IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 1, January 2026

DOI: 10.17148/IJARCCE.2026.15134

Static Wireless Charging for Electric Vehicles Using IoT

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Abstract: The recent boom in the electric vehicle (EV) industry has escalated the demand towards effective and safe electric vehicle charging solutions that are also convenient to use. The conventional wired charging systems are based on physical connectors that are vulnerable to mechanical damages, are unsafe and may be inconvenient to the drivers. We propose a solution to these shortcomings by introducing a static wireless charging system, which incorporates the Internet-of-Things (IoT) feature to monitor and control it in real-time. In our system, the inductive power transfer is used: an AC source with high-frequency is produced by using a power-electronics converter on the mains, which is fed to a transmitter coil. The alternating magnetic field is coupled to a receiver coil on the EV to induce an AC voltage which is then rectified, filtered and regulated to offer a constant DC supply to charge the batteries. An embedded Wi-Fi/BLE chip and microcontroller allow nonstop monitoring of such vital parameters as charging voltage, current, temperature, and status to a cloud-based dashboard, which contributes to a higher level of safety, diagnostics, and user experience. A prototype was also made and tested under stationary conditions. On-hand experimental findings provide credible transfer of power over a small air gap, with the preservation of output voltage and successful battery charging. The concept of real-time monitoring of IoT was found to be effective in delivering real-time data about the performance of the charging process and allowing faults to be identified remotely. The proposed design will save wear and tear on connectors, eradicate cable risks and increase the general convenience of the system in comparison to the standard wired system.The results of this research allow recognizing the possibility of combining the technique of charging an electric vehicle in place with the IoT-based monitoring system and positioning it as an attractive element of the following smart and automated charging systems.

Keywords: IoT, Electric vehicles, Wireless charging, Static charging, Wireless Power Transmission (WPT), Magnetic field

I. INTRODUCTION

The global push toward clean energy has accelerated the adoption of electric vehicles (EVs), which promise lower emissions, higher energy efficiency, and reduced running costs. Yet, widespread EV deployment is still constrained by the need for reliable, convenient charging infrastructure. Conventional wired charging relies on physical connectors that are vulnerable to mechanical wear, harsh environmental conditions, and safety hazards such as electric shock or short-circuits. Wireless power transfer (WPT) offers a compelling alternative by eliminating physical contact between charger and vehicle. Inductive-coupling static WPT, in particular, is well suited to stationary charging scenarios—parking lots, garages, and smart-home environments—thanks to its simplicity, robustness, and proven track record in EV applications.

In this study we design and implement a static inductive WPT system integrated with Internet-of-Things (IoT) technology. The transmitter generates a high-frequency alternating magnetic field that induces voltage in a receiver coil mounted on the vehicle. The induced power is rectified, regulated, and fed into the EV battery. IoT connectivity enables real-time monitoring of key parameters (current, voltage, temperature, power transfer efficiency), remote fault detection, and detailed performance analytics. The proposed system enhances charging safety, improves reliability, and supports intelligent energy management. By demonstrating the feasibility of combining wireless charging with IoT, this work contributes to the development of next-generation smart EV charging infrastructure and lays groundwork for future electric-mobility solutions.

II. LITERATURE SURVEY

Electric vehicles are used more nowadays due to a raising in usage of fuels and people are more concerned towards the environment. Charging plays very important role in electric vehicles but wired charging causes many problems that led to a variant wear and tear issues and safety risk while we plug in. To avoid this issue, wireless charging system is designed with a concern of safety and bit low maintenance [1][2].

Electric vehicles charging systems via wireless charging can be largely classified as either Static or Dynamic. Under a static charging of wireless charging, the vehicle is stationary when undergoing charging whereas in dynamic the vehicle is charged as it moves. The interest of many researchers on the topic of static wireless charging systems is due to their structure and implementation rather than dynamic charging systems, which have complex road infrastructure. Therefore, static charging should be working at the prototype level and at the small-scale applications of electric vehicles [3].

Inductive coupling between a transmitter and a receiver coil is typically used in static wireless charging. The transmitting coil is placed on the ground and the receiving one on the vehicle. This transmission takes place an alternating magnetic field that is generated by the transmitting coil. Various methods have been examined by the researchers to enhance efficiency in power transfer. It is discovered that effective design of compensation can be used to sustain resonance and minimize power losses within the system [4].

Coil misalignment is one of the most significant technical issues that have been reported in the case of static wireless charging system. Once a car is not placed properly over a charging pad, the connection between the coils is less, and it results in a lower efficiency and unbalanced power transmission. There are studies that have recommended better coil structure and tuning techniques to enhance the tolerance to misalignment, although loss of efficiency is yet to be fully removed. This demonstrates that it is essential to monitor and control the conditions of the charging to ensure proper operation [5]. Besides the problems related to efficiency, one should also note the issue of safety in the wireless charging systems. In a number of works, magnetic field leakage and electromagnetic interference with the devices in the immediate vicinity have been addressed. Scientists indicate that the effects can be minimized with the aid of effective coil design and shielding methods and enhance the safety of the systems. Despite these issues, the benefits of using a static wireless charging include less maintenance and better safety to users than using the traditional wired charging [6].

IoT technology has also been used recently in the electric vehicle charging system to enhance monitoring and control. The IoT systems enables real-time battery voltage, current, and charging status monitoring through the cloud platform or mobile apps. Thus, the current research is aimed at creating a workable static wireless charging system based on the IoT to offer safe charging services with real-time monitoring and interaction with the user [7].

III. PROPOSED METHODOLOGY

The proposed work presents the development of a static wireless charging framework for electric vehicles integrated with IoT technology. In this approach, the vehicle receives power wirelessly while positioned over a charging pad, eliminating the need for physical charging cables and thereby enhancing operational safety and user convenience [9].

Wireless energy transfer in the system is achieved through inductive coupling. When high-frequency alternating current is applied to the transmitter coil embedded in the charging pad, an electromagnetic field is generated. This field induces an electrical voltage in the receiver coil mounted beneath the electric vehicle, enabling contactless power transfer [9].

The transmitter section is composed of a regulated power source, an inverter unit, and a primary coil. The inverter converts the supplied power into high-frequency alternating current, which is essential for producing the magnetic field required for efficient wireless charging [9]. Careful consideration is given to coil positioning and alignment to improve overall power transfer efficiency [9].

The receiver section comprises a secondary coil along with rectification and voltage regulation circuits. The induced alternating voltage is converted into direct current and regulated to appropriate levels before being supplied to the vehicle battery [9]. The influence of air gap distance and coil misalignment on charging performance is also evaluated [9].

To enhance system intelligence, IoT capabilities are incorporated into the charging architecture. Electrical parameters such as voltage, current, and charging state are continuously sensed using appropriate sensors. A microcontroller processes this data and transmits it to a cloud platform through wireless communication technologies [8].

Through IoT integration, real-time charging information can be accessed remotely using a web or mobile interface. This enables effective monitoring of charging progress, early fault identification, and improved user experience without the

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need for physical supervision [8]. Additionally, the system includes essential safety mechanisms such as over-current and over-voltage protection. Upon detection of abnormal operating conditions or improper alignment, the charging operation is automatically interrupted, and alert notifications are generated through the IoT platform [8].

The performance of the proposed system is assessed using parameters including power transfer efficiency, charging duration, tolerance to misalignment, and reliability of IoT-based monitoring. The evaluation demonstrates that the integration of wireless charging with IoT results in a dependable and user-friendly solution for static electric vehicle charging applications [8][9].

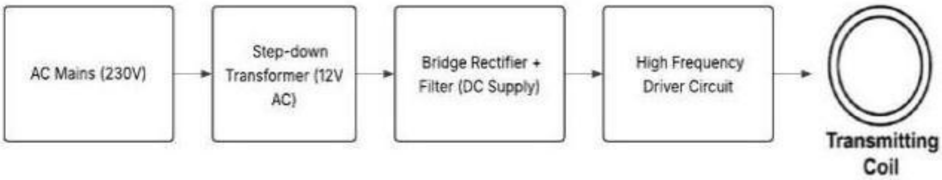

Fig 1. Transmitter Diagram

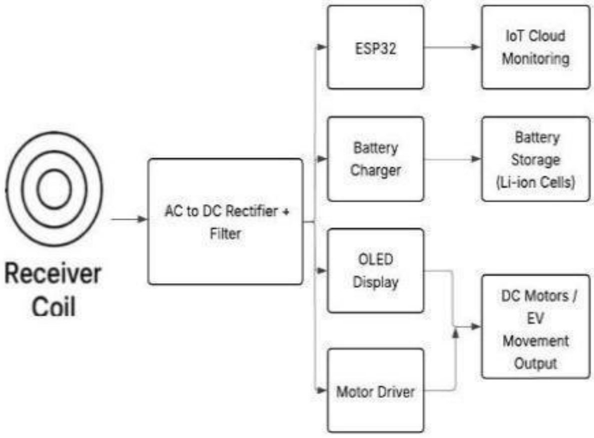

Fig 2. Receiver Diagram

The proposed approach presents a wireless electric vehicle charging system integrated with IoT-based monitoring. At the transmitting unit, the AC supply from the mains is reduced, converted into DC, and then transformed into a high-frequency alternating signal to excite the transmitter coil, thereby generating a magnetic field for contactless power transfer. At the receiving unit, the induced electrical energy is conditioned through rectification and voltage regulation to facilitate Li-ion battery charging. An ESP32 microcontroller continuously supervises battery-related parameters and presents the system status on an OLED display, while simultaneously transmitting the data to the Blynk IoT cloud platform for remote access. The accumulated energy is utilized to operate DC motors, emulating vehicle motion, which confirms the suitability of the system for intelligent and contactless EV charging applications.

A. EXPERIMENTAL HARDWARE SETUP

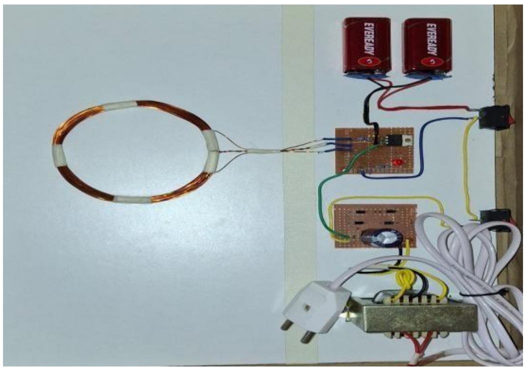

Fig 3. Transmitter Unit

Fig 4. Receiver Unit

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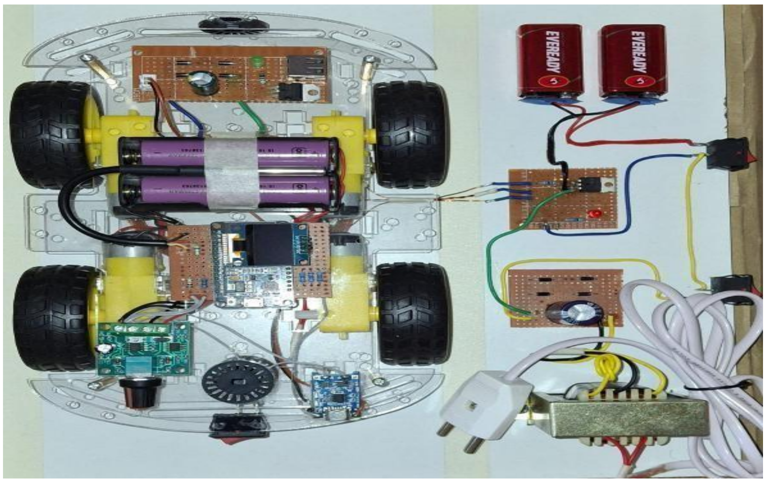

Fig 5. Prototype Model

Transmitter Unit
As depicted in Fig. 3, the transmitter section operates from a standard 230 V AC utility supply, which is reduced to 12 V AC using a step-down transformer. The stepped-down voltage is then converted into a DC signal through a bridge rectification stage followed by a filtering circuit, ensuring a smooth and regulated DC output. This DC supply is applied to a high-frequency driver module, which generates a high-frequency alternating current required for wireless power transmission.
The generated high-frequency current energizes the transmitting coil, resulting in the formation of a time-varying magnetic field. This magnetic field acts as the transmission medium, enabling contactless energy transfer to the receiver coil through inductive coupling.

Receiver Unit
The receiver subsystem, shown in Fig. 4, comprises a receiving coil, power conditioning circuitry, a battery charging module, and an ESP32-based monitoring and control unit. The alternating magnetic field produced by the transmitter induces an AC voltage across the receiver coil terminals. This induced voltage is converted into DC using a rectifier and filtering stage and subsequently regulated to a constant 5 V DC.
The regulated output is utilized for charging a Li-ion battery pack, where the received energy is stored. The stored electrical energy is further supplied to a motor driver circuit that operates DC motors, representing the motion of an electric vehicle. The ESP32 microcontroller continuously acquires battery voltage, charging current, and system status.
These parameters are displayed locally on an OLED screen and transmitted to a remote IoT cloud platform (Blynk), enabling real-time monitoring and data visualization.

Mathematical Modelling of Wireless Power Transfer
The operation of the proposed wireless charging system is fundamentally based on electromagnetic inductive coupling between the transmitting and receiving coils.

1. Mutual Inductance
The degree of coupling between the coils is characterized by their mutual inductance, which depends on the coupling coefficient and the self-inductances of the respective coils.

$$M = k\sqrt{L_1 L_2}$$

2. Induced Voltage at the Receiver
In accordance with Faraday's law of electromagnetic induction, the alternating magnetic field generated
by the transmitter induces a voltage in the receiver coil. The magnitude of this induced voltage is influenced by the operating frequency, mutual inductance, and transmitter coil current.

$$V_2 = j\omega M I_1$$

3. Power Delivered to the Load
The electrical power available at the receiver side is determined by the induced voltage and the equivalent load resistance connected to the receiver circuit.

DOI: 10.17148/IJARCCE.2026.15134

$$P_{out} = \frac{V_2^2}{R_L}$$

4. **Wireless Power Transfer Efficiency**

The efficiency of the wireless power transfer process is evaluated as the ratio of the power delivered to the receiver load to the power supplied at the transmitter input.

$$\eta = \frac{P_{out}}{P_{in}} \times 100$$

5. **Battery Charging Power**

The charging power of the battery is computed as the product of the charging voltage and charging current supplied by the receiver circuitry.

$$P_{bat} = V_{bat} \times I_{bat}$$

Prototype Implementation

The complete hardware prototype, illustrated in Fig.5, integrates both the transmitter and receiver units to experimentally verify the proposed wireless charging architecture. Accurate positioning and alignment of the transmitting and receiving coils facilitate efficient inductive coupling and stable power transfer. The prototype successfully demonstrates wireless energy transmission, secure battery charging, motor actuation, and real-time system monitoring through both on-device display and IoT-based cloud connectivity.

Major Hardware Components

1. **ESP32 Microcontroller:**

The ESP32 functions as the primary control unit of the proposed system. It acquires charging-related parameters including voltage, current, and battery condition, and communicates the collected data to the IoT cloud using its integrated Wi-Fi capability.

2. **Transmitting Coil with High-Frequency Driver:**

A transmitting coil powered by a high-frequency driver circuit is employed to produce an alternating magnetic field on the charging pad. This magnetic field forms the basis for contactless power transfer.

3. **Receiving Coil:**

The receiving coil is mounted underneath the electric vehicle structure. It intercepts the magnetic field generated by the transmitting coil and converts it into an induced alternating voltage.

4. **Rectifier and Filter Circuit:**

The alternating voltage obtained from the receiving coil is converted into direct current through a rectifier circuit. A filtering stage is included to provide a smooth and regulated DC output suitable for battery charging.

5. **Battery Charging Module with Lithium-Ion Battery:**

The battery charging module manages the charging process by controlling the voltage and current supplied to the lithium-ion battery. This ensures safe energy storage and stable system operation.

6. **Voltage and Current Sensors with Display:**

Voltage and current sensing units are integrated to continuously track charging conditions. The measured values are presented on an OLED display, enabling real-time monitoring by the user.

Software Components

1. **Arduino IDE:**

The Arduino Integrated Development Environment (IDE) facilitates the development, compilation, and uploading of the control program to the ESP32 microcontroller. It also enables serial monitoring, which assists in system testing and debugging.

2. **Embedded Firmware (ESP32):**

The firmware deployed on the ESP32 microcontroller governs sensor data acquisition, charging control algorithms, and communication with the IoT platform. It continuously tracks parameters such as voltage, current, and battery condition throughout the wireless charging operation.

3. **Blynk IoT Platform:**

The Blynk platform enables remote supervision of the wireless charging system, offering real-time visualization of

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operational parameters and system status via a mobile application.

Algorithm
1: Start.
2: Initialize ESP32, Wi-Fi connection, Blynk server, OLED display, DS18B20 temperature sensor, and charging status pin.
3: While system is ON, repeat:
3.1 : Read battery voltage from ADC and compute actual battery voltage
3.2 : Calculate battery percentage from measured voltage.
3.3 : Read temperature from DS18B20 sensor.
3.4 : Read charging status from TP4056 module.
3.5 : Display voltage, battery percentage, temperature, and charging status on OLED.
3.6 : Transmit all measured parameters to Blynk cloud. 4: Wait for a fixed delay.
5: Go to Step 3.
6: Stop.

IV. RESULTS AND DISCUSSIONS

This section is focused on testing and the analysis of the functionality of the proposed IoT-enabled stationary electric vehicle wireless charging system. The findings are discussed through real-time data of the prototype which we constructed where the ability to transfer power wirelessly, the behaviour of the charging system, the efficiency of the system, thermal safety, and the monitoring of the system in an IoT manner are considered. The results of the observed experiments indicate that in fact, this practice is feasible in the circumstances of the static alignment and provides us with a good idea of the degree of this method reliability and the areas where we can optimize it in the future.

A. Testing Methodology
The experimentally confirmed IoT-enabled electric vehicle static wireless charging system is a small-scale prototype that was tested in the lab. The testing highlighted the performance of charging, efficiency of systems, thermal safety and real-time monitoring. The transmitter was driven off a 230 V AC source, which we reduced and regulated to drive the transmitting coil, but the receiver coil remained at a constant air gap to transfer wireless power. The main electrical parameters that were measured using the IoT sensors included receiver-side output voltage, charging status, and temperature and displayed on a real-time monitoring dashboard.

B. Performance Matrices
In order to assess the static wireless EV charging system, we considered the following important parameters: receiver output voltage (V_2), system efficiency (η), accuracy of changing state, thermal stability (T), and reliability of the IoT monitoring. V_2 of the DC voltage that actually enters the battery following the wireless transfer is denoted V out, and the efficiency of the wireless transfer is denoted η. Properly charged status ensures it is properly charging, thermal stability is used to ensure that it is safe and a proper IoT monitor will ensure that we are always updated on the dashboard. A combination of these measures can help us to evaluate the feasibility and reliability of the offered system.

C. Experimental Results
The experiments revealed that the wireless transfer of power was alright and the system operated continuously. The coil on the transmitter circuit had generated an alternating magnetic field when we energized the transmitter circuit, which the receiver coil picked up without any actual electrical connection.
The system took a 230 V AC input which we reduced and regulated to about 14-15 V DC at the transmitter end. We were able to measure a DC output of approximately 4.08 V on the receiver end- it was just enough to charge the onboard battery with the charging module.
Combine all efficiencies at 36% and 48% which is consistent with our expectations of air-core resonant prototypes on a short distance basis. This proves the fact that the inductive coupling is under the condition of statical alignment.
The process of battery charging was successful, and the state of charging was properly shown on the dashboard provided by the IoT. In the active transfer, the dashboard read Charging On, and when the battery was fully charged, it changed to Charging Off, which indicated that the control logic and sensors used in the system are sound.
Thermal analysis showed that the temperature maintained a range of 26-30°C during the charging process no overheating or anomalous spikes, which demonstrated that the coils, power electronics, and control circuitry are safe and stable.

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D. IoT monitoring and system demonstration

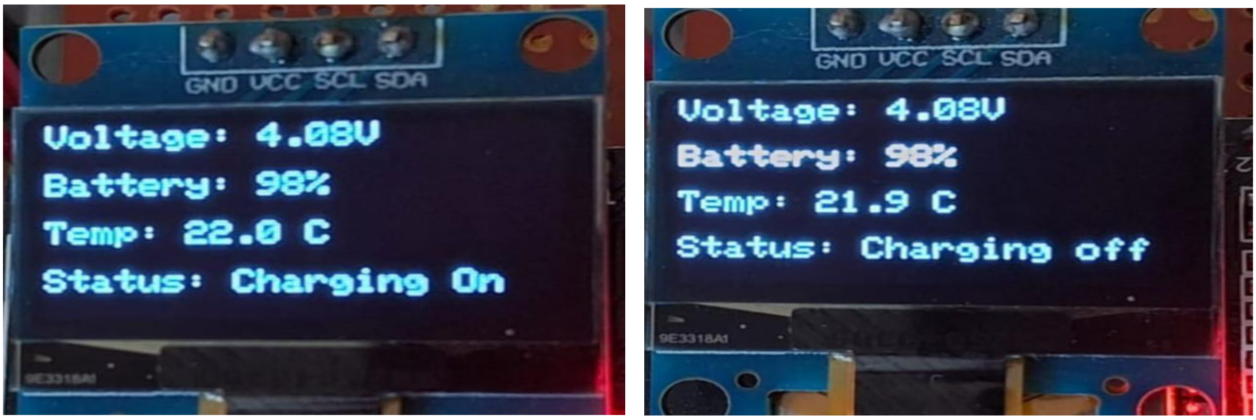

Fig 6. OLED Display

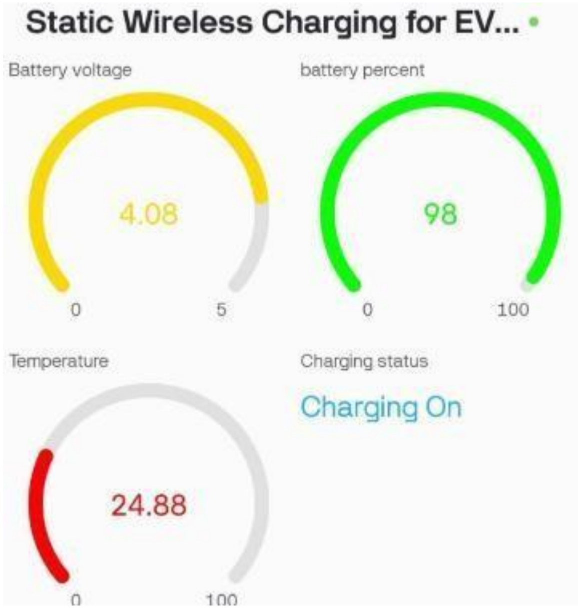

Fig 7. Real Time Data Monitoring through Blynk Dashboard

The IoT-based monitoring system enabled us to view the important charging parameters in real-time through a web-based dashboard. We monitored battery voltage, battery percentage, system temperature and charging state.
Throughout the demo, the dashboard continued to show the voltage at approximately 4.08 V, and the battery percentage increased to approximately 98% indicating that the charging process was almost complete. The temperature was maintained at 28.8º C, which is in the range of safety. The charging status display changed dynamically as the system responded, and thus the users could easily be informed.
Overall, the live monitoring demonstrates that this system may be practical in the context of smart EV charging infrastructure which would provide the stakeholders with remote control, detecting faults, and enhanced user interaction.

V. CONCLUSION

This project introduced the design, implementation, and experimental analysis of IoT-based wireless charging system in electric vehicle of a static system. An electrical prototype was constructed in the lab on a small scale to couple electrical power wirelessly between a transmitter coil and a receiver coil through electromagnetic induction, eliminating the necessity of having physical charging plugs. It was operated off a standard AC outlet and reduced to the right DC level and used to charge a battery resting on the receiver side in the unstirred position. Experiments revealed constant wireless power transfer, harmless heat levels and consistent battery charging. Also, we connected an IoT-based monitoring interface to display live values of such parameters as voltage, temperature, and the charging state, allowing us to remotely monitor the entire setup. The findings effectively demonstrate that the system is functional and indicates an easy, intelligent way to have future statical wireless EV charging.

VI. FUTURE SCOPE

With a few finer adjustments of the coil layout and the resonance, and improved shielding to enhance power transfer efficiency, we can improve the performance of our static wireless EV charging system even further. This could as well be extended to support power requirements of full-size electric cars. It would be smarter with the addition of advanced IoT features, such as predictive analytics, fault detection, and cloud data management. In the future, we could consider a dynamic system of wireless charging when EVs will be charged as long as they are traveling on roads with specially designed systems. That would reduce the dependence on fixed charging stations and allow drivers to continue charging during travel, increase range and reduce downtimes. Introduction of automated alignment, V2I communication, and real-time adaptive power control may increase both the dynamic and the static efficiency. Studies on the hybrid systems, to integrate both the fixed and dynamic wireless charging could result in the deployment of EV in a more flexible, convenient, and commercially viable way in the future.

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