A Dual Source Power Based EV Wireless Charging System

NAQVI Syed Zohair Raza, *XIAO Lan**, *JIANG Menghan*

College of Automation Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, P. R. China

(Received 18 January 2024; revised 13 July 2024; accepted 5 August 2024)

Abstract: Recently, there has been a huge increase in the usage of fuel resources for automobiles which is severely affecting the climate and causing global warming. The use of electric vehicle (EV) is an effective way to protect the environment and reduce travel costs. However, the EV charging system has a single charging source, and the charging rate is limited. In this paper, an EV wireless charging system based on dual source power supply has been developed. It realizes intelligent switching between 12 V photovoltaic output and 220 V AC dual source power, and has wireless transmission function. Based on the proposed power supply architecture, the micro wireless charging model is built, which enables the EV model to store power and realize static and mobile control through the wireless induction charging system.

Key words: renewable energy; inductive coupling; inductive charging; converters; automatic changeover; auto cutoff circuit

CLC number: TM46 **Document code:** A **Article ID:** 1005-1120(2024)S-0035-08

0 Introduction

The research and development of electric cars have accelerated because of the current altering climate conditions. An efficient energy management system and green energy are the main research trends in recent years with the utilization of solar energy to produce electric power[1]. To reduce pollution and global warming, people are becoming more and more aware of the necessity of converting their fuel-operated automobiles to electric automobiles[2]. Electric vehicles require a lot of time to charge at charging stations. Therefore, an inductive wireless charging system is an efficient way to charge electric cars in motion and stationary conditions. Furthermore, this unique wireless charging technique can reduce power losses and allows travelers to save time[3-4]. An integrated autonomous street light system enables the most effective energy storage system. These streetlights are automatically switched on as needed when the vehicles are in motion on the road and turned off automatically when there is no motion. This enables the storage of energy and is used when required[5]. A digital power bank module is used to save the DC power that is produced by the solar module. To step down the AC voltage, the stepdown transformer is used, which is further converted into DC Volts. The 16 V relay-based changeover circuit is deployed in this model for load balancing under power outages. Moreover, a specific copper coil is used in the transmitter for transmitting power and the receiver (installed beneath the car) for receiving power[6]. In this model working on inductive coupling, power fluctuation occurs when there is no wireless connection between the receiving coil and transmitter coil when the car moves away from the transmitting coil and the magnetic field affects human health[7].

The proposed model's major objectives include building a system that employs renewable resources to prevent pollution, minimizing greenhouse gas emissions, and offering a better and more effective charging system. In this work, a dual-source wireless charging system has been used

*Corresponding author, E-mail address: xiaolan@nuaa.edu.cn.

How to cite this article: NAQVI Syed Zohair Raza, XIAO Lan, JIANG Menghan. A dual source power based EV wireless charging system[J]. Transactions of Nanjing University of Aeronautics and Astronautics, 2024, 41(S): 35-42.

http://dx.doi.org/10.16356/j.1005-1120.2024.S.005

which has the potential to reduce charging time[8]. In addition, the wireless inductive charging system is applicable to charge the electric vehicles during the motion. Another benefit of this approach is cost savings and less noise pollution[9].

1 Block Diagram Explanation

The working footsteps of the proposed model is shown in Fig. 1. There are two power supply systems: One is renewable energy (solar panel) and the other is an AC voltage source. DC voltage from the solar panel is transferred to the power bank module, which stores energy in the battery and then transfers energy to the changeover circuit. AC voltage is supplied to the step-down transformer and then converted into DC voltage. Furthermore, it can be seen in the block diagram the "Atmega controller" is used to control the streetlight with the help of light dependent resistor (LDR) and infrared (IR) sensors. In addition, a wireless transmitter transmits the power to the receiver side where AC voltages are converted into DC voltages. This converted power is then fed to the "Auto-cutoff" charging circuit to charge the battery. And at this point, the battery charging voltage and receiving voltage can be noticed on the voltage detector 3-segment LCD. The design specification for power supply is shown in Table 1.

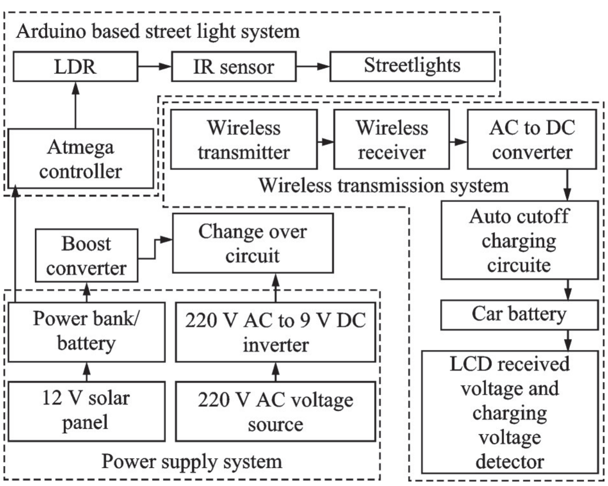

Fig.1 Block diagram of dual source energy EV wireless charging booth

(1) AC voltage source

This is the normal 220 V AC voltage at which different appliances are operated in our home. This operated AC voltage is produced from conventional power generation systems like coal or nuclear power plants.

Table 1 Design specification for power supply

Components	Output/Input
Solar module	12 V
5 V Charger	12 V/ 5 V
9 V Supply	220 V AC/ 9 V DC
4 V Charger	4.8 V/4 V

(2) Volts power supply

To use the 9 V power to supply a 12 V step-down transformer, a bridge rectifier and an electrolytic capacitor are used in this proposed model. In many applications where voltage adjustment and electrical isolation are required, step-down transformers are essential parts. They are available in a variety of sizes and voltage ratios to satisfy diverse needs. A step-down transformer has been used in this project to convert 220 V into 12 V[1]. Furthermore, a bridge rectifier (Diode 1N40007) has been used in this prototype project. After rectification of voltage, the electrolytic capacitor (Capacitor 50 V, 1 000 μF) has been connected across the output terminals of the bridge rectifier to smooth out the pulsing DC voltage[8]. In addition, a voltage regulator IC has been used to create a consistent DC output. From the bridge rectifier, the 12 V DC is fed to IC 7809, where a 12 V DC is converted into a 9 V DC through a changeover circuit. This DC voltage is supplied to the transmitter and the "Atmega controller".

(3) Solar module

To make the shift to cleaner renewable energy systems and more environmentally friendly power generation, solar modules are becoming more and more popular as a source of renewable energy. The solar system is now feasible for everyone due to advancements in efficiency and cost-effectiveness. In this prototype model, a 5 W solar module is used for the charging of batteries[10], as shown in Fig.2.

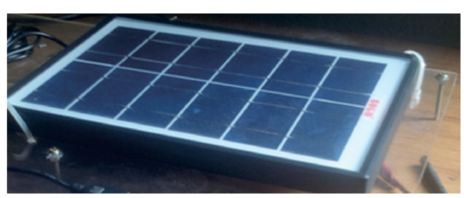

Fig.2 Solar plate

(4) Power bank

In this proposed model a modified 5 W charging circuit is used to charge the battery. The input of the circuit is 12 V, and its output is 5 V 2.1 A. Only liquid lithium-ion batteries 3.7 Ah are employed in this model and it is an overcharging-protected circuit.

(5) Buck booster

In this project, a buck booster is used because these converters are flexible and ideal for a variety of applications. This converter is used to step up the battery output voltage from 5 V to 9 V to supply the power for the wireless transmitter with the help of a change-over circuit, as shown in Fig.3.

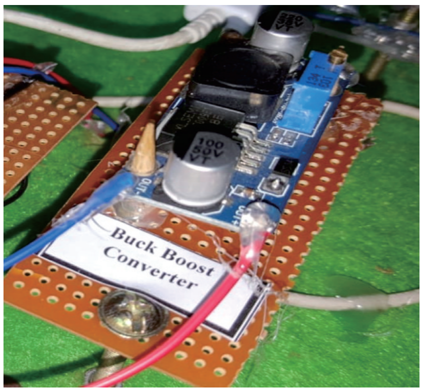

Fig.3 Buck booster converter

(6) Changeover circuit

A changeover circuit (Fig.4) provides a continuous power supply. This module is used here to supply power to both the wireless transmission system and automatic control street light system under overload conditions. The changer over the circuit has two inputs connected to the buck booster and one output which is connected to a wireless transmitter.

(7) Atmega328

Atmega 328 is a platform with open-source code that can be modified and adapted to any instructions and tasks that need to be completed. This board contains an internal regulating mechanism that keeps the voltage under control when the device is linked to an external device. This controller has been used in this model to control multiple functions with the aid of different sensors and is applicable to control the intensity of road lights with the help of IR and LDR sensors.

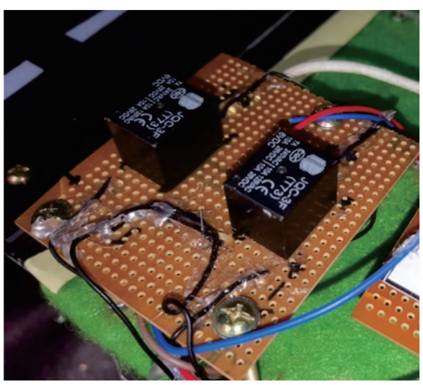

Fig.4 Changeover circuit

(8) LDR

An LDR is a rheostat whose resistance changes depend on how much light strikes its surface. Here a LDR is used as a detector for automatic street lights[11].

(9) IR sensor

Infrared is denoted by the letter IR. This particular LED emits infrared light. It is a device (photodiode) that works as a transmitter and receiver. To detect reflected light, the receiver continuously scans for IR light from the transmitter. When an object (car) is in front of the sensor, it is detected by the receiver because the light is reflected after striking the surface[12].

(10) Copper coil for transmitter and receiver

The transmitter and receiver are comprised of a power supply boost converter and copper wire. Here, the voltage regulator, rectifier, capacitance, resistance, and all of these components are connected to the transmitter circuit and receiver for the better progress of the system. The design specification of transmitter and receiver is shown in Table 2.

Table 2 Design specification for transmitter and receiver

Component	Copper coil	Number of turns	Diameter/cm
Transmitter coil	20 SWG	5	6
Receiver coil	20 SWG	15	6

(11) Auto cutoff charging circuit

In an auto-cutoff circuit, relays are the simplest parts and serve as a bridge between low-power digital electronics and high-power electronic gadgets. Here this circuit's main function is to charge a 4 V battery, and also saves the battery from extra charging.

(12) DC voltage indicator LCD

A three-segment DC voltage meter is developed here to specify the receiving voltage at the receiver and the charging voltage in the battery.

(13) Vehicle

In this proposed model, a manually operated electric car has been developed mounted with front and back lights. The receiving voltage indicator LED and full or low charging indicator LEDs are also mounted on this car.

2 Proposed System Analysis

In this prototype project, according to the block diagram, there are two circuits. One is for a wireless charging system and the other is for automatic street lights, as shown in Fig.5.

The 5 W solar module is used to feed 12 V to the automatic cutoff 5 V battery charger circuit, as shown in Fig.6.

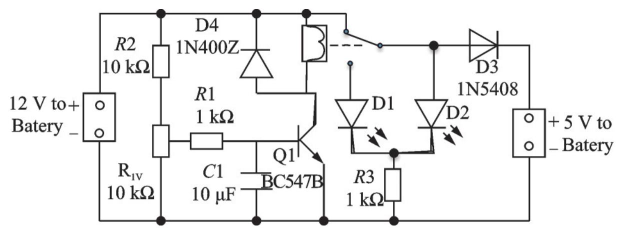

Fig.5 Auto cutoff 5 V battery charger circuit

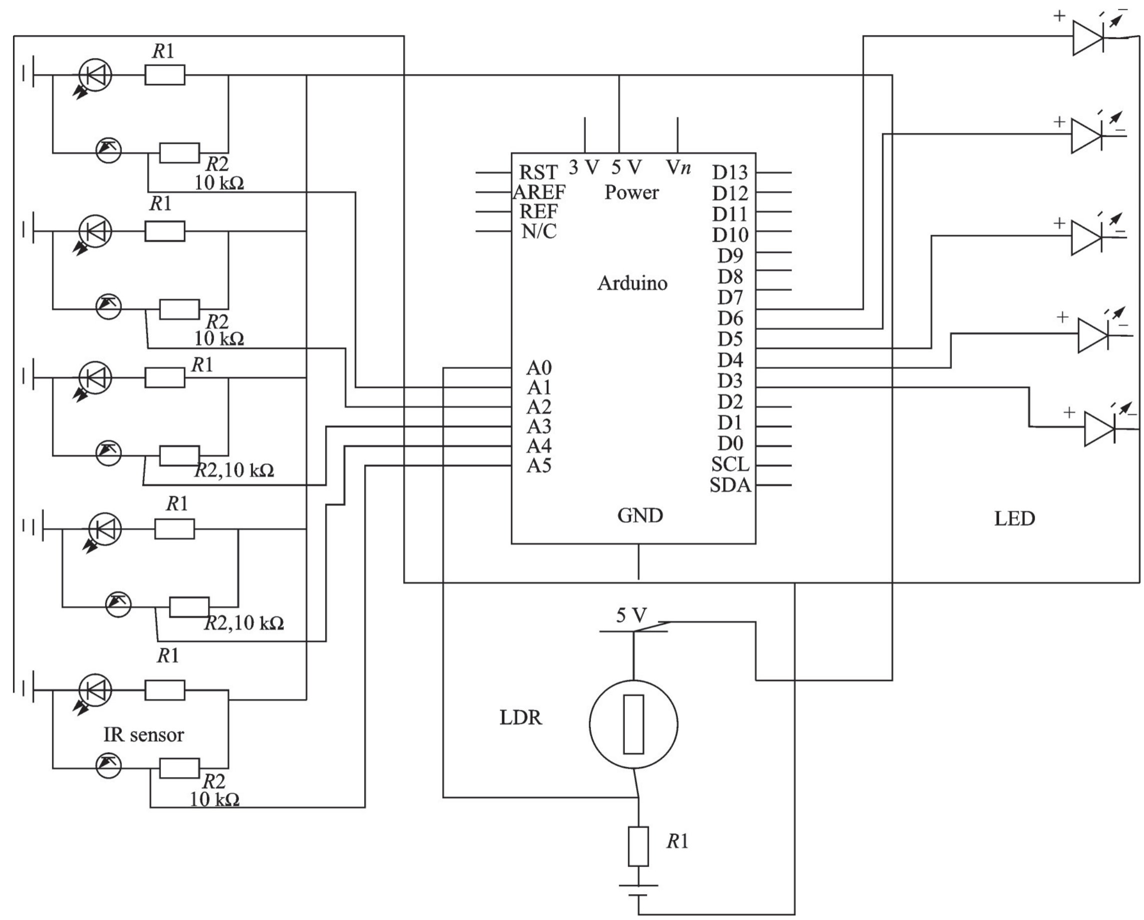

Fig.6 Automatic street light system (Arduino UNO Atmega328 controller)

Since the Arduino has five LED connections that work as road lights and five IR sensors that are mounted on the footpath of the road, the LEDs are linked to the Arduino's digital pins (D2, D3, D4, D5, D6). The Arduino ground pin is used to create additional LED lead wires. As a result, the Arduino's analog point is linked to the IR sensor's common pins. LDR is linked with Arduino's bottom pin, and its other lead is attached to the IR sensor's shared pins. It can save a lot of energy and automatically turn ON/OFF road lights according to the requirement.

A wireless charging system is proposed for electric car charging. There are two different sorts of sources for the wireless vehicle charging booth system. One source of electricity is a 220 V AC to 9 V DC power supply, as shown in Fig. 7, while

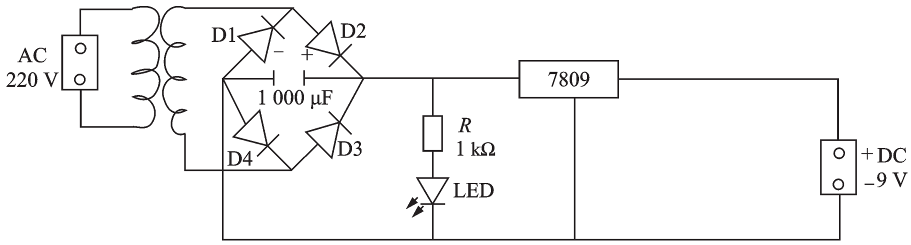

Fig.7 9 V power supply circuit

the other is a 5 W solar array that harvests energy from the sun and stores it in a battery. To change the AC 220 V into DC 9 V, some components such as rectifier, capacitor, resistance, and IC LM7809 are linked with 12 V stepdown transformer, as shown in Fig.8.

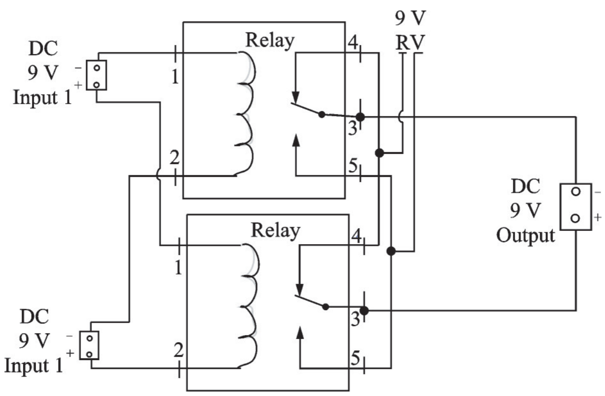

Fig.8 Changeover circuit

In this charging circuit, two 6 V DC relays are used for automatic power switching. The changeover circuit feeds the wireless transmission system under overload conditions.

The transmitter is powered by a 9 V supply. It is mounted beneath the PV road, 3.5 cm distance from the receiver which is installed on the electric car. Copper wire is used to make the transmitter, and the transmitter coil is created by twisting the wire as many times as was required. The diameter of the transmitter coil is 6 cm and five turns of the copper wires make it ready for induction. 20 SWG is the standard wire gauge for copper wire. A high-frequency magnetic flow is intended to be produced by this transmitter circuit. The transmitter circuit consists of a magnetizing inductor Lm, a resonant inductor Lr, and a resonant capacitor Cr, because the proposed model uses an LLC resonant converter. The resonant network circulates the energy and transmits it to the receiver coil, which has a specific turn ratio needed to produce the correct output voltage.

This wireless system works on the induction coupling principle, as shown in Fig.9. When an electric car crosses near the transmitting coil, the magnetic flux is produced in the transmitting coil which induces the current in the receiver coil which is transferred to the battery after filtering the voltage. Copper wire is twisted 15 times to produce the coil for the receiver, which has a 6 cm diameter. SWG for copper wire is 20. At the receiver side, the bridge rectifier (1N4007 X 4) is connected to a coil of 20 SWG enameled copper wire measuring 6 cm in diameter with 15 turns. Filter capacitor C2 is connected across the bridge rectifier's output terminals. Additionally, an IC 7805 positive voltage regulator has been used to regulate the DC supply coming from the rectifier and to convert it into 5 V DC. The important parameters are listed in Table 3.

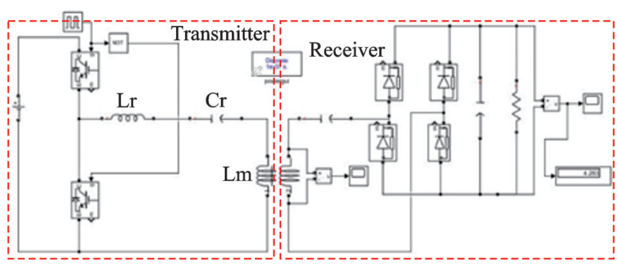

Fig.9 Wireless transmitter and receiver circuit

Table 3 Important parameters

Parameter	Value
Input voltage/V	12
Output voltage/V	4—5
Induced current AC/V	16
Frequency/kHz	1—2
Solar	12 V, 5 W

After rectification, the change in 5 V DC is fed to the "Auto-cutoff circuit" before being provided to the 4 V battery to charge it, as shown in Fig. 10. The "Auto-cutoff circuit" is operated with the help of different components such as a resistor, diode,

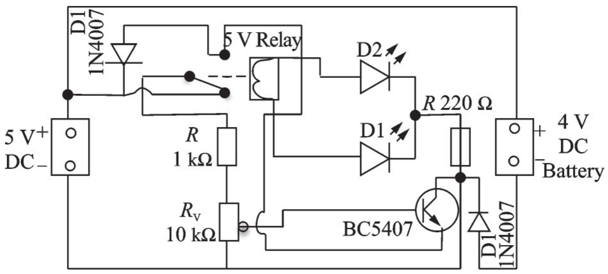

Fig.10 4 V battery auto cutoff charging circuit

transistor, LED, and 6 V relay. LED which is mounted on an electric car shows the receiving voltage and charging voltage. This charging system charged the battery to 20% in 1 min and to 100% just need to wait for 5 min. When the electric car is moving and passes in front of the IR sensor, the IR sensor sends the signal to the controller and LED lights get "ON" and when left in this place it gets "OFF" and vice versa. With the help of LDR, street lights get "ON" at night and "OFF" in the morning.

Figs.11,12 are the simulation results of wireless systems for understanding their working. These results show the accurate result of the proposed model.

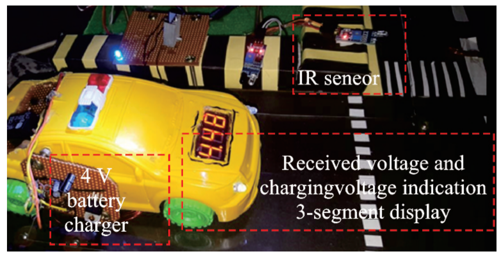

Fig.11 Proposed model working results

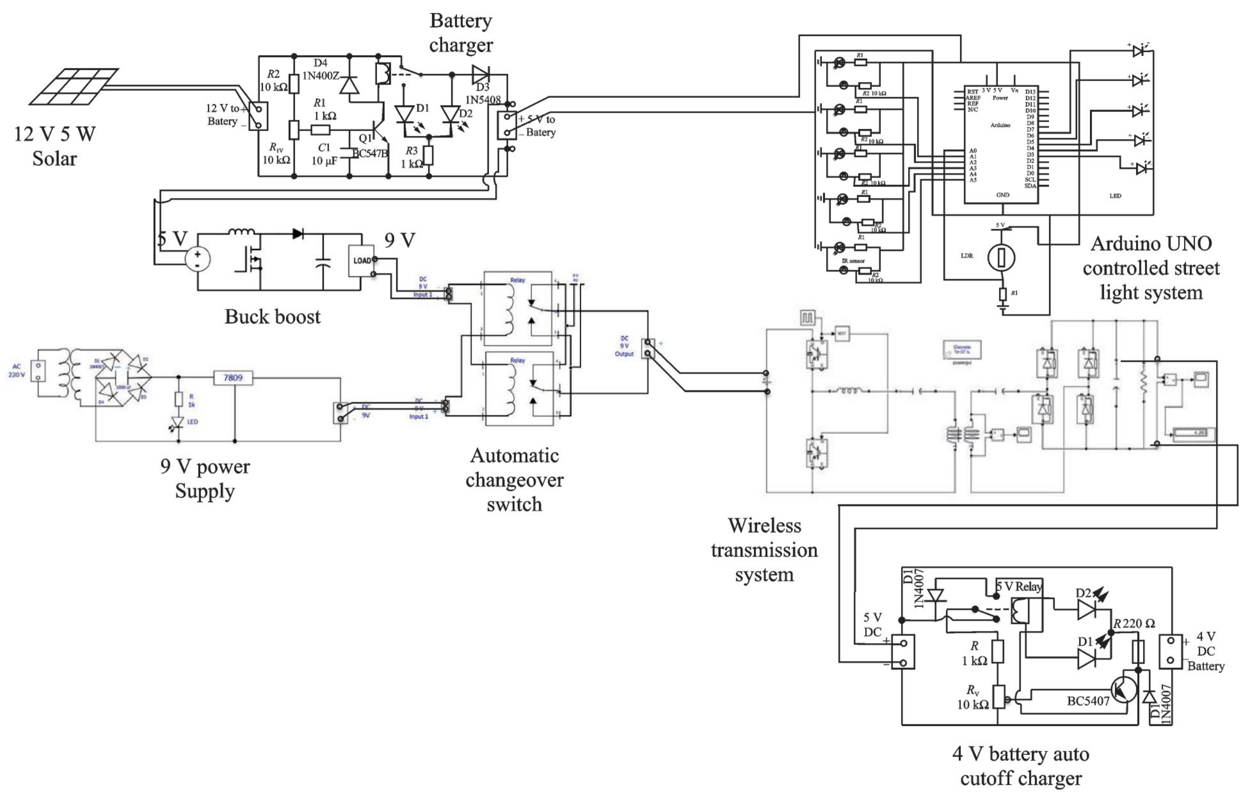

Fig.12 Overall system working procedure

3 Applications and Hardware Results

The wireless vehicle charging booth system can be installed in several places to save money and time[13]. Electric vehicles may be charged at hotels, hospitals, schools, colleges, universities, retail centers, and other places using this wireless charging method. Furthermore, another prominent application of the inductive charging system is the integration of stations into individual road segments to charge EVs while driving.

4 Conclusions

The proposed model three systems, dual energy source supply system, automatic street light system, and wireless power system, as shown in Fig.13, are interlinked together. The manually operated electric car with front and backlight is introduced with an automatic battery management system and also shows the indications of the charging level of the battery with three colors of LED's. The streetlight operated with the help of Arduino Atmega328, utilized two sensors LDR and four IR sensors. The auto-switched circuit is arranged for a continuous 9 V power supply to a wireless system. The receiving voltage and induced current at receiver side are shown in Fig.14 which illustrates the proper working of the proposed model. When the receiver

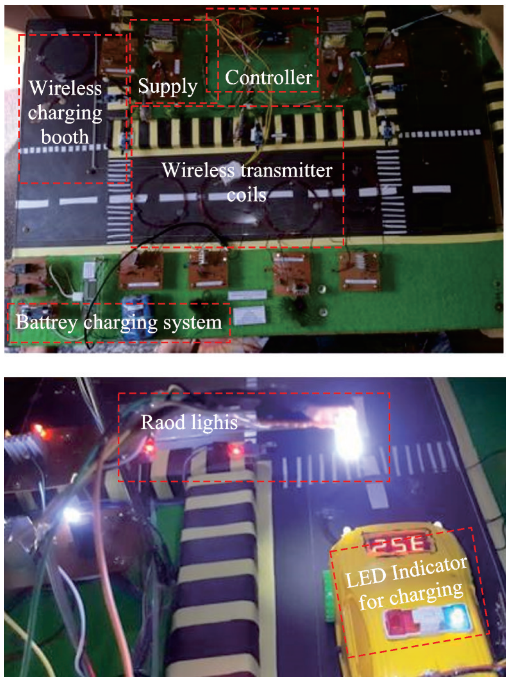

Fig.13 Proposed model prototype with results

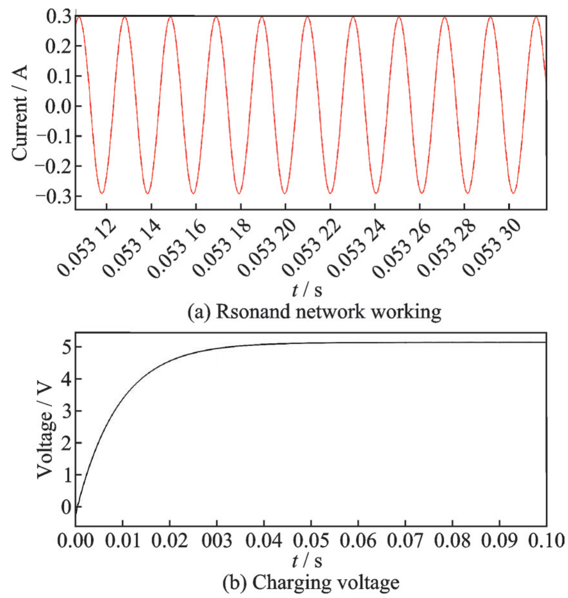

Fig.14 Charging voltage received at the battery side and resonant current

coil is disconnected from the transmitter coil range, the power oscillates which might advance after further studies on boosting wireless power transmission efficiency.

(1) The power supplied to the system with renewable energy sources without any distortion is the priority of this project.

(2) Intelligent battery systems store the energy without any delay.

(3) The wireless charging system is capable of saving time and cost-efficiently.

(4) Human health is affected by magnetic fields which can be further improved after taking different sensors under consideration to operate the wireless transmission when it's needed.

References

[1] TUMMAPUDI S, THABASSUM M, PEETALA R K, et al. Solar-powered wireless charging station for Electric Vehicles[C]//Proceedings of 2023 International Conference on Power, Instrumentation, Energy and Control (PIECON). Aligarh, India: IEEE, 2023:1-4.

[2] CHANDRA MOULI G C, VAN DUIJSEN P V, GRAZIAN F. Sustainable e-bike charging station that enables AC, DC, and wireless charging from solar energy[J]. Energies, 2020, 13: 3549.

[3] CHOWDARY K V V S R, KUMAR K, KUMAR R R. Impact of onboard DC-DC converter for dynamic wireless charging of electric vehicles[C]// Proceedings of 2021 1st International Conference on Power Electronics and Energy (ICPEE). Bhubaneswar, India: IEEE, 2021: 1-5.

[4] ODEH Y S, ELKAHLOUT I S, NAEIMI PV, et al. Planning and allocation of dynamic wireless charging infrastructure for electric vehicles[C]//Proceedings of 2022 9th International Conference on Electrical and Electronics Engineering (ICEEE). Alanya, Turke: IEEE, 2022: 306-310.

[5] SUSAN S S, RAJ A P, MISHRA A, et al. Vehicle Movement based innovative smart highway lighting system[C]//Proceedings of 2022 International Conference on Inventive Computation Technologies (ICICT). Nepal: IEEE, 2022: 483-488.

[6] ZHANG Shishuai, LIU Yuhang, CHEN Yuchun. Operation and monitoring technology of mobile wireless charging for electric vehicles[C] //Proceedings of 2021 IEEE 4th International Conference on Renewable Energy and Power Engineering (REPE). Beijing, China: IEEE, 2021: 37-42.

[7] ZHENG Zhao. Charge induction dust concentration detection technology based on active charging[C]//Proceedings of 2022 IEEE Asia-Pacific Conference on Image Processing, Electronics and Computers (IPEC). Dalian, China: IEEE, 2022:233-237.

[8] AL-HITMI M A, IQBAL A, RAHMAN S, et al. A dual active bridge based wireless power transfer system for EV battery charging controlled using high speed FPGA[C]//Proceedings of Informatics, IoT, and Enabling Technologies (ICIoT). Doha, Qatar: IEEE, 2020: 372-376.

[9] USHKEWAR S, PATIL G B, MOYAL V. Wireless charging in a dynamic environment for electric vehicles[C]//Proceedings of 2022 IEEE Bombay Section Signature Conference (IBSSC). Mumbai, India: IEEE, 2022: 1-5.

[10] DENG Kai. Research on current control of MRC coupling electric vehicle wireless charging[C]//Proceedings of 2022 9th International Forum on Electrical Engineering and Automation (IFEEA). Zhuhai, China: IEEE, 2022:838-84.

[11] SAHA D, SORIF S M, DUTTA P. Weather adaptive intelligent street lighting system with automatic fault management using Boltuino platform[C]// Proceedings of 2021 International Conference on ICT for Smart Society (ICISS). Bandung, Indonesia: IEEE, 2021:1-6.

[12] KUMAR P. IOT-based automatic street light control and fault detection[J]. Turkish Journal of Computer and Mathematics Education, 2021, 12: 2309-2314.

[13] PATIL P S, PADAGANUR S. Challenging issues in wire less power transmission methods a survey[J]. International Journal of Scientific and Technology Research, 2018, 7(8):136-139.

Acknowledgments This work was supported in part by the National Natural Science Foundation of China (No. 62371233), and in part by the Aviation Science Foundation Project(Nos. 2022Z024052003 , 20230058052001).

Authors Mr. **NAQVI Syed Zohair Raza** graduated with a B.S. in Electrical Technology from National College of Business Administration and Economics in Pakistan in 2021. Currently, he is pursuing a master's degree in Electrical Engineering from the Department of Electrical Engineering, Nanjing University of Aeronautics and Astronautics, in Nanjing, China. His research interests include power electronics and wireless electrical energy transmission.

Prof. **XIAO Lan** received her B. S. and Ph. D. degrees in electrical engineering from Nanjing University of Aeronautics and Astronautics (NUAA), Nanjing, China, in 1993 and 1998, respectively. In 1999, she was the faculty at the College of Automation Engineering, NUAA, where she is currently a professor at Jiangsu Key Laboratory of New Energy Generation and Power Conversion. Her current research interests include soft-switching DC-DC converters, soft-switching inverters, and renewable energy generation systems.

Author contributions Mr. **NAQVI Syed Zohair Raza** set all the prototype setups, conducted the experiments, and analyzed the different results.Prof. **XIAO Lan** contributed to the discussion and background of the project study and conducted the analysis for accurate results. Dr. **JIANG Menghan** contributed to the simulation analysis of the project and gave the right shape to the setup of the system. All authors commented on the manuscript draft and approved the submission.

Competing interests The authors declare no competing interests.

(Production Editor: ZHANG Bei)

基于双源电源的电动汽车无线充电系统

NAQVI Syed Zohair Raza，肖 岚，姜盟瀚

（南京航空航天大学自动化学院，南京 211106，中国）

摘要：近年来，汽车燃料资源的使用量大幅增加，严重影响气候并导致全球变暖。使用电动汽车(Electric vehicle, EV)是保护环境和降低出行成本的有效途径。然而，电动汽车充电系统充电源单一，电动车充电速率受限。本文开发了一种基于双源电源的电动汽车无线充电系统。它实现了12 V光伏输出和220 V交流电双源供电及智能切换，并且具备无线传输功能。基于提出的供电架构搭建了微型无线充电模型，使得EV模型借助无线感应充电系统存储电力并实现了静止与移动控制。

关键词：可再生能源；感应耦合；感应充电；转换器；自动切换；自动切断电路