testing the battery charging control system and provides a detailed discussion of the findings. The section covers component measurements, sensor performance, battery charging tests, and the calculation of charging efficiency.

3.1 Voltage Divider Sensor Testing

In this study, the Voltage Divider sensor was used to measure the battery voltage within the range of 0–25 volts during the charging process. The high voltage from the battery is proportionally reduced through a resistor network, allowing it to be safely read by the ADC on the microcontroller without exceeding the maximum ADC input limit of 5V. The acquired data is utilized to monitor the battery condition in real time.

Table 1. Voltage Divider Sensor Test Results

No	Voltage (V)	Result
1	0 - 5	Readable
2	6 - 10	Readable
3	11 - 15	Readable
4	16 - 20	Readable
5	20 - 25	Readable
6	> 25	Not Readable

The test results show that the Voltage Divider sensor is able to detect battery voltage values starting from 0 V up to 25 V. The sensor provides valid readings when the voltage is less than 25 V, but it is unable to detect accurately when the battery voltage exceeds 25 V.

3.2 PZEM-017 Sensor Test

In this study, the PZEM-017 sensor was employed to measure both voltage and current in the battery charging system. The sensor operates by monitoring the real-time values of the DC power supplied to the battery and transmitting the data to the microcontroller via Max485

serial communication. The readings obtained from the PZEM-017 sensor are utilized to evaluate the performance of the battery charging process.

Table 2. PZEM-017 Sensor Test Results

No	Voltage (V)	Current (A)	Result
1	0 - 5	0 - 5	Readable
2	6 - 10	6 - 10	Readable
3	11 - 15	11 - 15	Readable
4	16 - 20	16 - 20	Readable
5	20 - 25	20 - 25	Readable
6	> 25	> 25	Readable

The test results show that the PZEM-017 sensor is capable of measuring battery charging voltage from 0 V up to 25 V and current from 0 A up to 25 A. According to the datasheet, however, the PZEM-017 sensor has a broader measurement capability, with the ability to measure voltage up to 300 V and current up to 50 A.

3.3 Battery Charging Test

The battery charging system in this study was tested using the constant current method. The objective of this test was to optimize battery charging speed compared to the conventional method. The charging process was carried out continuously with a fixed current, while the voltage and current data were monitored in real time through the HMI display.

According to the study by Rohman (2020) on the performance analysis of lead-acid batteries, a 12 V battery consists of six cells, each with a nominal voltage of approximately 2 V [11]. Furthermore, Hidayat (2019) in his experimental study on lead-acid battery charging stated that a fully charged 12 V lead-acid battery has a final charging voltage of around 13.6 V to 13.8 V [12].

In addition, Battery University (2018) in its article *Charging Lead Acid Batteries* emphasized that if the initial voltage of a 12 V battery is below 12.0 V, the battery can be categorized as “soaked” or sulfated, indicating reduced capacity [13][14]. In this experiment, five tests were conducted on five different brands of 12 V lead-acid batteries, each with different initial voltage conditions (both sulfated and in good condition).

Table 3. Battery Charging Test Results

Baterai	Test No.	Initial Voltage (V)	Final Voltage (V)	Current (A)	Charging Time	Relay
GS Astra 12V 7Ah (Degraded)	1	4.8	12.2	2.7	5h 50m	No Cut-off (Degraded)
	2	5.1	12.3	2.7	6h 5m	No Cut-off (Degraded)
	3	6.2	12.4	2.7	5h 35m	No Cut-off (Degraded)
	4	7.4	12.4	2.7	5h 20m	No Cut-off (Degraded)
	5	8.0	12.5	2.7	5h 10m	No Cut-off (Degraded)
Yuasa 12V 7Ah (Degraded)	1	9.1	13.0	2.7	4h 40m	No Cut-off
	2	9.4	13.1	2.7	4h 35m	No Cut-off
	3	9.6	13.0	2.7	4h 25m	No Cut-off
	4	9.7	13.1	2.7	4h 20m	No Cut-off
	5	9.8	13.2	2.7	4h 15m	No Cut-off
Incoe 12V 7Ah (Degraded)	1	10.2	13.7	2.7	3h 50m	Cut-off
	2	10.4	13.7	2.7	3h 45m	Cut-off
	3	10.7	13.7	2.7	3h 42m	Cut-off
	4	10.8	13.7	2.7	3h 38m	Cut-off
	5	10.9	13.7	2.7	3h 35m	Cut-off
Panasonic 12V 7Ah (Degraded)	1	11.0	13.7	2.7	3h 20m	Cut-off
	2	11.2	13.7	2.7	3h 18m	Cut-off
	3	11.3	13.7	2.7	3h 15m	Cut-off
	4	11.4	13.7	2.7	3h 12m	Cut-off
	5	11.1	13.7	2.7	3h 10m	Cut-off
Zeus 12V 7Ah (Degraded)	1	12.0	13.7	2.7	3h 3m	Cut-off
	2	12.0	13.7	2.7	3h 4m	Cut-off
	3	12.1	13.7	2.7	3h 5m	Cut-off
	4	12.2	13.7	2.7	3h 3m	Cut-off
	5	12.0	13.7	2.7	3h 2m	Cut-off

3.4 Fast Charging and Conventional Charging Test

A charging test using both fast and conventional methods was conducted to verify that the fast-charging approach yields shorter charging times than the conventional method. Both methods used the same battery, a 12 V 7 Ah Zeus lead-acid battery, with charging carried out using the CTEK XS 0.8 charger for the conventional method and the proposed system for the fast charging method [15].

Table 4. Comparison of Fast Charging and Conventional Charging

Charging Method	Test No.	Initial Voltage (V)	Final Voltage (V)	Current (A)	Charging Time	Status
Fast Charging	1	12.0	13.7	2.7	3h 3m	Cut-off
	2	12.0	13.7	2.7	3h 4m	Cut-off
	3	12.1	13.7	2.7	3h 5m	Cut-off
	4	12.2	13.7	2.7	3h 3m	Cut-off
	5	12.0	13.7	2.7	3h 2m	Cut-off
Conventional Charging	1	12.2	13.7	2.7	10h 5m	Full
	2	12.1	13.7	2.7	10h 2m	Full
	3	12.0	13.7	2.7	10h	Full
	4	12.0	13.7	2.7	10h 7m	Full
	5	12.1	13.7	2.7	9h 8m	Full

3.5 Discussion Fast Charging and Conventional Charging Duration

The experimental results demonstrate that charging a 12 V 7 Ah lead-acid battery with a constant current of 2.7 A requires an average time of approximately **3 hours**, which is significantly shorter compared to the conventional charging method that takes about **10 hours**. This indicates a time efficiency of more than 60%, proving that the fast charging method is far more optimal for applications requiring rapid and effective battery charging [16].

Another advantage is that the applied fast charging system is already equipped with an automatic cut-off mechanism, ensuring that once the battery reaches full capacity, the charging current is immediately stopped. This feature prevents the risk of overcharging and potential cell damage, thereby improving battery safety and reliability.

These findings are consistent with the study conducted by Sulzer et al. (2019) in *Faster Lead-Acid Battery Simulations from Porous-Electrode Theory*, which reported that lead-acid batteries remain stable even when charged at high current rates up to 5 C, especially when supported by an automatic current cut-off system. Accordingly, the applied current of **2.7 A** (approximately **0.39 C** for a 7 Ah battery) clearly falls within the category of safe fast charging [17].

Furthermore, research by Bizhani et al. (2021) in *A Comprehensive Comparison of a Lead-Acid Battery Electro-Thermal Performance Considering Different Charging Profiles* also confirmed that

constant-current fast charging with automatic cut-off not only reduces charging time but also avoids excessive heat buildup that could arise from overcharging [18].

Therefore, based on both experimental results and previous studies, it can be concluded that fast charging at 2.7 A is not only effective in reducing the charging duration of 12 V 7 Ah lead-acid batteries but also safe due to the integrated cut-off protection system. This makes fast charging a more optimal solution compared to the conventional method [19][20].

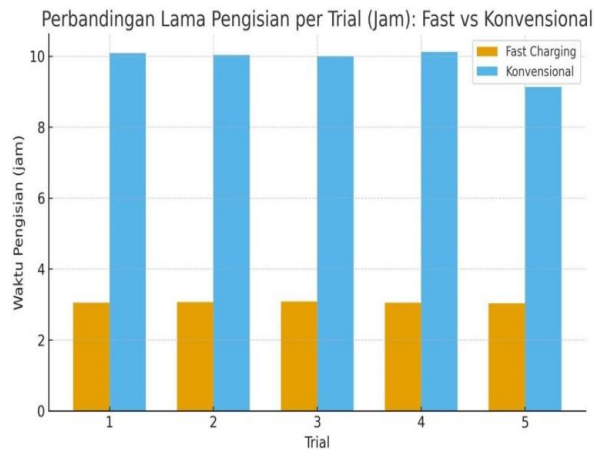


Figure 4. Comparison of Battery Charging Duration Between Fast Charging and Conventional Methods

4. Conclusion

This study successfully developed and tested a battery charging control system based on the Arduino Mega microcontroller integrated with Voltage Divider and PZEM-017 sensors. The system was able to accurately monitor voltage and current in real-time and regulate the charging process through a MOSFET with automatic cut-off protection.

Experimental results showed that the fast charging method using a constant current of 2.7 A charged a 12 V 7 Ah lead-acid battery in approximately 3 hours, significantly faster than the conventional method, which required around 10 hours. This indicates more than 60% improvement in charging efficiency. Furthermore, the automatic cut-off mechanism effectively prevented overcharging, ensuring battery safety and extended lifespan.

Overall, the proposed system demonstrates that fast charging with constant current and cut-off protection is not only efficient but also safe for lead-acid battery applications.

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