Design and Development of Onboard Charger with Smart Monitoring System for Battery Electric Vehicles

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Abstract— **The widespread use of electric vehicles and battery-powered equipment has led to the development of various battery chargers. To charge the batteries in an electric vehicle, an AC-to-DC charger is designed with a 230 V AC input, which is stepped down to 24 V AC using a transformer. The bridge rectifier then converts the stepped-down AC to an output voltage of 24 V DC, which is the desired voltage for the battery. To meet the charging requirements, the circuit is designed to deliver a voltage and current of 24 V and 5 A, respectively. Once the battery is fully charged, the current sensor will detect that the current has dropped to 1A and send a signal to the Arduino UNO. The Arduino UNO will then cut off the gate signal of the MOSFET, causing it to automatically cut off the battery The monitoring system displays the battery voltage, input power, output power, and battery percentage. The voltage divider and current sensors are connected to an Arduino UNO microcontroller, which collects and sends the data to a user application via an ESP8266 module over a wireless network. The battery levels are displayed on user applications such as mobile and web interfaces, making this a simple, efficient, and low-cost charger for electric vehicles.**

Keywords: **Step-down transformer, Bridge rectifier, Arduino UNO, Wireless network, User Application, Current Sensor.**

I. INTRODUCTION

The depletion of natural resources has become a global issue in recent years, resulting in the need to regulate carbon emissions. As a result, there is a growing need for alternative options to Internal Combustion Engine driven vehicles. The replacement of conventional vehicles is gaining priority, and for this reason, Electric Vehicles (EVs) have been proposed as a better alternative.

Due to the rapid growth in EV sales, many countries have begun to issue interest in establishing governmental incentive policies to support the development of EVs regarding the future of vehicle sales, including the United States, China, India, and many countries within the European Union. which requires them to sell an increasing number of zero-emission vehicles over the year. Accordingly, various eco-friendly vehicles such as battery electric vehicles and hybrid electric vehicles, have been developed. These vehicles necessarily require a rechargeable battery system [1] as a power source for the electric traction system.

The battery is one of the most critical components in the development of an EV. Its energy density, charging time, lifetime, and cost are restricting practical applications. The charging time and lifetime of a battery depend on the characteristics of the battery charger [2] and its usage [3]. There are two kinds of chargers for the EV's application namely, on-board type and off-board type. “On-board” [4] would be appropriate for a household utility, these are limited by size and weight, and the “Off-board” permits fast charging of the battery.

The onboard charger allows the battery to charge at any time and convenience, given the availability of the supply grid [5]. It would increase the acceptance of EVs. It can use any household outlet and extend the range of EVs significantly.

Several research articles have been published on EV technologies, and some related literature surveys have briefly discussed these advancements.

M. Senthilkumar K.P. Suresh T. Guna Sekar C. Pazhani Muthu, “Efficient Battery Monitoring System for E-Vehicles” [1] proposes a battery management system to monitor the real-time health of the batteries using google apps script. By using machine learning algorithms to predict the life cycle of the battery and give suggestions to the user regarding the time and duration of each charge cycle.

Kotla Aswini, Jillidimudi Kamala, Bugatha Ram Vara Prasad, Lanka Sriram, Bhasuru Kowshik, Damaraju Venkata Sai Bharani “Design and Analysis of Bidirectional Battery Charger for Electric Vehicle” [2] proposes an onboard bidirectional battery charger for Electric Vehicles, the hardware topology and the control algorithms of the presented battery charger are validated through computer simulations, using the MATLAB software.

Dr. R. Essaki Raj, Poovizhi.S, Roshini Sathyamurthy, Rubadevi R “AC-DC Converter for Electric Vehicle Charger” [6] proposes a converter plays an AC/DC converter for power factor correction and output regulation. This converter circuit is simulated using MATLAB software.

Harish N, Prashant V, and Dr. Sivakumar’s “IOT-based Battery Management System” [11] Propose the importance of overcharging the battery. Further, this paper explains the importance of monitoring the battery parameters by using controllers and tracking electric vehicles.

The proposed converter has minimum components such as a step-down transformer, diode bridge rectifier, and auto cut-off controlling circuit to charge the battery with the monitoring system by using a web and mobile application to monitor the real-time battery performance and estimated time for charging and discharging battery for at present load conditions.

II. Charging Topologies of The Converter

AC to DC [6] converter topologies are electronic circuits used to convert alternating current (AC) power into direct current (DC) power. There are several topologies used in AC-to-DC converters, including the single diode rectifier, and bridge rectifier The DC-to-DC conversions are buck converter, boost converter, buck-boost converter, and flyback converter. The single-diode rectifier and bridge rectifier are simple topologies commonly used for low-power applications. Buck and boost converters are switching regulators that provide efficient voltage regulation by stepping down or stepping up the input voltage, respectively. Buck-boost converters can both step up and step down the input voltage. Each topology has its advantages and disadvantages, and the choice of topology depends on the specific application requirements.

For the AC/DC Conversion stage [6], there are primary topologies used. AC-DC and DC-DC conversion follow nearly the same strategy, with the only difference being the use of a rectifier stage and optional PFC circuit in AC-DC conversion [7]. charging takes place with an AC power source, Such EVs have these charges built-in within the vehicle itself and are called onboard chargers. A regular 230 V AC is enough to supply the EVs via these onboard chargers.

The design of EV chargers is of prime importance when considering the EV's battery life and charging time. An ideal EV charger's necessary features include compactness and high reliability. Such a charger should be affordable and carry low volume and size.

III. Proposed On-Board EV Charger

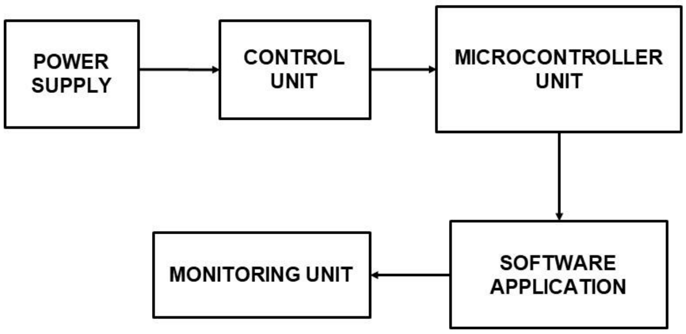

Figure 1. Block Diagram of the charger

The block diagram of the charger was built with five important units as shown in Figure 1 3.1 Power Supply, 3.2 Control Unit, 3.3 Microcontroller Unit, 3.4 Software application, 3.5 Monitoring Unit.

3.1 Power Supply

The Transformer will step down the power supply voltage(0-230V) to (0-24V) level AC. The bridge rectifier is an electronic device or circuit that converts AC into pulsating DC. A rectifier circuit may use four Diodes. That means a pair of diodes will act as a short circuit path to the negative half of the cycle and will allow us to obtain the negative half as output.

3.2 Control Unit

The Control unit explains the Auto Cut off the battery. Once the battery is fully charged, the current sensor will detect that the current has dropped to 1A and send a signal to the Arduino UNO. The Arduino UNO will then cut off the gate signal of the MOSFET, causing it to automatically cut off the battery.

3.3 Microcontroller Unit

Wi-Fi is to be used to communicate between the measuring circuit according to the microcontroller and the monitoring circuit application by using ESP8266 this is a self-contained SoC microchip that consists of a TCP/IP protocol stack that permits access to any microcontroller to a Wi-Fi network. It has enough storage capability and onboard processing that allows it to interact with the other sensors. This module requires an external logic level converter as it is not capable of 5V-3V logic shifting to communicate with Arduino and Wi-Fi modules.

3.4 Software Application

The ESP8266 reads the data from the voltage divider and current sensor and sends the results to the web page or mobile application by using a Wi-fi module. The monitoring software installed on Android smartphones is designed to monitor the data of the battery (voltage, Battery Percentage, Input power, and output Power) received from the microcontroller. Which can be used to monitor the health and charge state of the battery. By storing and retrieving data coming from the hardware setup.

3.5. Monitoring Unit

The Voltage divider is a circuit consisting of resistors that change the higher voltage into the lower voltage to monitor the voltage level of the battery. The output waveform of the circuit is riding on DC voltage as an offset and the output of the circuit is connected directly to the ADC pin of the Arduino Microcontroller. The Arduino Microcontroller board with the ESP8266 allows a Wi-Fi connection to the Ubidots to view online data on the battery power of the application via smartphone. The visualization of charging the battery is designed. The block diagram consists of Microcontroller, a monitoring section [8] [9], and display results as shown in Figure 2. The microcontroller can monitor and control the sensor. The output of the voltage divider is given to the microcontroller unit to read the voltage level of the battery [10]. The logic level converter is used to communicate the microcontroller to ESP8266 and vice versa. ESP8266 module is used to upload the data into the cloud. The display results will also be viewed on the webpage and applications through the internet. The LCD is used to view the battery parameters such as voltage, battery percentage, and power. The Buzzer is used to indicate once the battery is fully charged. Ubidots [11] is a Platform for Android and the web to control microcontrollers over the internet. It can build a graphic interface for the project by dragging and dropping widgets. The graphic interface can display sensor data, store data, and visualize it. It is supporting any hardware it is linked to the internet over an ESP8266 chip, it will get online and ready for the Internet of Things (IoT) [12]. It is used to display commands from a microcontroller using an Internet-based cloud system, by detecting the voltage and current.

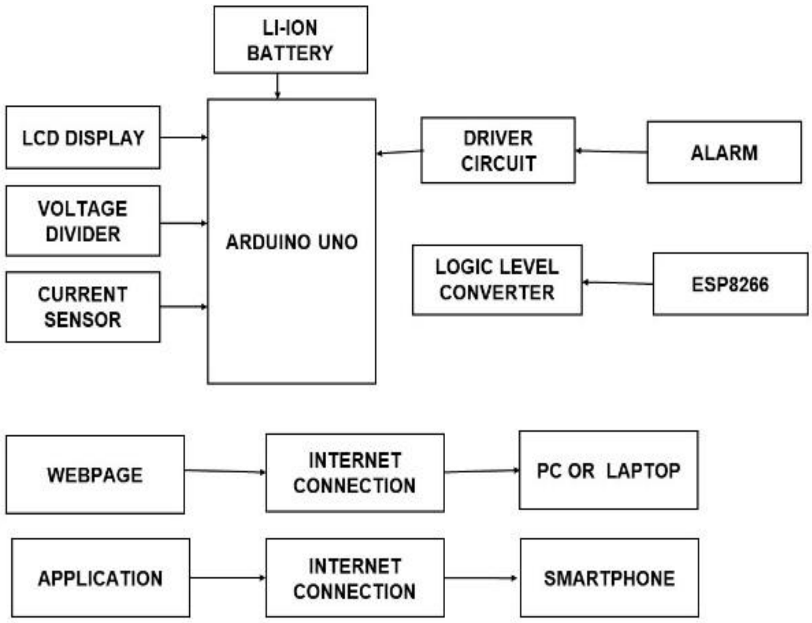

Figure 2. Block Diagram of the Monitoring system

3.5.1 Circuit Diagram of Proposed EV Charger and Monitoring System

The Circuit diagram of the proposed charger and monitoring system is shown in Figure 3. Circuit Diagram explains the input 230V AC is stepped down to 24V AC which is given to the bridge rectifier and it converts 24V DC. The Capacitor acts as the filter circuit and the dc voltage goes up to 35V. The Maximum peak charging voltage of the Li-ion battery is 35V. The Arduino gives the voltage to the gate of the MOSFET and it turns ON. The optocoupler is used to isolate the monitoring section and charging circuit. The MOSFET triggers at 2A which is on time and its fall time goes to charges up to 5A. Once the battery is fully charged, the current sensor will detect that the current has dropped to 1A and send a signal to the Arduino UNO. The Arduino UNO will then cut off the gate signal of the MOSFET, causing it to automatically cut off the battery [13]. The voltage divider is used to minimize the higher to lower voltage and it sends to the Arduino microcontroller. The Arduino takes 5V as power supply so the transformer (12V AC) is given to the rectifier circuit as converted to DC. The buck-Converter Module is step down the DC voltage to 5V which gives supply to the microcontroller unit. The Logic Level Converter is used to communicate with Arduino to the Wi-Fi module and vice-versa. The Monitoring parameters are displayed in LCD, Webpage, and Mobile Application. The buzzer is used to give the alert message once the battery is fully charged.

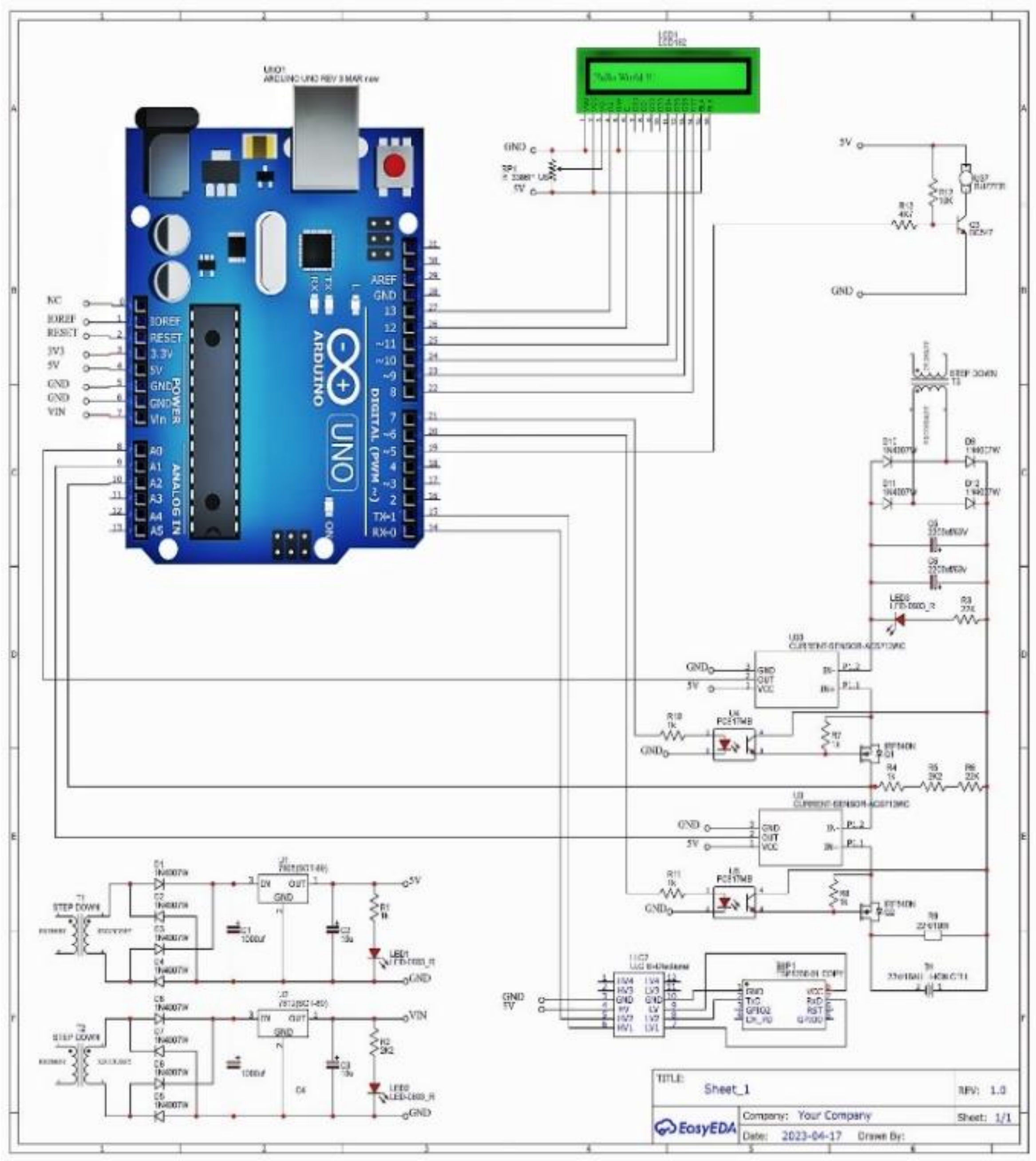

Figure 3. Circuit diagram of the proposed charger and monitoring system.

IV. RESULTS AND DISCUSSIONS

4.1 Simulation Output Waveform

The simulation work of this AC to DC charger is done with the help of the proteus simulation application. By using this the output waveforms of the charger are taken and displayed below.

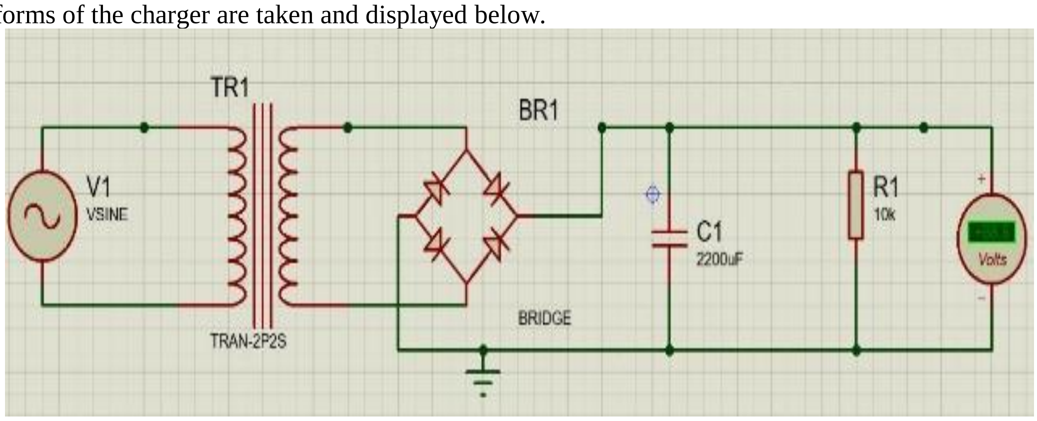

Figure 4. Simulation Circuit of the AC to DC Charger

When an AC signal is applied across the bridge rectifier, we notice that the current flow across load resistor R_L is the same during the positive and negative half-cycles. The output DC signal polarity may be either completely positive or negative.

Table 1. Design Specification of the Charger

Parameters	***Values***
Input AC voltage	230V AC
Step-down Transformer	230V AC to 24V AC
Bridge Rectifier	KBPC3510
Capacitor	2200 µF
Output Voltage	24V DC
Battery	24V/16 Ah

The above parameters are used to design a proposed charger. The designed parameters and values for the charger are tabulated in Table 1. These parameters and values were chosen to meet the design specifications of the charger.

If the diode's direction is reversed, we get a completely negative DC voltage. Thus, a bridge rectifier allows electric current during both positive and negative half cycles of the input AC signal.

The input waveform from the supply has an amplitude of 230 V in the supply shown in Figure 5. This supply is given to the bridge rectifier circuit.

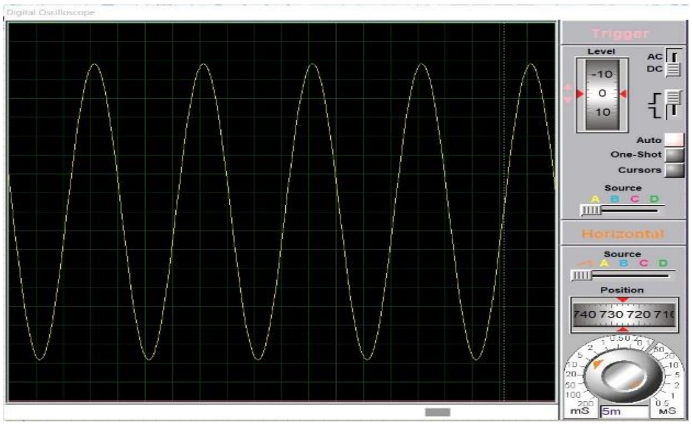

Figure 5. AC input waveform

The rectified waveform is done by the bridge rectifier. But this is not the pure DC voltage waveform shown in Figure 6. So, this is not preferred to give to the battery.

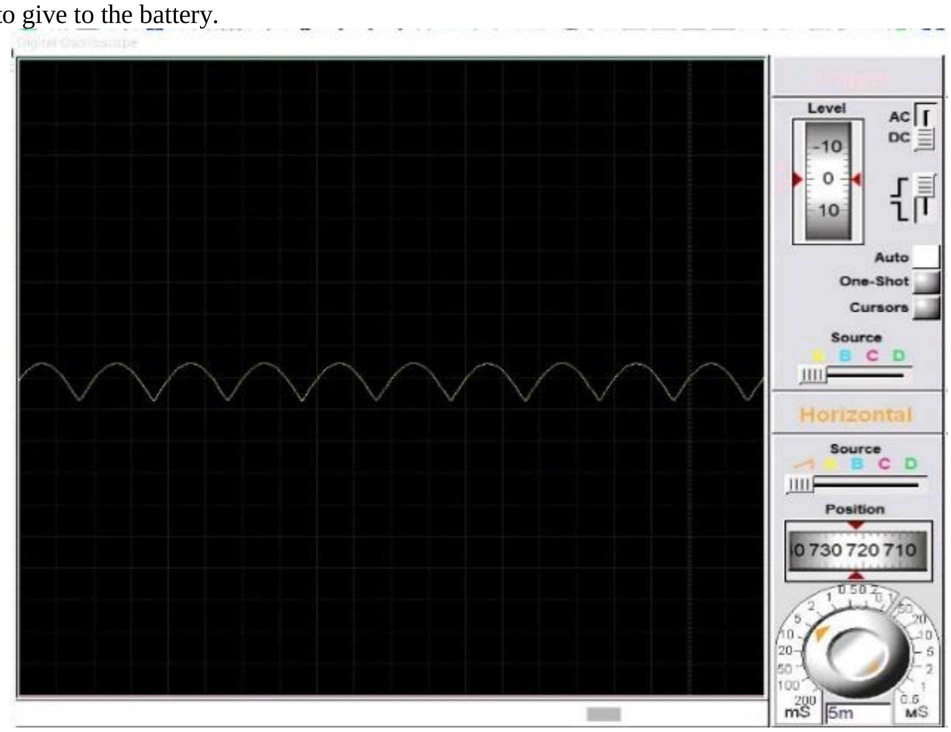

Figure 6. The output waveform from the bridge rectifier

The output smoothing capacitor voltage waveform is partially a DC waveform shown in Figure 7. This allows charging the battery of the EVs.

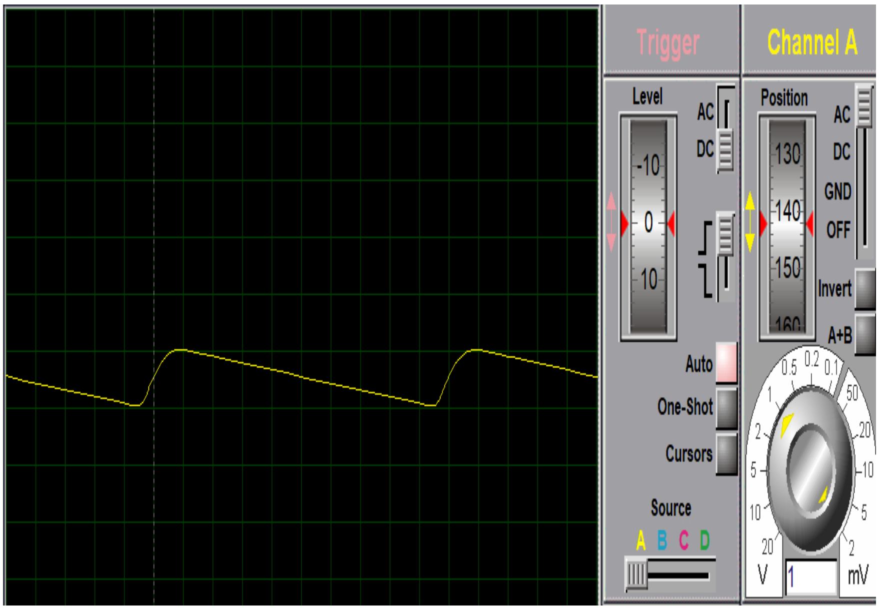

Figure 7. The output waveform from the smoothing capacitor

The pure DC output voltage, the voltage from the filter capacitor will have oscillated. Because the capacitor will keep on charging shown in Figure 8. So, the voltage from the capacitor will not be constant and not be preferred to give to the battery. This is the DC output voltage waveform of the rectifier circuit which is given to the battery.

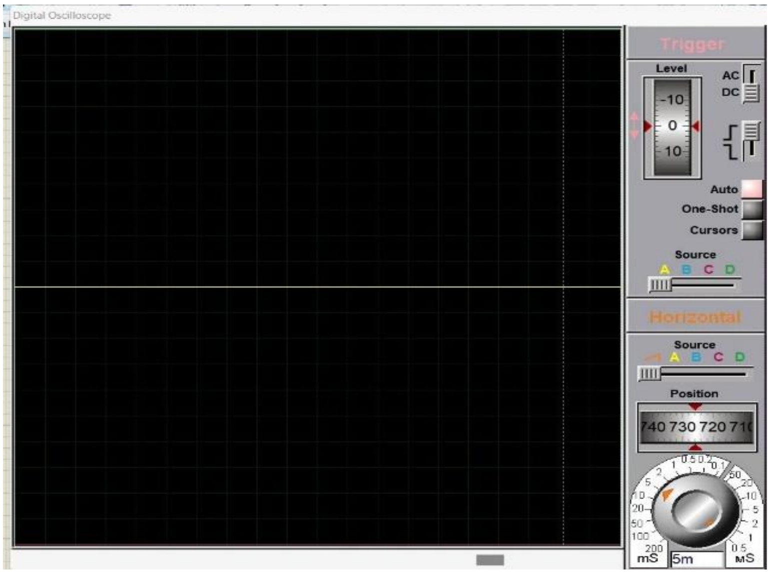

Figure 8. The output waveform from the rectifier circuit

4.2. Hardware Results

There are two main Hardware circuits for this proposed charger, the Auto cut-off charger and the other is Monitoring System. These two circuits are discussed below.

4.2.1 Monitoring System

The Battery is the major Component of the Monitoring System. The battery voltage, input power, output power, and battery percentage are monitored and displayed in the Ubidots dashboard. These details are sent to the mobile applications which can be used to monitor the state of battery health.

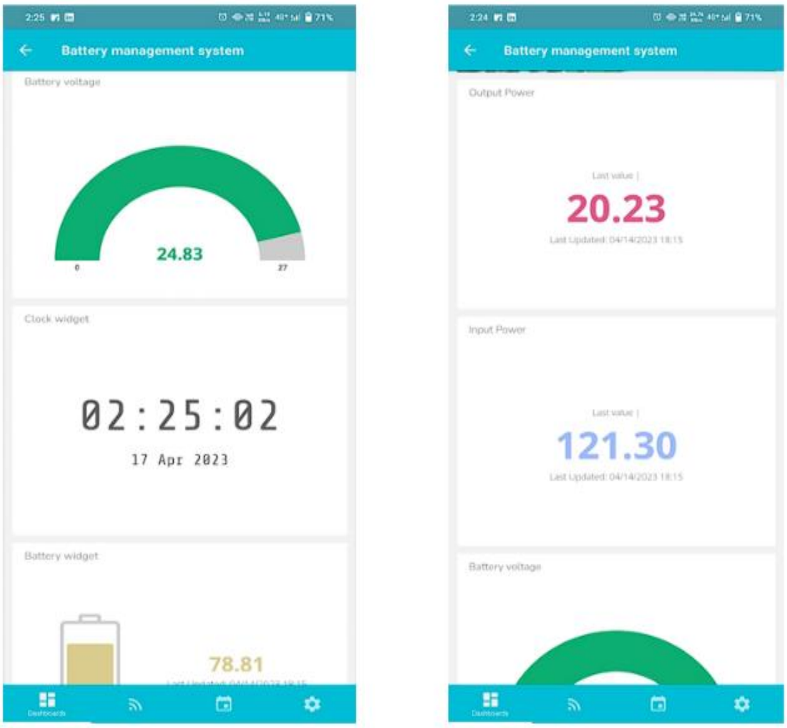

Figure 9. Battery Parameters Monitored in Mobile Application

The Android mobile application [14][15] keeps track of the battery parameters. As shown in Figure 9, the parameters are input power, output power, clock widgets, battery voltage, and battery percentage. Per minute, the battery percentage is calculated. In addition, the Ubidots website was monitored [16][17].

4.2.2. Monitoring LCD Display

Instead of using an application, the LCD displays the voltage, input and output power, and battery percentage parameters. The Timer updated the status of the battery Percentage every Minute.

Figure 10 Battery parameters monitored in LCD

4.2.3. Experimental Setup

The Experimental Analysis and Setup of an E-vehicle Charger. The set-up consists of a step-down transformer, bridge rectifier, MOSFET, Capacitor, Current Sensor, and Optocoupler. With this Analysis, the waveforms have been taken under various conditions.

4.3 Waveform Analysis

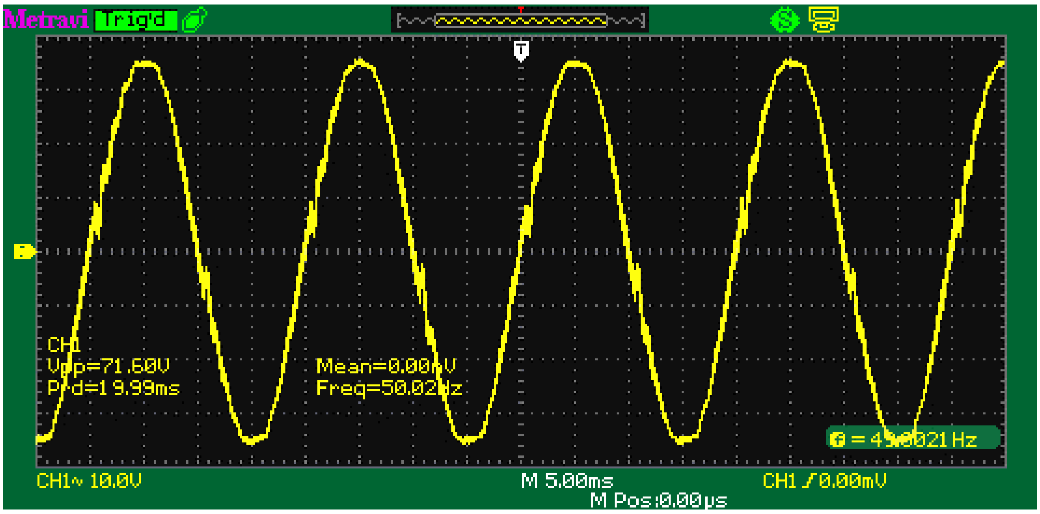

Figure 11. Input AC Waveform.

This Graph was Captured using a Digital Storage Oscilloscope (DSO) and the input AC signal is taken from the Step-down Transformer. The input waveform from the supply has an amplitude of 35V as shown in Figure 11.

Figure 12 Pure DC voltage MOSFET Switching

This Graph was Captured and displayed in Digital Storage Oscilloscope (DSO) as shown in Figure 12. Channel 1 shows the pure DC voltage and it is obtained in the battery. Channel 2 shows the MOSFET switching pulse. When the gate signal is given to the MOSFET by using Arduino UNO through Optocoupler. The output of the MOSFET works in the Discontinuous Mode [Zero-Crossing].

5. Experimental Set-up

The Hardware consists of Charging, Auto-cut-off, and Monitoring System as shown in Figure 13 below. It involves various Components Transformer, bridge rectifier, battery, Arduino, Buck-Converter, MOSFET, Optocoupler, and ESP8266. The working circuit is a step-down transformer circuit given to the bridge rectifier that is converter to pulsating DC. The MOSFET gate was given to the supply by using an optocoupler. Once the battery is fully charged, the current sensor will detect that the current has dropped to 1A and send a signal to the Arduino UNO. The Arduino UNO will then cut off the gate signal of the MOSFET, causing it to automatically cut off the battery. Battery Parameters are monitored and the data is sent through the ESP8266 module over the internet to the user application.

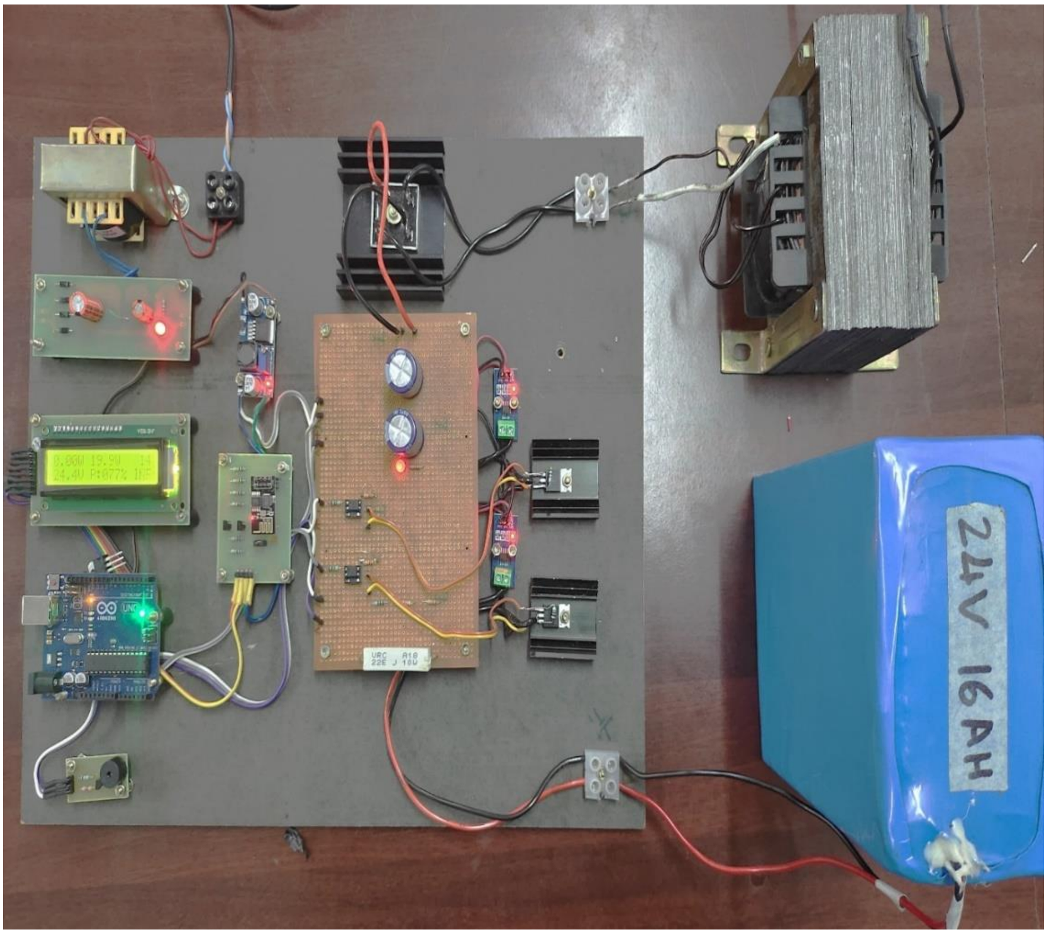

Figure 13 Hardware Image of Proposed Charger and monitoring system

V. CONCLUSION

The paper explains the design and experimental evaluation of an AC/DC converter with a full-bridge rectifier for charging a vehicle's battery. The simulation diagram is done in the proteus design suite and the different waveforms of the circuit are collected and placed. The charger can provide a constant output of DC voltage and current at rated output power. The application constantly displays the real-time output voltage/power of the charger. The designed converter with the monitoring system provides a simple, efficient, and low-cost onboard charger for electric vehicles.

REFERENCES:

[1] M. Senthilkumar K.P. Suresh T. Guna Sekar C. Pazhani Muthu, "Efficient Battery Monitoring System for E-Vehicles" 2021 7th International Conference on Advanced Computing & Communication System (ICACCS).

[2] Kotla Aswini, Jillidimudi Kamala, Bugatha Ram Vara Prasad, Lanka Sriram, Bhasuru Kowshik, Damaraju Venkata Sai Bharani "Design and Analysis of Bidirectional Battery Charger for Electric Vehicle" International Journal of Engineering Research & Technology (IJERT) Vol. 10 Issue 07, July 2021.

[3] Nikita N. Mutrak, Kaveri Pagar, Ankita Pawar, Ashwini Bodke, Dr. Mukesh K. Kumawat. "IoT-based Battery Monitoring System" International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 06 June 2020.

[4] M.M. Morcos, Curtis R. Mersman, G.D Sugavanam, Norman G. Dilman "Battery Chargers for Electric Vehicles" IEEE Power Engineering Review, November 2000.

[5] Safy Saeeda, SK. A. Shezanb, M.I. Arbabc, Sohel Ranad. "Battery Monitoring System for the Smart grid applications" Australasian Universities Power Engineering Conference (AUPEC) 2017.

[6] Dr.R. Essaki Raj, Poovizhi.S, Roshini Sathyamurthy, Rubadevi R "AC-DC Converter for Electric Vehicle Charger" International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 06 June 2020.

[7] Sayed Mahmud, Anika Bushra, Tamanna Sumaiya, Hossain Md Arafat, Rahman Md Ashiqur "Study of AC to DC Converter".

[8] C. Sathya, P. Kalaivani "IoT Based Battery Management System for Electric Vehicles" IJISET - International Journal of Innovative Science, Engineering & Technology, Volume 9, Special Issue, May 2022.

[9] Bharathi S.H, Y.V Nithin Reddy, Dinesh, Ram Gopal "IoT-Based Battery Monitoring System for Electric Vehicle" Turkish Journal of Computer and Mathematics Education Vol.12 No.13 (2021).

[10] Swapnil P. Karmore,Anjali R.Mahajan, Suruchi Kitey "Battery Monitoring and Analysis based system" 2013 IEEE.

[11] N. Harish V Prashal and Dr. D.Sivakumar "IOT based Battery Management System" International Journal of Applied Engineering Research ISSN 2018.

[12] Mohd Helmy Abd Wahab Nur Imanina Mohammed Anaur, radzi amb ar, Aslina Baharum, Shanoor Shanta, Mohd Suffian Sulaiman Shukor Sanim Mohd Fauzi,Hazibul Fahri Hanafi “IOT-Based battery Monitoring System for Electric Vehicle” International Journal of Engineering & technology 2018.
[13] Chien-Wu Lan, Shih-Sung Lin, Sih-Yan Syue, Hao-Yen Hsu, Tien-Cheng Huang, Kuang-Hsiung Tan, “Development of an Intelligent Lithium-Ion Battery-Charging Management System for Electric Vehicle” 2017 IEEE International Conference on Applied System Innovation.
[14] Wang Menghua, Xiao Bing “A Real-time Android-based Monitoring System for the Power Lithium-ion Battery Used on Evs” 2017 10th International Conference on Intelligent Computation Technology and Automation.
[15] Dimas Anton Asfani, Yulistya Negara, Gusti Ngurah Satriyadi Hernanda, Daniar Fahmi, Muhammad Nur Yuniarto, Rizal Hardiyanto, Raditya Premananda “Real-Time Battery Monitoring and Fault Identification Application on Electric Scooter” 2019 International Seminar on Application for Technology of Information and Communication.
[16] Irsyad Nashirul Haq, Edi Leksono, Muhammad Iqbal, FX Nugroho Soelami, Nugraha, Deddy Kurniadi, Brian Yuliarto “Development of Battery Management System for Cell Monitoring and Protection” 2014 IEEE International Conference on Electrical Engineering and Computer Science.
[17] Selamat Muslimin, Renny Maulidda, Evelina Evelina, M. Nawawi, Iskandar Lutfi, Johansyah Al Rasyid, M. Fadli, Puput Anggraini, M. Yusuf, Wanda Merian PA “Energy Management on Electric Vehicles Using Fast Charging Banking Capacitor using Internet of Things (IoT) System” 5 th T1 T2 2021 International Conference.