

Automated Dual-Spot Wireless Charging and Parking Management System for Electric Vehicles

1st Priyanshu

Dept. of Electronics Communication Engineering, MIET
priyanshuchillar19@gmail.com

2nd Aryan Panwar

Dept. of Electronics Communication Engineering, MIET
aryanpanwar10005@gmail.com

Abstract—The high rate at which Electric Vehicles (EVs) are being adopted all over the world has greatly raised the need to have power charging infrastructure that is efficient, automated, and user-friendly. The traditional wired charging systems despite their extensive application are faced with a number of constraints which include manual operation, mechanical failure and wear and tear, non-automation and non-intelligent parking control. Such disadvantages lower the efficiency and user-friendliness, particularly in a very dense urban setting.

To overcome these issues, this project suggests a hi-tech Automated Wireless Power Transfer System with Smart Parking Management. The system will accommodate two parking slots, where two vehicles can be charged at the same time or they can be charged selectively and space is used efficiently. It integrates automation by hardware with smart sensing to form a smooth charging experience.

The system has a central control unit, an Arduino Uno microcontroller. It keeps track of the readings of several Infrared (IR) sensors placed at every parking slot. The sensors detect the presence or absence of a vehicle by detecting a break in the infrared signals. According to such detection, the system automatically identifies slot occupancy and sets the availability status, which is graphically displayed to users in LED indicators (e.g., green when available, red when occupied).

In the case of wireless power transmission, the system utilizes electromagnetic induction principle. The transmitter circuit (a circuit based on transistors) is a high-frequency oscillator that produces an alternating magnetic field in a primary coil. When an automobile with a second coil is placed in a close proximity (usually 1-2 cm), this magnetic field creates an electric current in the receiver coil and this way, wireless transfer of energy is possible without the use of physical connectors. This will reduce energy losses associated with mechanical connections and increase safety by removing exposed conductive components.

A relay-based switching mechanism is also embedded in the system permitting the independent control of every charging slot. This will ensure that power is only supplied to the occupied slot hence enhancing energy efficiency, and unnecessary power consumption is prevented. The Arduino-controlled relay module dynamically switches between slots according to sensor inputs to ensure reliable and automated operation.

The prototype also uses a low-voltage input (e.g. 9V DC) and provides a constant output between 2 and 5V, so it can be used in both demonstration and small-scale usage. The system performs optimally with a small air gap, and exhibits moderate power transfer efficiency, which can be improved with resonant inductive coupling methods.

On the whole, the solution is a low cost, scalable, and smart solution to EV charging infrastructure. It not only makes the charging process simpler but also incorporates smart parking control, which makes it very appropriate in urban applications. Moreover, the system can be greatly enhanced in the future, including the possibility to be connected to Internet of Things (IoT) systems to provide remote monitoring, mobile applications used to book slots, automatic billing systems, and high-efficiency

resonant wireless charging technologies.

Index Terms—Wireless Power Transfer (WPT), Electric Vehicles, Smart Parking System, Arduino Uno, IR Sensors, Inductive Coupling, Automation, Dual-Spot Charging, Relay Control, EV Infrastructure.

I.

INTRODUCTION

The growing use of Electric Vehicles (EVs) has resulted in a significant demand to have smarter and more convenient charging systems. The conventional wired charging systems may be characterized by such problems as cable breakages, security, and inconvenience to the users. In response to this, Wireless Power Transfer (WPT) has become a promising technology, which has come into the limelight due to the trail blazed by Andre Kurs at the Massachusetts Institute of Technology. Nonetheless, the majority of available systems are dedicated to the transfer of power and they do not take into consideration parking management.

The proposed project is to implement an integrated system that consists of wireless charging and smart parking. It will automatically identify the presence of a vehicle, will allow charging wirelessly, and real-time information on the availability of slots by using simple indicators. Such a system may prove very helpful in intelligent cities, charging stations, and automated parking facilities, providing a more efficient and convenient solution.

A. Contributions

This project is unique in that it smartly integrates wireless charging and smart parking into one to provide a seamless user experience, where vehicles may be parked and simultaneously charged. It proposes a two-slots independent charging system, where two vehicles are able to charge at the same time without interference to one another, making the system more realistic in application to the real world. Integration of IR sensors allows automatic recognition of a vehicle in every parking slot, and removes manual intervention and makes it more accurate. The system has also provided real-time LED feedback to users to easily indicate slot occupancy and charging position, thus, it is easy and simple to use. One of the main advantages of this project is that it is cheap to implement with Arduino, which guarantees that the prototype is affordable, simple to assemble, and can be further developed and experimented.

- 1. Literature Survey: The latest advances in the sphere indicate the great improvement in both the technology of wireless charging and smart parking. Inductive coupling of wireless charging has permitted the transmission of

power without connection, making it more convenient and reducing wear and tear. Meanwhile, sensor-based smart parking systems have also assisted in the detection of vehicles and space optimization. Moreover, EV infrastructure based on IoT is also being considered to integrate charging stations, allowing remote monitoring and control.

Nevertheless, even with the progress, the majority of the current systems have their limitations. Most of the solutions are configured to serve one vehicle at a time, and this is why they are not as efficient in real-life use cases. Automation is usually restrictive and there is a need to have some degree of manual intervention. Most significantly, these systems are usually geared towards either parking or charging and not a combination of both in one solution.

- 2. Identification of Research Gaps: There are a number of research gaps, based on the analysis of the existing systems. Dual-spot wireless charging systems capable of serving multiple vehicles at a time are not available. Many solutions do not effectively use real-time parking indication, which may create inefficiencies and confusion to the user. Furthermore, automation of EV charging systems remains low, which could be improved. The other significant loophole is the lack of a fully integrated system that integrates sensing, charging and control into one single system that is cohesive.

- 3. Future Directions: Future enhancements of this project have multiple promising directions. One of them is the integration of IoT with the help of such modules as ESP8266 which may allow to monitor the system remotely and control it smarter. Coming up with a mobile app on parking and charging status would also increase the convenience to the user. The solution can be made more sustainable and eco-friendly by adding solar-charging systems. Moreover, AI-based energy optimization can be utilized to manage the power distribution efficiently, minimize wastage, and enhance the overall system.

- 4. Comparative Analysis: An analysis of existing systems and the proposed solution shows that there are some significant differences. Whereas both solutions enable wireless charging, the majority of current systems lack scalability capabilities and are not geared towards practical usage. They usually support only one vehicle at a time, are not properly automated, and without smart parking features. They tend to support single vehicles only, lack proper automation and lack smart parking capabilities. The suggested system, however, will be designed to overcome these drawbacks by providing multi-spot charging, enabling an automated work, and integrating the smart parking functions. Cost is another major benefit, other existing solutions are often costly because of intricate infrastructure but this project is centered on low cost implementation and so is more feasible and can be used by a greater number of people.

II.

LITERATURE REVIEW

Summary of key literature relevant to wireless charging and parking management system

Application Wireless power transfer (WPT) systems have been actively researched in applications to electric vehicles, the most established technique of short-range energy transfer being inductive coupling. Further refined methods such as resonant coupling have been considered to enhance efficiency and performance. Meanwhile, intelligent parking systems based on such technologies as IR and ultrasonic sensors are created to identify the presence of vehicles and to optimize the use of parking spaces. Nevertheless, all these systems are usually created separately and are not integrated with charging systems.

Based on the analysis of the available studies, some major conclusions can be made. Power transfer via wireless technology turns out to be effective and dependable in short-range charging and smart parking systems are highly effective in providing convenience to the user and improving space handling. With all this comes a noticeable gap in terms of integrating these technologies into one system. This initiative fills that gap by incorporating wireless charging, smart parking, and automation into a single, unified solution and providing a more efficient, user-friendly, and future-oriented solution to EV infrastructure.

A. Wireless Power Transfer (WPT) Systems.

Transmission of power wirelessly has been extensively investigated to be used in electric cars to remove the physical connections. The most common method of short distance energy transfer is the inductive method of coupling, which is easier and reliable. More sophisticated methods have been developed like resonant inductive coupling which are more efficient and permit a marginally larger distance. These systems have enhanced safety, less maintenance and ease of use than wired charging systems.

B. Smart Parking Technologies

Smart parking systems have been developed based on sensors such as IR and ultrasonic sensors, which identify the presence of vehicles and in parking space availability. The systems assist in lessening the traffic jam, saving time, and enhancing the efficiency of parking, in general. Visual indicators or digital displays are also a part of many modern solutions that assist users in locating free parking slots. Nevertheless, they are typically only useful in terms of detection and monitoring.

C. IoT-Based EV Infrastructure

With the growth of the Internet of Things (IoT), EV infrastructure is becoming more connected and intelligent. Charging stations can also be remotely monitored, data collected, and controlled with IoT-enabled systems. Users are able to get real-time data on charging status, availability, and system performance. At the same time as these developments, the majority of IoT-based solutions either charge or monitor as opposed to offering an all-encompassing integrated system.



Fig. 1. System architecture

D. Existing System limitations

In spite of the considerable advancement achieved in individual technologies, the current systems have a number of limitations. The majority of the solutions are implemented to work with one vehicle, which restricts their effectiveness in crowded conditions. Automation is not usually complete, but some of its stages must be worked on manually. Also, integration is obviously missing, wireless charging, smart parking and control systems are typically developed independently which makes them less efficient.

E. Summary of Literature Findings

Based on the review of the current literature, a number of important findings can be made. Short-range charging of EVs with wireless power transfer is proven to be successful and efficient. Smart parking systems can enhance user experience and space utilization to a large extent. IoT improves monitoring and control functions. Nevertheless, the introduction of these technologies into one, unified system is weak and undeveloped.

F. Contribution of the Project to Research

This project will help fuse the gap identified by integrating wireless charging, smart parking, and automation into a single unit. The proposed solution provides a more efficient, user-friendly, and scalable solution by incorporating sensing, charging, and control functionality, which will be appropriate in the context of the smart city and EV infrastructure in the future.

III. SYSTEM ARCHITECTURE AND METHODOLOGY

The system is developed based on modular architecture in which every component undertakes a particular operation to facilitate effective and easy running of the system. It starts with the detection layer, which is an IR sensor that detects the existence of a car in the parking slot. This data is then transferred to the control layer where the Arduino Uno interprets the input and decides based on it. According to this, the output layer is able to give real time feedback by using LEDs to show slot status. At the same time, the relay triggers the power transmission mechanism, when a transistor oscillator creates a magnetic field in the main coil, allowing wireless energy transfer. This energy is then caught by the power reception layer via a second coil, which provides it to be charged. In general, the system operates with the following key methodologies: electromagnetic induction as a wireless charging, sensor-based detection, which is used to offer automation, relay-based switching, which is used in order to offer control, and real-time monitoring that improves the user experience and efficiency.

A. System Architecture

The proposed system follows a well-structured and modular architecture in which each layer performs a specific function to ensure smooth and efficient operation

Detection Layer - The detection layer will detect the presence or absence of a vehicle in the parking slot. It has IR sensors, which constantly keep an eye on the space. This makes it automatically and correctly detected without any human intervention.

Control Layer - The brain of the system is the control layer, which is executed with an Arduino Uno. It is the receiver of the signals sent by the IR sensors and does some logic-based processing. It is based on the input to determine the occupied parking slot, initiating charging, and the output to be shown. It also controls other components like relays and LEDs.

Power Transmission Layer - The production of wireless power is done by this layer. An alternating current in the primary coil is generated using a transistor based oscillator circuit. This alternating current generates a magnetic field around the coil which is necessary to transfer energy wirelessly.

Power Reception Layer - The energy emitted by the primary coil is received by the power reception layer. The receiver side (vehicle or charging unit) has a secondary coil around. This coil is induced by the magnetic field through the electromagnetic induction and the resulting current is charged to use.

Output Layer - The output line presents the user with feedback by the way of LED indicators. These LEDs show the current system status, e.g., available parking slot, occupied parking slot or charging parking slot. This renders the system user-friendly and easy to comprehend.

This layer by layer architecture will make sure that every section of the system will play a certain role but collaborate to attain automated parking and wireless charging.

B. Workflow

The system is automated and works in a step-wise manner:

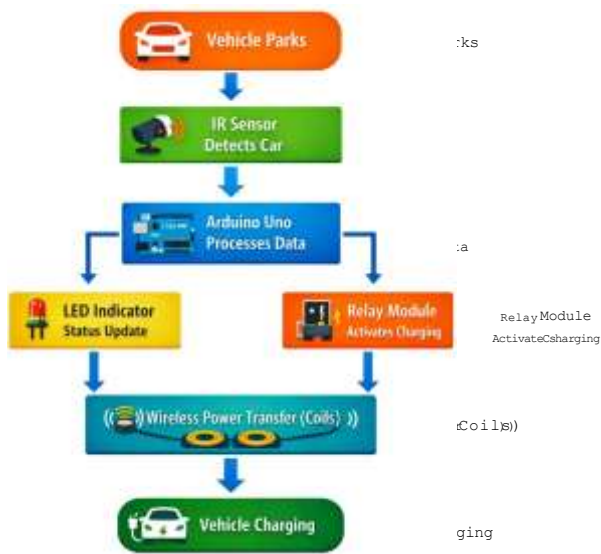


Fig. 2. The system follows an automated and continuous workflow to ensure smooth parking and wireless charging:

- 1) **Vehicle Entry**-This starts when a user parks the vehicle in the parking slot. The system is in the standby mode until it detects a vehicle.
- 2) **Detection**-IR sensors are installed and they detect the presence of the vehicle by sensing obstruction. After being sensed, the sensor sends a signal to the Arduino Uno.
- 3) **Signal Processing**-The sensor input is fed into the Arduino Uno where it is processed with predefined logic. It determines the occupancy of the slot and makes decisions based on the same.
- 4) **Status Indication**- LED indicators are updated based on the processed data. As an example, an LED can display occupied, another can display charging, which can be easily seen by the user.
- 5) **Charging Activation** - Once it has been established that the vehicle is present, the Arduino triggers a relay switch. This relay is used as a control mechanism in order to initiate the wireless charging system in a safe manner.
- 6) **Wireless Power Transfer**-The transmitter coil is made by an alternating current which creates a magnetic field in the coil. It is then picked up by the receiver coil which turns it back into electrical energy to charge the vehicle battery.
- 7) **Continuous Monitoring**-The system constantly checks the parking slot and charging process. In case the vehicle is absent, the sensor notices this and the system will stop charging and will change the status accordingly.

C. Key Methodologies

- **Electromagnetic Induction**
This is the main idea of wireless charging. Alternating current in the primary coil generates a magnetic field, which causes a current to flow in the secondary coil. It does not require physical connections and thus charging is safer and easier.

- **Sensor-Based Detection** The parking slot has IR sensors that automatically detect the presence of vehicles. This minimizes the workforce and enhances accuracy making the system hundred percent automated.
- **Relay-Based Switching**
An electronic switch is required to regulate the charging, which is achieved with the aid of a relay. It will make sure that the charging process only begins when a vehicle is present and it stops when the slot is empty, enhancing safety and energy efficiency.
- **Real-Time Monitoring** Parking and charging status are constantly monitored by the system. LED indicators allow giving instant updates and enable users to grasp the system status in a short period of time.
- **Microcontroller-Based Control System** The main controller of the whole system will be the Arduino Uno. It processes sensor data, drives other devices, such as LEDs and relays, and coordinates all the components appropriately. This is an approach that allows automation and rational decision-making in the system.
- **Oscillator-Based Signal Generation** The high-frequency alternating current is produced by a circuit of transistor-based oscillator. A changing magnetic field within the transmitter coil is necessary and is formed by this alternating signal. Without this, transmission of power wirelessly would not exist.
- **Energy Efficiency Optimization** The system is based on the consumption of power when needed, i.e., when a vehicle is there. The control and real-time monitoring through relay can be used to minimize unwarranted energy usage. This enhances the performance of the entire system and renders it more sustainable.

D. Technology Stack

The Technology stack has been discussed in Table 1.

IV. PROBLEM STATEMENT

The fast development of electric vehicles (EVs) has demonstrated that the existing charging and parking infrastructure has a number of shortcomings. Nevertheless, technological progress has not yet made many of the current solutions user-friendly, efficient, or completely automated. These problems make it inconvenient to users and decrease the effectiveness of EV infrastructure as a whole. The main issues covered by this project are discussed below:

A. Absence of Smart Charging Infrastructure :

The majority of current EV charging systems use the conventional plug-in connections, wherein customers are required to plug in and out charging cables by hand. This process is not only inconvenient, particularly in a public area, but also can cause cables to wear and tear as time goes by. It also poses safety hazards like electric shocks or mis-handling. The lack of wireless or automated charging systems reduces the efficiency of the entire system and makes it less user-friendly.

TABLE I

PARKING MANAGEMENT

TECHNOLOGY STACK FOR PROPOSED MODEL WIRELESS CHARGING AND

Component	Technology	Justification
Controller	Arduino Uno	The Arduino Uno works as the brain of the system. It takes input from sensors, processes the data, and controls all the outputs like LEDs and relays, ensuring everything runs smoothly and automatically.
Sensors	IR Sensors	IR sensors are used to detect whether a vehicle is present in the parking slot. They make the system smart by automatically sensing movement or obstruction without any manual effort.
Transistor	TIP122 / 2N2222	These transistors are used to build the oscillator circuit. They help generate the alternating signals needed to create a magnetic field for wireless charging.
Power Supply	9V Battery	The 9V battery provides power to all components in the system. It ensures that the Arduino, sensors, and circuits function properly.
Relay	Relay Module	The relay acts like an automatic switch. It turns the charging system ON or OFF based on the signals from the Arduino, making the system safe and energy-efficient.
Coils	Copper Coils	Copper coils play a key role in wireless power transfer. One coil sends energy by creating a magnetic field, while the other receives it and converts it into electrical energy for charging.
LED Indicators	LEDs	Used to provide real-time visual feedback to the user, such as whether a parking slot is free, occupied, or charging.
Oscillator Circuit	LC / Transistor-based Circuit	Helps generate high-frequency alternating current required for creating the magnetic field in wireless power transfer.
Voltage Regulation	Voltage Regulator	Ensures stable voltage supply to sensitive components like Arduino and sensors, protecting them from damage.
Programming Software	Arduino IDE	Used to write, compile, and upload code to the Arduino Uno for controlling the system.

B. No unified Parking Management :

Most modern systems consider parking and charging as two different systems. The first step that the users must undertake is to find a parking space and then seek a charging facility which might or might not be situated at the same point. This results in confusion, wastage of time and poor resource utilization. There should be a single system that integrates both parking and charging to make the process simple and enhance overall efficiency.

C. Inefficient User Experience:

Another significant problem is that the users have a hard time locating existing charging points. Real-time data on slot availability or charging status is not available in most systems. Consequently, users might be forced to physically scan several areas causing frustration and loss of time. This absence of visible signals or signpost decreases the ease of modern EV infrastructure that should bring.

D. Limited Automation :

A large number of current systems are still operated manually at various points, like when charging is switched on, when checking the process or when determining the slot occupancy. This does not only augment human effort but also provides the chance of errors. Lack of automation renders the system less efficient and less reliable particularly in high-demand scenarios.

On the whole, these issues demonstrate the necessity of a clever, unified, and automated system that can enhance users experience, increase efficiency, and facilitate the rising demand of EV infrastructure.

V. RESULTS AND DISCUSSION

Findings of this project demonstrate that the system is effective with the ability to integrate smart parking with wireless charging. The IR sensors are able to pick vehicle presence fast and precisely to enable the system to act in real time. When a car is spotted, the process automatically

begins to charge, which is convenient and minimizes manual work. The dual-slot is also functional, and both parking spots are independent. Regarding performance, the system has a 9V input and an output of approximately 2-5 V, and a range of 1-2 cm and an efficiency of 40-60

A. Real-Time Detection

The IR sensors keep a close eye on the parking slot and easily identify when a vehicle enters or leaves the slot. This is a rapid reaction that enables the system to respond immediately, with no time lag. All of this is automatically done and so there would not be a need to check manually and this makes it easier and more reliable. It also makes sure that the system will always display the accurate and updated position of the parking slot.

B. Efficient Charging Activation

Once a vehicle is spotted, the system will automatically initiate the charging process. The user does not have to use any cables or switch any switches, and it is smooth and hassle-free. It also saves energy and enhances safety by having only to charge when necessary. This will minimize the errors such as forgetting to start or stop charging.

C. Stable Dual-Spot Operation

The system has been developed in a manner that the two parking slots can operate simultaneously without interfering with each other. In case a vehicle is being charged, the charging process of another vehicle is not disrupted. This makes the system more viable and applicable in actual-life scenarios where a multiplicity of vehicles has to be dealt with. It also enhances the system efficiency and usability.

D. Performance

The system uses a 9V input power that is sufficient to run all the components without any difficulties. Once transferred wirelessly, it gives an output of approximately 2-5V, utilized in charging. The electric charge is only effective within a short

radius of 1-2 cm which is natural to this kind of technology. The system has approximately 40-60

E. Discussion

The system is very convenient as it operates smoothly and automatically. As soon as a car is parked, the sensors promptly identify it and the charging process begins itself without any manual operation. This eliminates the use of cables and switches. The LED indicators update users in real-time on whether the parking and charging are on or off, and they can easily interpret the indicators. Wireless charging also offers a better experience by removing physical connections, which makes the system safer and more resistant.

This solution is far easier and simpler compared to a traditional system. It saves time by automating the whole process, including detection through to charging and minimizes the necessity of manual work. The system is more efficient and does not require users to deal with cables or slot availability, particularly in busy environments.

The other significant benefit is its prospective. It can be further enhanced with the introduction of such advanced technologies as IoT, mobile applications, or AI-based optimization. This renders it adaptable, scalable and applicable to smart city applications, where efficient and intelligent charging solutions are needed.

VI. CONCLUSION AND FUTURE WORK

The offered system manages to unite the wireless charging and smart parking in a single solution and streamline the general process considerably, making it much more efficient and convenient. Wireless power transfer eliminates the physical cables and thus not only enhances safety, but also minimizes any maintenance concerns. Meanwhile, the intelligent parking system makes sure that the process of finding vehicles and charging them occurs automatically, allowing users to enjoy a comfortable and unproblematic experience. The other notable feature of this system is that it is a cheap prototype, which is practical and affordable but can also be expanded to bigger real-world models like EV charging stations, and smart city infrastructure.

In the future, this system can be enhanced and developed in a number of ways. A significant improvement would be the incorporation of IoT-based monitoring that would enable users and operators to monitor the parking availability and the charging status remotely in real-time. In addition to this, a mobile application might be created to offer functionalities such as slot booking, notifications, and system control via their smartphones. Resonant coupling methods can also be used to enhance the efficiency of wireless charging, enabling it to transfer energy over slightly longer distances. Moreover, a smart billing system should be implemented, which will automatically compute and control the cost of charging, which is more appropriate in a commercial context. Lastly, the AI-driven optimization in energy utilization may be used to control the energy consumption more efficiently, demand forecast, and enhance the overall system functionality.

On the whole, this project is not only an illustration of a working solution but a good foundation of the future innova-

tions so it is a leap towards smarter and more sophisticated EV charging systems.

REFERENCES

- [1] "Wireless Power Transfer via Strongly Coupled Magnetic Resonances," Science, 2007.
- [2] "Vehicle Detection Using Sensors," International Journal of Computer Applications (IJCA), 2015.
- [3] "Wireless Charger Design Using Tesla Coil," IEEE, 2018.
- [4] "Arduino-Based Wireless Charging System," IEEE, 2020.
- [5] "Experiments with Alternating Currents of High Potential and High Frequency," 1891.
- [6] "Wireless Power Transfer for Electric Vehicles – Standards and Applications," 2019.
- [7] "Design and Implementation of Wireless Charging System for Electric Vehicles," IEEE Transactions on Power Electronics, 2019.
- [8] "Design and Optimization of Circular Magnetic Structures for Inductive Power Transfer," IEEE Transactions, 2013.
- [9] "A Review of Wireless Power Transfer Technologies for Electric Vehicle Charging," Energies, 2018.
- [10] "Smart Parking Systems Using IoT: A Review," IJERT, 2020.
- [11] "IR Sensor-Based Smart Parking System Using Arduino," IJIRT, 2019.
- [12] "Wireless Power Transfer Research and Applications," 2017.
- [13] "Efficient Wireless Non-Radiative Mid-Range Energy Transfer," Annals of Physics, 2008.
- [14] "Wireless Power Transfer for Electric Vehicle Applications," IEEE Journal of Emerging and Selected Topics in Power Electronics, 2015.
- [15] "Magnetic Resonant Coupling as a Potential Means for Wireless Power Transfer to Multiple Small Receivers," IEEE Transactions, 2009.
- [16] "Inductive Power Transfer Systems for Electric Vehicles," IEEE, 2013.
- [17] "A Review of Wireless Power Transfer for Electric Vehicles: Prospects and Challenges," Renewable and Sustainable Energy Reviews, 2016.
- [18] "Review of Charging Power Levels and Infrastructure for Plug-in Electric Vehicles," IEEE, 2013.
- [19] "Wireless Charging of Electric Vehicles Using Magnetic Resonance Coupling," IEEE Transactions, 2014.
- [20] "An Introduction to RFID Technology," IEEE Pervasive Computing, 2006.
- [21] "Design of Smart Parking System Using Arduino and IoT," International Journal of Engineering Research, 2021.
- [22] "IoT-Based Smart Parking System," IEEE Conference, 2016.
- [23] "Plug-in Electric Vehicles: A Case Study of Smart Charging Infrastructure," Transportation Research, 2015.
- [24] "Design and Implementation of Shaped Magnetic-Resonance-Based Wireless Power Transfer System for Roadway-Powered Moving EVs," IEEE Transactions, 2014.
- [25] "Maximizing Air Gap and Efficiency of Magnetic Resonant Coupling for Wireless Power Transfer," IEEE, 2011.