A Comprehensive Analysis of Dynamic Wireless Charging for Electric Vehicles

Swati Joshi, Samiran Muley, Ashish Muley, Shriyog Muley, Muhmmad Zaid Aarif Kureshi, Mitali Mukkawar, Neeraj Mulchandani

Department of Engineering, Sciences and Humanities (DESH) Vishwakarma Institute of Technology, Pune, 411037, Maharashtra, India

F.Y. B.Tech Students Engineering Design and Innovation (EDAI1) Project Paper, SEM 2 A.Y. 2022-23 Vishwakarma Institute of Technology, Pune, India

Abstract — The swift expansion of electric vehicles (EVs) has underscored the demand for effective and user-friendly charging solutions. This research paper offers an in-depth analysis of dynamic wireless charging advancements for electric vehicles. It begins by presenting an overview of a model and a couple sensors that can be used for the implementation in real-life applications. The efficiency of the power transmitted was analyzed in the real-time experiment. Electromagnetic induction is the main cause of wireless power transfer and a model for real-time application was created. This model shows the advantages and disadvantages that come with the usage of each sensor that was used. A relatively affordable system was thus proposed through this model.

Keywords — Dynamic Wireless Charging, Arduino-UNO, Wireless Transmission, Conduction Coil, Electric Vehicles

I. INTRODUCTION

In recent years, electric vehicles have started becoming more and more popular in response to the changing global environment and environmental problems. By eliminating emission of pollutants, electric vehicles can drastically reduce global CO2 levels and create sustainable transportation. But the need to power electric vehicles has become an important subject since many consumers fear that they would not be able to charge their vehicle if it runs out of power in the middle of the road. There are also not as many electric charging stations in many parts of the world as there are petrol pumps, contributing to this fear. Electric vehicles today need plug-in chargers, meaning that they have thick charging cables that a person needs to physically connect to the vehicle to charge the car. This, as well as the lack of charging stations, can create a lot of discomfort and is a very inconvenient system for many people. Systems based on Wireless Charging have been introduced in many different electronic devices, such as phones and ear buds. But it must be noted that these systems could also be used in the implementation of wire-free charging for electric vehicles. With the introduction of wire-free charging, charging these vehicles can become much simpler and more efficient. Since these vehicles will be charged on the road itself, there is no need for a person to either go to their house or find a charging station to power their vehicle. So far, two new ways to power an electric vehicle through wireless charging have been introduced. These are dynamic and static wire-free charging systems. In the static wire-free charging system, the electric vehicle stays stationary at an appropriate location. Through electromagnetic induction, the vehicle will be charged at that spot until it is taken out of the location. This will ensure that the vehicle stays sufficiently charged all the time when it is not in motion. In the dynamic wire-free charging system, the electric vehicle will be charged while it is in motion. Sensors will detect the 2 vehicle moving past them on the road and will let current flow, which will charge the moving vehicle through induction. This can ensure that vehicles stay charged on long roads and highways where they are constantly in motion for long periods of time. In this paper, we will be reviewing and implementing the wireless charging system on a smaller scale to test out the necessary parameters when building the system on roads

II.LITERATURE REVIEW

Research papers related to study, technology used, and implementation of the model proposed in the paper:

Dynamic Wireless Charging for Electric Vehicle: This paper is a study about the implementation of a project. A DC current has been supplied from the main power source. Then, to convert DC to high-frequency AC, inverters are used, and current is supplied to the primary. The AC supplied forms alternating flux, which then induces and forms current in the secondary coil due to the EM induction phenomenon. This AC output is again rectified, and the battery of the EV gets charged using direct current.

A New Wireless Charging System for Electric Vehicles Using Two Receiver Coils: This paper introduces us to the technique of using multiple coils, which increases the efficiency of power transmission. It also explores the potential of employing two receiver coils and contrasts this strategy with the conventional approach, which relies on a single receiver coil. This investigation is grounded in a fresh mathematical depiction of the wireless power transmission system.

Cutting the Cord: The paper discusses the IPT system (inductive power transfer), which transfers power between two physically detached subsystems. Power will be provided by a primary transmitter and received by a movable secondary receiver. A compensation circuit is to be used to connect to the primary coil. A secondary compensation circuit, which is connected to the battery of the vehicle, contains a rectifier and a dc-voltage regulator.

Coil Design and Efficiency Analysis for Dynamic Wireless Charging System for Electric Vehicles: In the system of this paper, a dispersed coupling structure named GPSSC is used. This paper examines the transmitting coils embedded beneath the road at specific intervals, capable of activating and deactivating to charge vehicles in motion. The paper also formulates the efficiency expression for GPSSC transmission. Various spacings of the receiving coil are tested in experiments to determine the optimal charging condition.

Review of static and dynamic wireless electric vehicle charging system: The efficiency of power transfer in this document is contingent on the alignment of coils and the air-gap distance between the source and receiver. Furthermore, several designs of wireless transformer structures are elucidated to enhance power transfer efficiency. Magnetic planar ferrite plates are utilized on both the transmitter and receiver sides to mitigate detrimental leakage fluxes and enhance magnetic flux distribution

Design of Intelligent Vehicle Based on Dynamic Wireless Charging: This paper focuses on the design aspect of modeling a system. The first step to building a dynamic wireless charging system would be figuring out the requirements such as speed, ranges of vehicles, and the type of sensors being used. For the next steps, the tools and technologies required for each 3 part of the design need to be identified and compared with each other to find an efficient and costeffective combination.

Electric Vehicle Wireless Charging Technology: A state-of-the-art review of magnetic coupling systems: This paper talks about the actual technologies that can be used to wirelessly charge vehicles and on what principles these technologies operate. Essentially, the technology for wirelessly charging electric vehicles functions based on the principles of magnetic inductance and magnetic resonance. Magnetic-coupling systems for efficient power transfer were also discussed in the paper.

An Overview of Dynamic Inductive Charging for Electric Vehicles Multidisciplinary Digital Publishing Institute: LCL filters and their efficiency and application has been discussed in this paper. LCL filters and their adjustments can result in a decrease in the apparent power rating, known as the VA rating. But they can reduce the losses in the rectifier pickup winding which ensures that efficiency remains high. LCL filters account for the resistive and reactive impedance from components, making it more accurate. They are beneficial in scenarios where there is large misalignment between coils of vehicle and road and thus ensure reliable operation.

The Impact of the Speed and Temperature Variation on the Electric Vehicles Reliability: This paper provides an overview of various electric vehicle (EV) types and their constituent components. It goes further to investigate how changes in temperature and vehicle speed can affect the failure rates of these components. Additionally, the paper presents a flowchart detailing a reliability model specifically designed for full-electric vehicles. This model serves as a valuable tool for assessing and ensuring the reliability of the individual components within an electric vehicle, contributing to a better understanding of their performance under varying conditions.

An Autonomous Coil Alignment System for the Dynamic Wireless Charging of Electric Vehicles to Minimize Lateral Misalignment: This essay illustrates how inductive charging can be applied to the on-the-go charging of electric automobiles. The safe transfer of power between the vehicle's load coil and the pavement source coil is emphasized throughout the article. To maximize power transfer, this study interprets the load coil's alignment with the vehicle's source coil. The autonomous coil alignment system (ACAS) is the name of the method described in this research.

III. METHODOLOGY

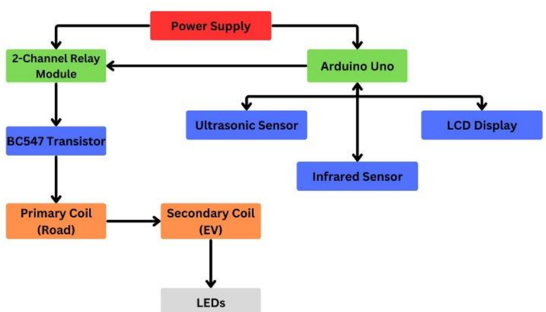
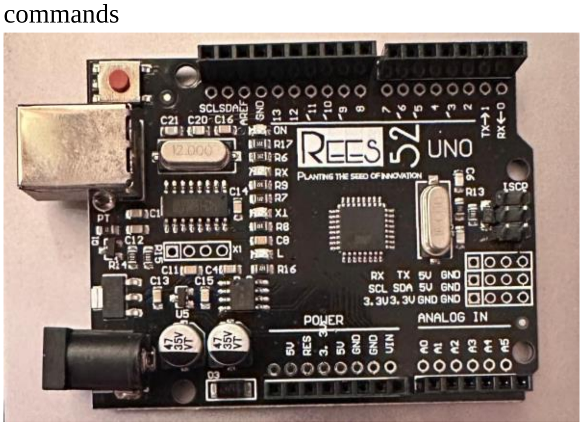


Fig. 1 Block Diagram of System

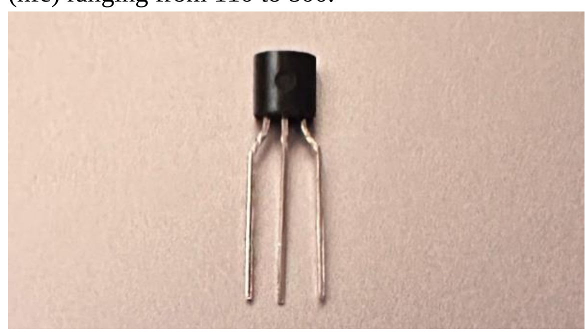
IV. TOOLS

1] Arduino UNO - The Arduino UNO microcontroller has IC of ATmega328P which operates at a voltage of 5V. This controller is used for the purpose of communicating hardware with the embedded software commands

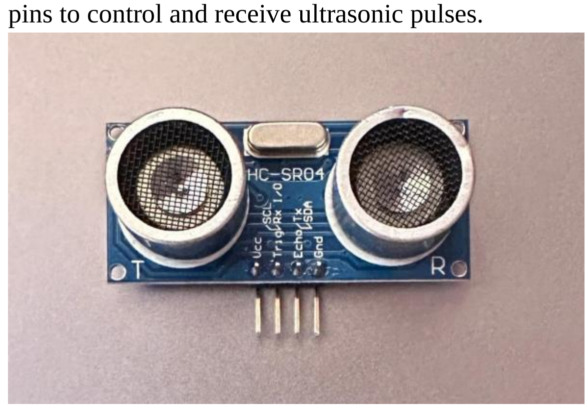


2] Tesla Coil [18 Gauge]: This copper wire of 1.024mm (about 0.04 in) of AWG (American Wire Gauge) diameters is coiled with enough turns depending upon the requirement for the purpose of wireless energy transfer. This operates on principle of high voltage as well as high frequency to be electrically operated.

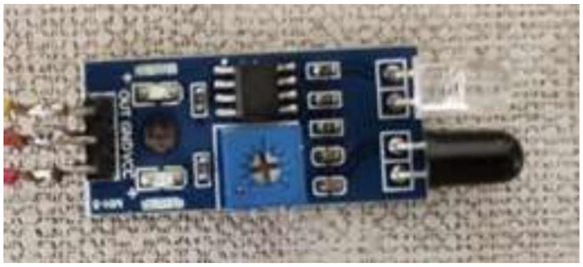
3] Transistor BC547: A common NPN BJT (Bipolar Junction Transistor) is used as an oscillator to produce alternating current (AC) signals. Key specifications include a collector current (Ic) of 100mA, a collector-emitter voltage (Vce) of 45V, a maximum power dissipation (Pd) of 500mW, and a DC current gain (hfe) ranging from 110 to 800.



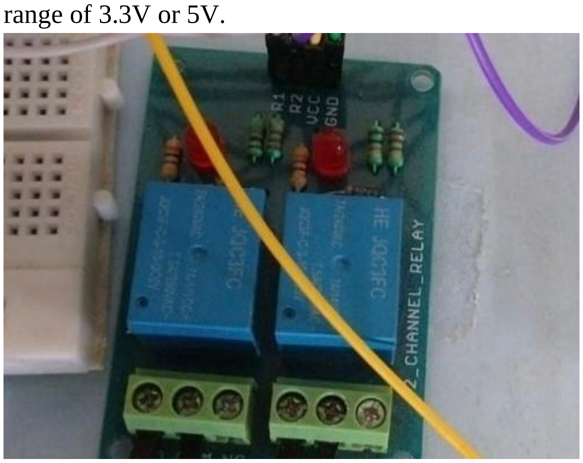
4] Ultrasonic Sensor: The ultrasonic sensor offers variable range capabilities and operates on the same concept as ultrasonic transceivers, with typical ranges between 2 cm and 400 cm. It offers high-accuracy distance measurement with little interference at a frequency of about 40 kHz. This sensor is frequently used in applications like distance measuring and obstacle identification because it uses trigger and echo pins to control and receive ultrasonic pulses.



5] Infrared Sensor: The near-infrared operating range of the infrared (IR) sensor allows it to pick up infrared reflection or proximity. It transmits digital or analog output signals to show whether an object is there or not. Generally, it has very low range as compared to ultrasonic sensor



6] 2-Channel Relay Module: Two separate relays are included in a 2-channel relay module for flexible control. Depending on the module, these relays are frequently either electromechanical or solid-state configured. They are rated for both the maximum load current and the maximum switching current, and they support widely used voltage options like 5V and 12V. Each channel has two sets of contacts that are typically open (NO) and normally closed (NC), and they each accept low-voltage control signals, typically in the range of 3.3V or 5V.



V. WORKFLOW

For this research into wireless charging, an Arduino Uno was used to simulate the microcontrollers that would be installed on the roads to detect and automatically charge vehicles. A power supply of 220V and 50KHz was provided to a 9V charger. This charger converted high AC voltage to DC power supply which further was provided to Arduino Uno microcontroller to power it and all the mechanical components of the system. An ultrasonic sensor and an IR sensor were connected to the Arduino so that vehicles on road may be detected. Both sensors were used to gauge the accuracy, advantages and disadvantages of the sensors as well as to detect which one is more suitable in practical applications. The sensors were laid out along the side of the road so that a moving vehicle would be detected. The ultrasonic sensor used ultrasonic sound waves for detection while the IR sensor used infrared light to do so. Once the vehicle is within a certain range of the sensors, it would mean that the vehicle is close enough to be wirelessly charged. Two copper coils were installed under the road for electromagnetic induction and generation of current in the vehicle. These copper coils were connected to the Arduino itself via two relays. Since the voltage necessary to generate a current in the coils is greater than what an Arduino can provide, relays were connected to make sure the Arduino wasn't overloaded and current flows in the coil smoothly. The relay has a 3.3V connection in its NO pin which is connected to the Arduino. Its COM pin is connected to the coil itself underneath the road. Once the sensors detect a vehicle on the road, they will send a signal to the Arduino microcontroller. The microcontroller will then send a signal to the relays, which would then allow current to flow into the copper coil. Once the current starts flowing into the copper coils, an electromagnetic field was generated, but for a very short amount of time of no significance. Thus, to maintain a continuously generated electromagnetic field, the constant DC current was changed into an AC current using a BC547 transistor. In this transistor, the collector was connected directly to the coil and the emitter was connected to the ground. The base was connected to a 22KOhm resistor which was also connected to the coil. The coil itself had three endpoints – two were connected to the transistor while the last one was given the power supply of 3.3V through relay. When the current flows into the copper coils, a stable electromagnetic field is generated around it. Copper coils were also attached to the bottom of the vehicle moving on the road. Therefore, once an electromagnetic field is generated and the vehicle moves through it, current would be generated in the copper coils of the vehicle because of electromagnetic induction. Since the current generated through induction was very small, the coils were connected to LED's. Once current was flowing in these coils, the LEDs would then light up and signal that the vehicle was charging. Similarly, to help detect if the copper coil was charging the vehicle or not, an LCD was connected to the Arduino Uno. 7 This LCD would then show if any relay was activated which would then signal that a copper coil is activated, and a vehicle is passing over it. To program the Arduino Uno and give it its functions, Arduino IDE was used.

VI. RESULTS & DISCUSSION

After running several trials by passing the vehicles in front the sensors, all the readings for the experiment were gathered. From the test cases, the magnetic field of primary coil radiates in all directions, and the flux i.e., the strength decreases dramatically with accordance of the distance following the inverse square law. Placing the secondary coil as close as possible gives out the maximum efficiency. In addition, the cross section of the secondary coil plays an important role in determining the amount of energy it can hold. A secondary coil with equal dimensions to the primary coil, oriented parallel, and a vertical spacing of only a few tens of millimeters provides the best cross section. The "coupling factor," which has a substantial impact on the efficiency of the energy transfer, is determined by the distance between, alignment of, and sizes of the various coils. When all the flux produced by the primary coil is absorbed, the perfect coupling factor of 1 is achieved. Distance between coils, alignment and sizes of various coils determine efficiency in transfer. There are two different ways to wirelessly transfer power: resonance wireless charging and inductive wireless charging. The electromagnetic resonance theory underlies resonance charging, in which the transmitter and receiver coils are tuned to the same frequency. This design offers a user-friendly alternative with a longer range since it provides for more freedom in coil alignment and positioning. Resonance charging is also renowned for its improved energy transfer effectiveness and low heat production. Inductive charging, on the other hand, frequently has a limited range and depends on accurate coil alignment and closeness for optimal energy transfer. While inductive charging can sometimes be less effective and generate more heat than resonance charging, it may still be appropriate in some situations where short-range, closely linked charging is allowed but does not always provide the same benefits. Based on the planned application, efficiency requirements, and user experience concerns, one should select between these two technologies. After analyzing the results, a few conclusions can be drawn about the differences between the sensors. When using the ultrasonic sensor for detecting the electric vehicle, since the detection angle of the sensor is small, it will only detect the vehicle when it is very close to it. If the vehicle isn’t at the right angle, the ultrasonic waves that the sensors sent out won’t bounce back to it and it would fail to detect the vehicle. This would, in turn, not activate the coils and charge the vehicle. In addition, an ultrasonic sensor can be affected by its surroundings such as wind and rain and it also has a smaller range compared to the IR sensor. Even so, ultrasonic sensors have a relatively low cost so installing them on the side of roads will not be too expensive. Since price is a major factor when building roads, this could count as a major advantage for ultrasonic sensors. For the IR sensor, it was very sensitive to light so any reflection on the vehicle could cause it to not detect the vehicle. Any physical obstruction between the sensor and the vehicle would also cause it to not be able to detect the vehicle. But IR sensors are less affected by weather factors such as wind and rain. They also have a faster response time compared to the ultrasonic sensors since light travels faster than sound. Both sensors have their advantages and disadvantages when it comes to this specific application. When building roads for practical projects, each sensor and their features need to be considered thoroughly to ensure a fully functioning system for wirelessly charging electrical vehicles.

VII. FUTURE SCOPE

In the context of saving maximum energy and more life expectancy of components we try to minimize mechanical switches and use the least power. MOSFETs, rather than relay, are much more 8 efficient for achieving this due to their very high switching power. Also, they can provide us with PWM (Pulse Width Modulation) which can provide varied intensity of power based on the consumption of energy by vehicle. Use of Infrared Proximity Sensor or likewise sensors which work on optical sensitivity could provide more precise and fast data to ensure the presence of object. A lane for electrical vehicles needs to be provided on the roads separately than for other vehicles to implement this system in a real-life situation. In this way, it can be ensured that there are no unnecessary interactions between electrical and normal vehicles.

VIII. CONCLUSION

The project successfully worked and was a basic prototype of the real based model. The glowing of LED on the car through wireless conduction, synchronization of ultrasonic sensors with relay module, and display of the working copper coil on lcd was the proof of successful testing. In conclusion, this research paper has provided valuable insights into dynamic wireless charging for electric vehicles. Dynamic wireless charging (DWC) has emerged as a promising solution to enhance the convenience and practicality of electric vehicle (EV) charging systems.

IX. ACKNOWLEDGMENT

We would like to thank Swati Joshi Ma'am, Mahajan Sir, and Sawant Sir for contributing and suggesting improvements and tweaks is our project

REFERENCE

[1] Viknesvaran K , Priyadharshini P, Santhosh J, Prakash N, "Dynamic charging of electric vehicles" ,Tamil Nadu, India ,International Research Journal of Engineering and Technology (IRJET),Volume: 09 Issue:05,May 2022,DOI:e-ISSN: 2395-0056.

[2] N. Mohamed ,F. Aymen, M. Alqarni, R. Turky, B. Alamri, Z. Ali, S. Aleem, "A new wireless charging system for electric vehicles using two receiver coils", Saudi Arabia, Ain Shams Engineering Journal 13 (2022) 101569.

[3]S. Lukic , Z. Pantic , "Static and dynamic inductive wireless charging of electric vehicles", IEEE Electrification Magazine , September 2013,DOI:2325-5987/13/$31.00.

[4]X.Zhang1, Z. Yuan1, Q. Yang1, Y. Li2, J. Zhu1, Y. Li1",Coil Design and Efficiency Analysis for Dynamic Wireless Charging System for Electric Vehicles",IEEE,2015,DOI :10.1109/TMAG.2016.2529682.

[5] M. Mohamed, T.Arasan, "Study on Electric Vehicles in India Opportunities and Challenges", International Journal of Scientific Research in Environmental Science and Toxicology, February 16 2018.

[6] Y. Yao , L.Du, "Design of Intelligent Vehicle Based on Dynamic Wireless Charging",China,12th International Conference on Advanced Computational Intelligence (ICACI) Dali, August 14-16, 2020.

[7] T. Fisher, K. Farley, Y. Gao, H. Bai ,Z. Tsz Ho Tse, "Electric vehicle wireless charging technology: a state-of-the-art review of magnetic coupling systems ",Cambridge University Press, 2014. 9

[8] A.Ghaedi, M.Mahmoudian,R. Sedaghati, "The Impact of the Speed and Temperature Variation on the Electric Vehicles Reliability", Hindawi: International Transactions on Electrical Energy Systems Volume, 2022,DOI:10.1155/2022/4876218.

[9] C. Panchal ,S. Stegen,J. Lu,"Review of static and dynamic wireless electric vehicle charging system", Australia: Engineering Science and Technology, an International Journal,2018,DOI:10.3390/en15155613.

[10] P. Magudeswaran, G. Pradheeba, S. Priyadharshini, M. Sherline Flora,"DYNAMIC WIRELESS ELECTRIC VEHICLE CHARGING SYSTEM", Tamil Nadu, International Research Journal of Engineering and Technology (IRJET),Volume: 06 Issue: 03 | Mar 2019.

[11] K. Hwang, J.Cho, D.Jim, J.Park, J. Kwon,S. Kwak, H.Park, S. Ahn, "An Autonomous Coil Alignment System for the Dynamic Wireless Charging of Electric Vehicles to Minimize Lateral Misalignment", Energies 2017.

[12] N. Mohamed, F. Aymen, Z. M. Ali, A. F. Zobaa, and S. H. E. A. Aleem, "Efficient power management strategy of electric vehicles based hybrid renewable energy, "Sustainability, vol. 13, no. 13, p. 7351, Jun. 2021, Doi: 10.3390/su13137351.

[13] A. Ahmad, Z. A. Khan, and M. S. Alam, "A review of the electric vehicle charging techniques, standards, progression and evolution of EV technologies in Germany, "Smart Sci., vol. 477, pp. 1–18, Jan. 2018, Doi: 10.1080/23080477.2017.1420132.

[14] P. García, L. M. Fernández, J. P. Torreglosa, and F. Jurado, "Operation mode control of a hybrid power system based on fuel cell/battery/ultracapacitor for an electric tramway, "Comput.Electr. Eng., vol. 39, no. 7, pp. 1993–2004, Oct. 2013, Doi: 10.1016/j.compeleceng.2013.04.022.

[15] A. Trivino-Cabrera, M. Ochoa, D. Fernandez, and J. A. Aguado, "Independent primary-side controller applied to wireless chargers for electric vehicles," in

Proc. IEEE Int. Electr. Vehicle Conf. (IEVC), Dec. 2014, pp. 1–5, Doi: 10.1109/IEVC.2014.7056193.
[16] N. Mohamed, F. Aymen, and B. H. Mouna, "Influences of photovoltaics cells number for the charging system electric vehicle, 'in Proc. 17th Int. Multi-Conf. Syst., Signals Devices (SSD), Jul. 2020, pp. 244–248, Doi: 10.1109/ssd49366.2020.9364141.
[17] Y. Wang, Z. Wu, Y. Chen, A. Xia, C. Guo, and Z. Tang, "Research on energy optimization control strategy of the hybrid electric vehicle based on Pontryagin's minimum principle, "Comput. Electr. Eng., vol. 72, pp. 203–213, Nov. 2018, Doi: 10.1016/j.compeleceng.2018.09.018.
[18] T. M. Fisher, K. B. Farley, Y. Gao, H. Bai, and Z. T. Tse, "Electric vehicle wireless charging technology: A state-of-the-art review of magnetic coupling systems, "Wireless Power Transf., vol. 1, no. 2, pp. 87–96, 2014, Doi: 10.1017/wpt.2014.8.
[19] N. Mohamed, F. Aymen, Z. Issam, M. Bajaj, and S. S. M. Ghoneim, "The impact of coil position and number on wireless system performance for electric vehicle recharging, 'Sensors, vol. 21, no. 4343, pp. 1–19, 2021, Doi: 10.3390/s21134343.
[20] J. Wang, Y. Cai, L. Chen, D. Shi, R. Wang, and Z. Zhu, "Review on multipower sources dynamic coordinated control of hybrid electric vehicle during driving mode transition process, "Int. J. Energy Res., vol. 44, no. 8, pp. 6128–6148, Jun. 2020, Doi: 10.1002/er.5264.