



Thyristor-based Rechargeable Battery Charger

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In this project, our main objective is to design an automatic battery charger using Silicon-Controlled Rectifier (SCR) and simulate their operation. Batteries play a crucial role in safely storing electricity by converting electrical energy into chemical energy. The primary focus of our project is on thyristor-based rechargeable battery chargers, known for their high quality and competitive pricing. We delve into the design and simulation of automatic battery chargers employing SCR technology. This article encompasses the simulation, implementation, and partial construction of such a charger. The electronic circuit will be tailored to meet specific charging process requirements.

Keywords: *Automatic battery charging; simulation; SCR; implementation; controlled rectifier.*

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1. INTRODUCTION

Traditional battery charging methods often struggle with efficiency, safety, and versatility. This project introduces a novel approach using a thyristor, a semiconductor device, to precisely regulate the charging current for various batteries, including 12V lead-acid batteries commonly found in automobiles, motorcycles, and solar panel systems. This innovative technique ensures optimal efficiency, minimizing wasted energy while delivering the needed power. Thyristor control also promotes safety by meticulously regulating the charging process, preventing overcharging, overheating, and potential battery damage. Moreover, the flexibility of this method allows for tailoring to diverse battery types and sizes, making it suitable for a wide range of applications. Automatic features like timers and voltage monitoring further enhance safety and convenience by automatically stopping the charging upon reaching full capacity. While initial component and design costs exist, the long-term cost-effectiveness is undeniable due to optimized charging processes and extended battery life. Overall, thyristor-based charging emerges as a reliable, efficient, and safe solution for recharging batteries across various applications [1].

2. LITERATURE REVIEW

Using thyristors to implement rechargeable battery adapters has been the topic of a number of published papers. A paper by R. K. Aggarwal and V. K. Gupta titled "Thyristor Controlled Battery Charger" describes the design and implementation of a thyristor-controlled battery charger. The paper discusses the benefits of using thyristors in battery chargers, including their ability to modulate charging current and prevent overcharging. Additionally, the results of experiments conducted on the battery charger are presented [1].

"A Thyristor-Based Battery Charger for Electric Vehicles" by S. K. Pandey and A. K. Mishra details the development of a thyristor-based battery charger for electric vehicles. The difficulty of creating a battery charger for electric vehicles is discussed in the article, including the requirement to offer a high charging current and prevent the battery from overcharging. Additionally, the outcomes of trials done on the battery charger are shown [2].

Thyristors, including silicon-controlled rectifiers (SCRs), gate turn-off thyristors (GTOs), and

bipolar junction transistors (BJTs), have long been utilized in battery converters for modulating charging currents, especially in early lead-acid battery chargers since the 1970s. Despite their advantages of affordability, longevity, and versatility in current output, thyristors can be sensitive to transients and difficult to deactivate once activated. Recently, there has been interest in integrating insulated gate bipolar transistors (IGBTs) into chargers due to their faster switching speed and higher current handling capacity, albeit at a higher cost and shorter lifespan. The choice between thyristors and IGBTs depends on factors like cost, performance, and lifespan requirements. Advances in thyristor-controlled battery chargers encompass techniques such as power factor correction, battery management, and soft-switching, leading to more efficient and reliable charging solutions for various applications [2].

3. METHODOLOGY

The methodology describes the systematic implementation of a thyristor-based rechargeable battery converter. By meticulously considering battery specifications, selecting the appropriate thyristor, designing an appropriate control mechanism, and incorporating safety features, the proposed charger can charge rechargeable batteries efficiently while ensuring their durability and safe operation. Based on the demands of the application, an appropriate rechargeable battery type (e.g., lead-acid, lithium-ion, nickel-cadmium) is chosen. The battery's nominal voltage, capacity, charge current, and temperature restrictions should all be considered when determining the charging requirements. When designing the battery charger circuit, the thyristor, trigger circuitry, rectifier, transformer, and filtering components were included as shown in Fig. 1 [3].

3.1 Working Principle

The thyristor used in a rechargeable battery charger acts as a controlled switch to modulate the charging current flowing through the battery by altering the gate triggering angle or gate signal pulse width. The thyristor is activated at a specific phase angle during each AC half-cycle during constant current charging, allowing a controlled amount of current to travel through the battery. A constant charging current is sustained until the battery voltage reaches a predetermined threshold.

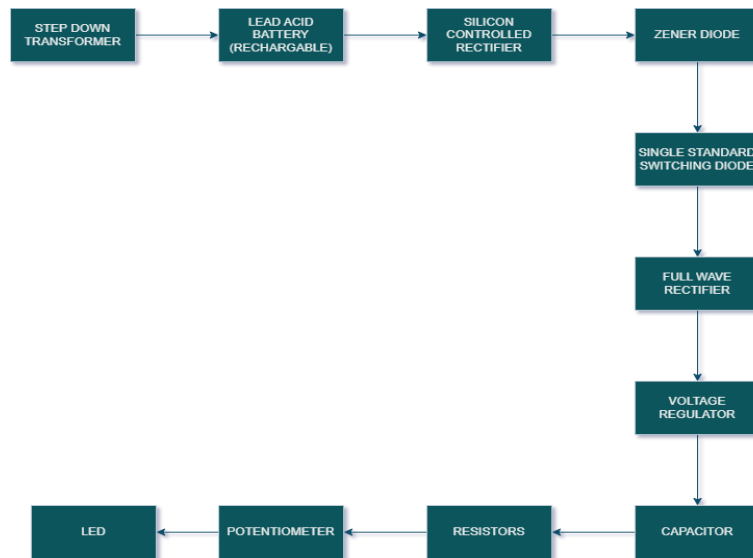


Fig. 1. Block diagram of a rechargeable battery charger by using thyristor

During PWM charging, the thyristor is swiftly turned on and off using pulse-width modulation. The average charging current supplied to a battery is determined by the gate signal's duty cycle. By varying the duty cycle, it is possible to modify the charging current accordingly.

By adjusting the conduction angle or pulse width, the charging voltage and current can be matched to the battery's charging needs, ensuring a safe and efficient charging process [4,5].

3.2 Components

The main components used in the system are:

a) Step-Down Transformer

A step-down transformer is an electrical device that decreases the voltage level from the primary winding to the secondary winding. It typically has more turns in the primary coil than in the secondary coil, resulting in a lower output voltage compared to the input voltage. This type of transformer is commonly used to convert high-voltage, low-current electricity into low-voltage, high-current electricity, making it suitable for various applications such as power distribution, voltage reduction for household appliances, and electronics. Fig. 2 shows the diagram of a step-down transformer [6].

b) Zener Diode 1N4462

The Zener diode 1N4462 is a general-purpose, 7.5-volt Zener diode that is classified as a power

diode. It is hermetically sealed in a DO-41 package and can handle a maximum power dissipation of 1.5 watts. The 1N4462 has a breakdown voltage of 7.5 volts, which means that it will start to conduct current when the voltage applied to it exceeds 7.5 volts. This makes it useful for applications where a constant voltage is required, such as voltage regulators and reference circuits. Fig. 3 shows the image of a typical Zener diode 1N4462 [7].

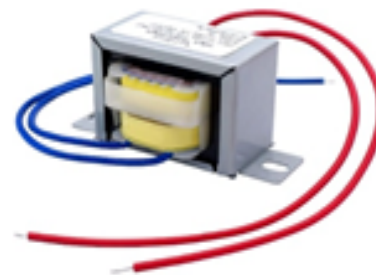


Fig. 2. Step-down transformer [6]



Fig. 3. Zener diode [7]

c) Full Wave Rectifiers

One kind of rectifier, called a full wave rectifier, shown in Fig. 4, transforms the two halves of an alternating current (AC) signal into a pulsating direct current (DC) signal. They are more efficient than half-wave rectifiers, and they produce a smoother DC output [8].



Fig. 4. Full wave rectifier [8]

d) Voltage Regulator

A voltage regulator shown in Fig. 5 is a device designed to automatically uphold a steady voltage level. This can be achieved through either a conventional feed-forward setup or by utilizing negative feedback mechanisms. The regulation process can involve electromechanical or electronic components, and the device's purpose is to manage and stabilize one or multiple AC or DC voltages, depending on its specific design [9].



Fig. 5. Voltage regulator [10]

3.3 Operation Flowchart

Fig. 7 shows the operational flowchart of designing a rechargeable battery charger by using thyristor.

3.4 Test/Experimental Setup

A type of semiconductor device known as a thyristor can be used to switch high currents.

Because they may be used to regulate the flow of current to the battery, they are perfect for battery chargers. A phase-controlled rectifier is a type of battery charger that frequently employs thyristors. The thyristors in a phase-controlled rectifier are on and off at times during the AC cycle. By doing this, the charger is able to regulate the amount of current going to the battery. A feedback circuit is often used to adjust the output voltage of a thyristor-based battery charger. The feedback circuit regulates the firing angle of the thyristors to keep the output voltage of the charger at a consistent value while monitoring the output voltage of the charger. The experimental setup for a battery charger based on thyristors is rather straightforward. Both a battery and a power source can be connected to the charger. A voltmeter can be used to check the charger's output voltage. With the aid of an ammeter, the charger's current flow can be observed. Fig. 7 shows the experimental setup of our circuit without a transformer.

Fig. 8 shows the experimental setup of our circuit with the addition of a step-down transformer.

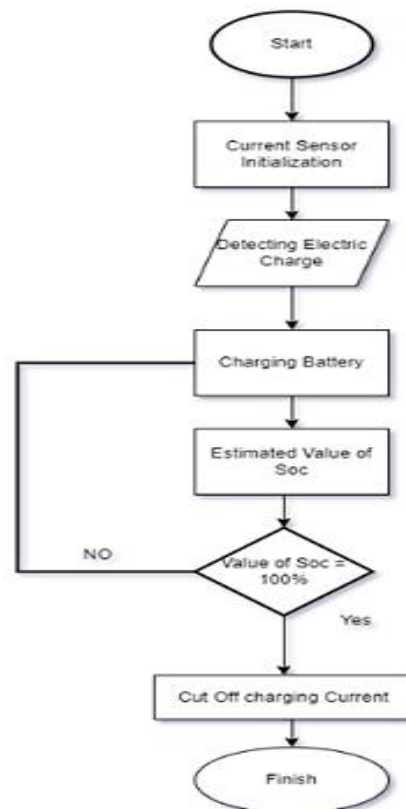


Fig. 6. General flow chart of a rechargeable battery charger by using thyristor

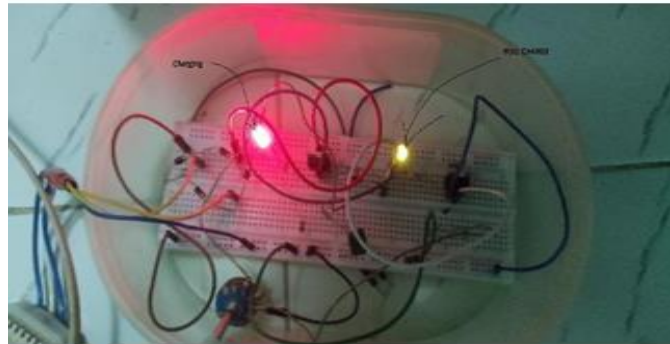


Fig. 7. Experimental setup without transformer

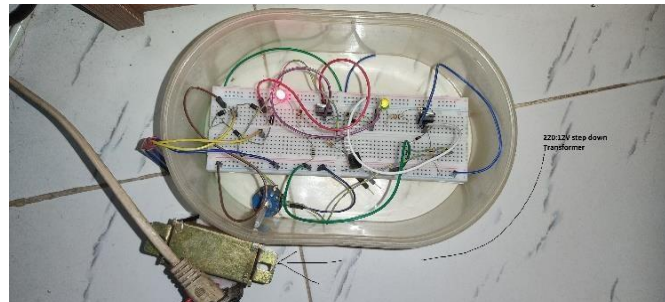


Fig. 8. Experimental setup with transformer connection

Fig. 9 shows the experimental setup of our circuit when a 9V battery is being charged up by the recharger circuit.

charging port for the battery. Fig. 10 shows that the measured output voltage across the 1.5 k Ω resistor is 7.49V which is stored up in the battery.

The output is measured from the junction of a 1.5 k Ω resistor connected to ground, serving as the

Fig. 11. shows the output waveform of the circuit when an oscilloscope is connected to it.

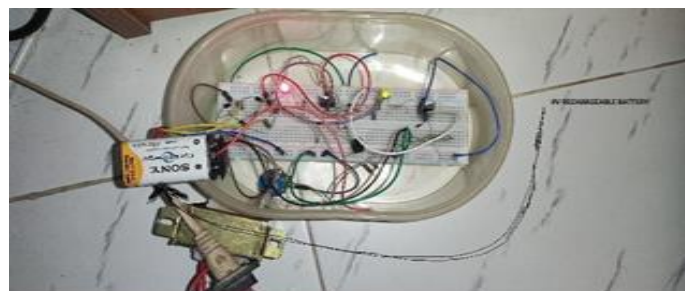


Fig. 9. Experimental setup showing the battery is being charged up by the recharger circuit



Fig. 10. Experimental setup showing the output voltage obtained from the circuit

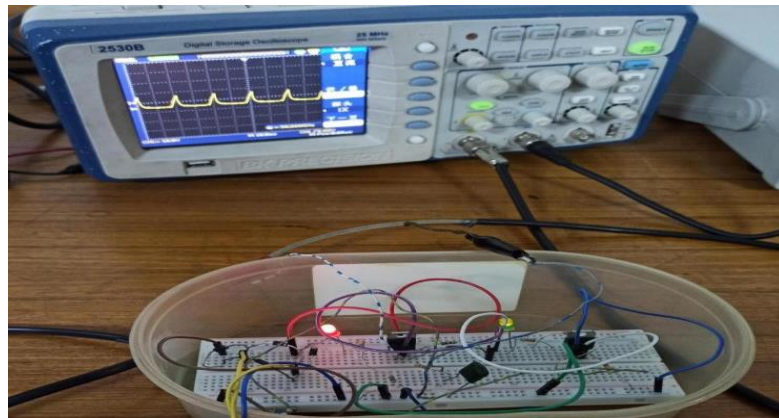


Fig. 11. Visual representation of the output as seen on the oscilloscope

4. RESULTS AND DISCUSSION

4.1 Simulation Analysis

A single-phase transformer, two LEDs, a single-phase full-wave diode rectifier, a voltage regulator, diodes, resistors, capacitors and a rechargeable battery are included in the simulated circuit in addition to the primary and auxiliary SCRs. There are also other electronic and power components such as a voltage regulator. It will be demonstrated that each of the highlighted components has a specific purpose in the operation of the circuit. While the primary SCR (D2) regulates the charging process, the second auxiliary SCR (D3) signals when the charging process is complete, and the battery is fully charged. In both cases, the LED is used to show how long the two SCRs have been running. The circuit receives 240 V from an AC source via a single-phase transformer 240/14 V and a single-phase full-wave diode rectifier, which

rectifies the AC-to-DC voltage required to charge the batteries. The gating signal is received by R1 and D5, which first causes the primary SCR1 (D2) to conduct. Green LED1 (connected in series) glows during the conducting phase to signal the start of the battery charging procedure. The battery will be charged continuously until it is almost at 11 V. When the charging current drops below the holding current, I_H , conduction ceases, and the SCR1 state changes to Off as a result. As soon as the battery is fully charged and the primary SCR1 ceases to operate, the auxiliary SCR2 begins to operate. Multisim simulator was used to replicate the tests as depicted in Fig. 12.

4.2 Measured Response/Experimental Results

Fig. 13 shows how the capacitors C1–C2 control the output DC voltage at 14 V, which is adequate for charging, and smooth the DC voltage.

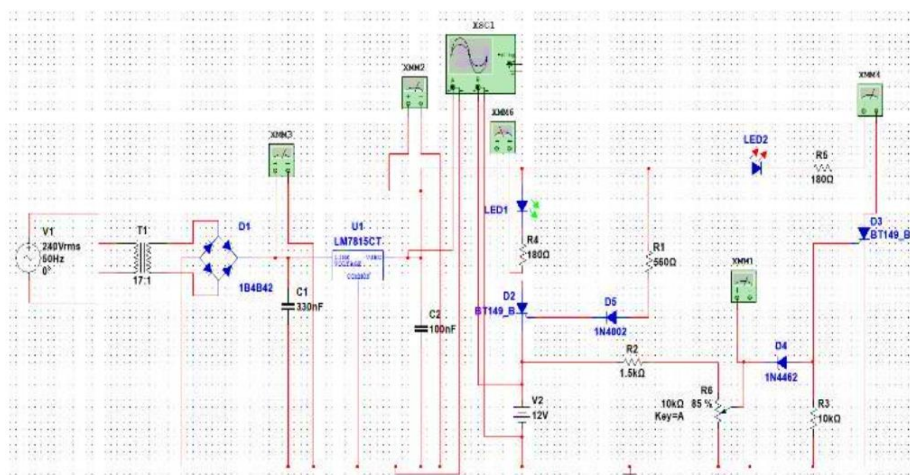


Fig. 12. Simulation of the project

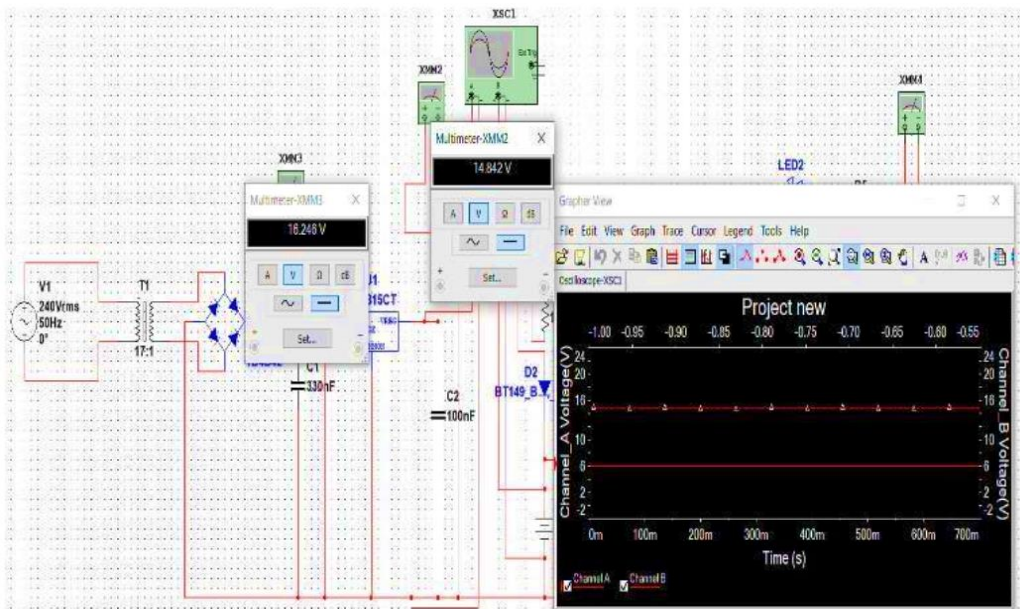


Fig. 13. The voltage regulator's input and output

When the battery voltage is 6 V, the first thyristor SCR1 is on and the second thyristor SCR2 is off since the current passing through them is 31.937 mA and 6.582 uA (extremely little). 1.388 mA (smaller than during the charging phase) is the current flowing through the first Thyristor SCR1 as shown in Fig. 14.

1.539 V, which is insufficient to turn on the Zener diode. Since the SCR2 is also not activated, it remains in the Off state with the red LED off.

Fig. 15 demonstrates that throughout the charging process, the potentiometer's voltage is

When the potentiometer reaches 7.43 V after the fully charging phase, the Zener diode is in the "On" position and thus electricity can flow to the SCR2 and turn it on as shown in Fig. 16.

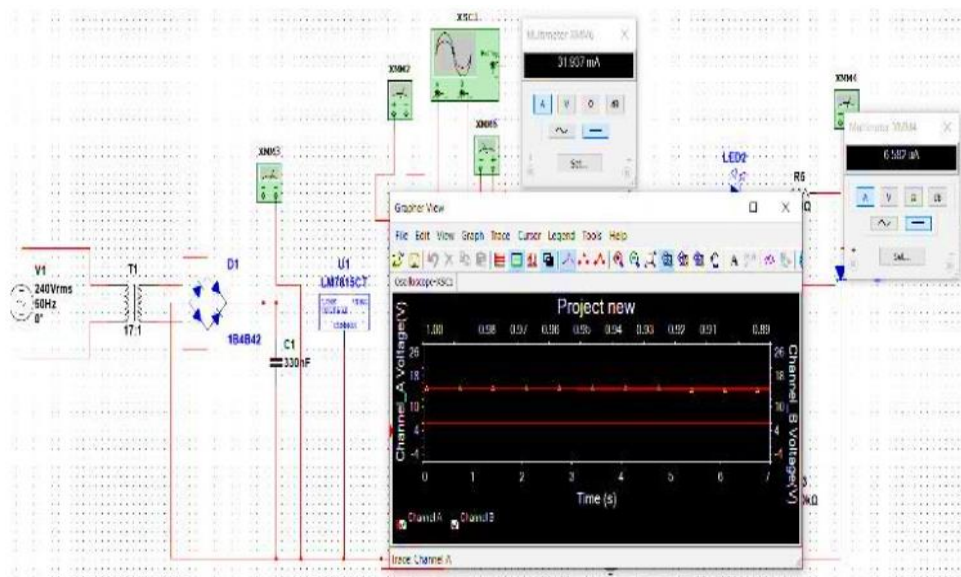


Fig. 14. The current values during the charging process

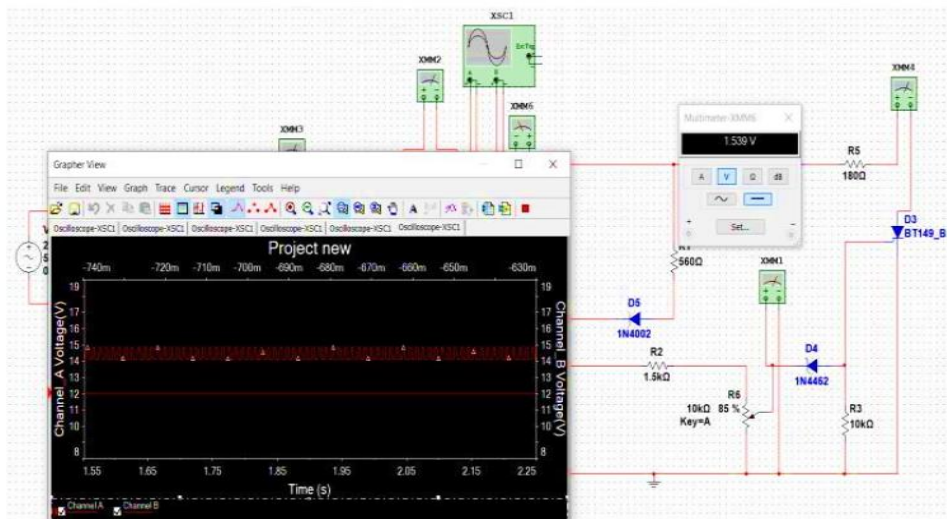


Fig. 15. The potentiometer voltage value during the charging process

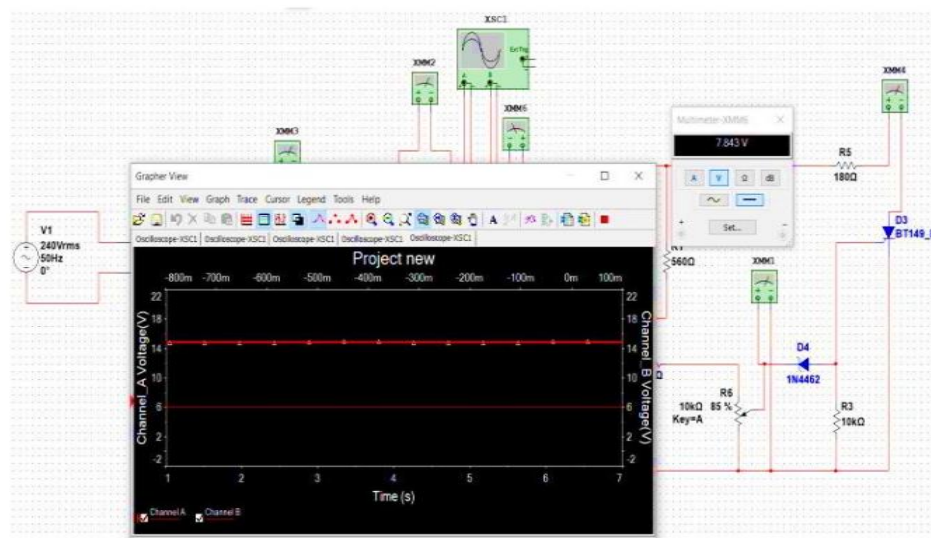


Fig. 16. The potentiometer voltage value after the full charging process

5. FUTURE POTENTIAL

Thyristors are a flexible and effective approach to regulate the current going to a battery. They can be used to create a variety of battery charging systems and are reasonably cheap and simple to utilize. Battery chargers built around thyristors work well in situations where high currents are needed. They are therefore perfect for recharging big batteries, like those seen in electric cars. Battery chargers built around thyristors work effectively for applications where the battery voltage needs to be accurately controlled. They are therefore perfect for recharging batteries used in vital items like medical equipment. Thyristor-based battery

chargers have a promising future. The need for effective and dependable battery chargers will increase along with the demand for electric vehicles and other battery-powered gadgets. Battery chargers based on thyristors are ideally positioned to supply this need.

6. CONCLUSION

In summary, we have built a thyristor-based rechargeable battery charger employing two SCRs, with a focus on the charging period and auxiliary functions for discharge duration. Following the design phase using software, we successfully constructed the charger in the

laboratory. A comparison was made between simulation calculations and laboratory results, revealing a consistent match between the two. This alignment underscores the achievement of our charger's primary objective.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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