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Designing an Effective Method for Automatic Electric Vehicle Charging Stations in a Static Environment

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Abstract

This article outlines an Effective Method for Automatic Electric Vehicle Charging Stations in a Static Environment. It consists of investigated wireless transformer structures with various ferrite forms. WPT technology has rapidly advanced in the last few years. At kilowatt power levels, the transmission distance grows from a few millimeters to several hundred millimeters with a grid to load efficiency greater than 90%. The improvements have made the WPT more appealing for electric vehicle (EV) charging applications in both static and dynamic charging scenarios. Static and dynamic WEVCS, two of the main applications, are described, and current developments with features from research facilities, academic institutions, and businesses are noted. Additionally, forthcoming concepts based WEVCS are analyzed and examined, including "dynamic" wireless charging systems (WCS). A dynamic wireless power transfer (DWPT) system, which can supply electricity to moving EVs, is one of the feasible alternatives. The moving secondary coil is part of the dynamic WPT system, which also comprises of many fixed groundside (primary) coils. An equivalent circuit between the stationary system and the dynamic WPT system that results from the stationary system is demonstrated by theoretical investigations. The dynamic WPT system's solenoid coils outperform circular coils in terms of flux distribution and misalignment. The WPT-related EV wireless charging technologies were examined in this study. WPT can assist EVs in overcoming their restrictions on cost, range, and charging time.

Keywords

Dynamic Wireless Power Transfer (DWPT), Wireless Charging System

(WCS), Electric Vehicle (EV), Dynamic Performance

1. Introduction

In high power applications such as electric vehicles (EVs) and plug-in electric vehicles (PEVs) in stationary applications, wireless charging systems (WCS) have been proposed. Figure 1 depicts the fundamental block diagram of an electric vehicle static wireless charging system. Nevertheless, our nation is witnessing a surge in the utilization of static wireless power transfer using a probe, as depicted in Figure 2. WCS can offer greater benefits in terms of ease of use, dependability, and simplicity when compared to plug-in charging solutions. With the advent of wireless charging for electric vehicles (EVs), the way we power our cars is evolving. Rather than plugging in a charging cable, electric vehicles that use wireless charging can just park their batteries over a coil or specific charging pad to replenish their batteries. The drawback or restriction of WCS is that they can only be used in stationary or parked modes, like in parking lots, garages, or at traffic lights. A few more difficulties for stationary WCS include limited power transfer, large constructions, lower range, higher efficiency, and electromagnetic compatibility (EMC) concerns [1]. In the United States (U.S.), the transportation industry is the main source of greenhouse gas emissions. About 29% of the nation's overall energy consumption in 2018 came from this sector, with 92% of it directly attributable to fossil fuels [2]. The benefits of DWPT show that the control strategy using a dc/dc converter on the receiving side of a WPT system is appropriate for high power, high reliability requirement applications, such as the contactless power supply for electric vehicles or railroads. However, as depicted in Figure 3, this approach cascades the dc/dc converter with the WPT resonant component, which consists of compensation networks, coupling coils, and high frequency converters [3]. Research has been done on the dynamic mode of operation of the WCS for EVs in order to enhance the two areas of sufficient volume of battery storage and range. Battery storage devices can be charged

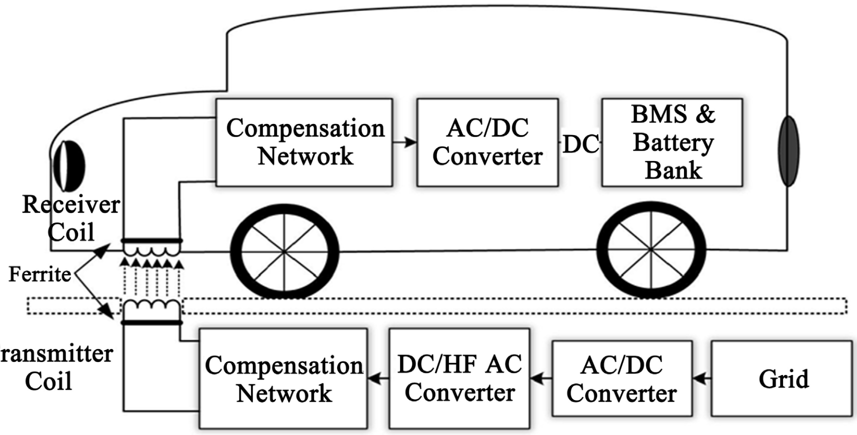

Figure 1. Basic block diagram of static wireless charging system for EVs.

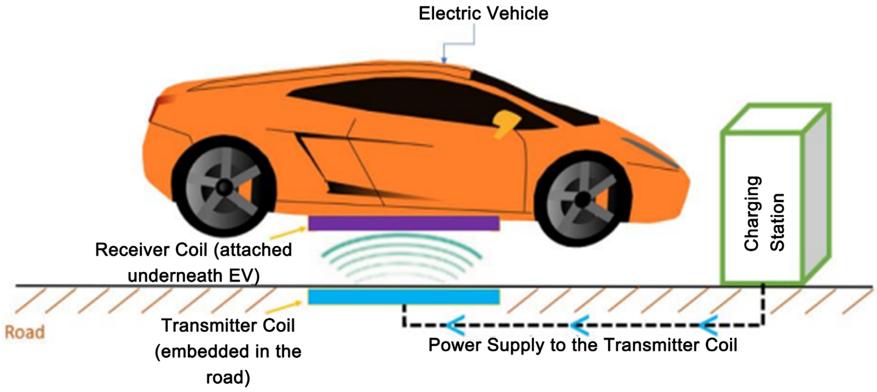

Figure 2. Use of static wireless power transfer using a probe in our country.

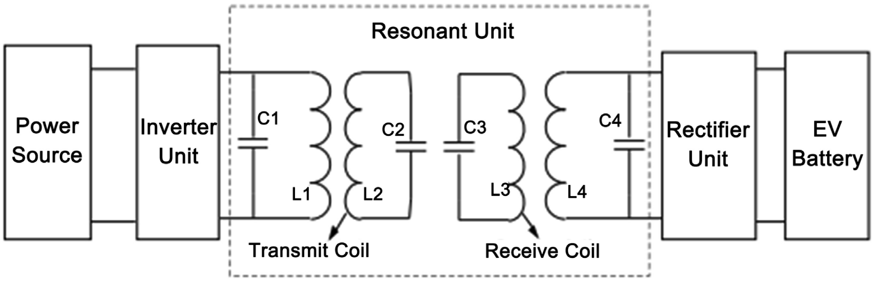

Figure 3. Typical WPT system topology with a DC-DC converter in the receiving side.

using this technique even when the car is moving. The vehicle's transportation range is extended and requires less costly battery storage. But before becoming widely used, a dynamic WCS must overcome two major obstacles: a huge air gap and coil misalignment. The air gap between the source and the receiver as well as the coil alignment affects power transmission efficiency. For compact passenger cars, the average air-gap distance ranges from 150 to 300 mm; for larger cars, it may go up. Because the vehicle is driven automatically in the dynamic mode, aligning the transmitter coil at the ideal driving position is simple. Furthermore, in order to minimize parasitic losses and enhance system performance, several compensation techniques—such as series and parallel combinations—are used on both the transmitting and receiving ends.

2. Literature Review

In article [1], the possibility of wireless electric vehicle charging systems (WEVCS) as an approachable way to encourage electrified mobility, reduce greenhouse gas emissions, and deal with growing gas prices is examined. Wireless transformer structures and the related health and safety issues that are in line with international standards. It also covers current wireless power transfer methods.

The authors of this paper [2], suggest a sequential two-level planning strategy, in order to take into account, the goals of both the BEV users and the public infrastructure planning agency. Overall system net energy consumption and overall system travel time are two distinct planners' objectives that are taken into consideration.

In article [3], the authors proposed to control the system impedance properties, which can reduce interaction and boost the efficiency of the dynamic system. Results from experiments and small-signal analyses show that the proposed technique is appropriate for various operating situations and offers faster response times and less overshoot than traditional PI control.

The authors of this paper [4], propose an intelligent WPT system for EVs with automatic coil alignment using a fingerprint method is investigated and simulated. The system optimizes energy utilization and lowers electricity costs by minimizing human mistake, saving time, and autonomously initiating charging during off-peak hours.

In article [5], the study presents a system design optimization tool that uses driving data, vehicle attributes, and wireless charger features to improve WCI in automated mobility districts (AMDs). The program finds the best design parameters by using a multi-objective optimization layer and using predefined objectives and constraints.

The authors of this paper [6], in order to encourage the widespread adoption of electric cars (EVs), this study examines the critical role that EVs play in reaching sustainable energy goals and emphasizes the necessity of growing DC fast-charging networks.

The authors of this paper [7] have proposed the presentation of a cutting-edge dynamic wireless charging technology based on magnetic coupled resonant power transfer. This charging system's transmitting coil has a selectable on/off switch that allows charging while driving. Research is being done to better the transmitting and receiving coil structures. Additionally, the proposed grouped periodic series spiral coupler (GPSSC), a dispersed coupling structure, is explained along with its properties.

In article [8], the authors proposed a novel MOD (Metal Object Detection) strategy based on multi-thread sensing coils is put forth. First, a simulation is used to analyze and validate the basic operation of the standard even sensing coil, as well as its restriction on position-dependent detection sensitivity.

The authors of this paper [9], In order to control power fluctuation, a segmented dynamic wireless charging system (DWCS) based on double transmitting coils and a T-type compensation network is given. Add switches in series with the transmitting coils to eliminate cross coupling effects. The parameters of the T-type network are designed using a genetic algorithm-based multi-object optimization for the reactive component and the power fluctuation factor.

In article [10], the authors proposed a comparison of various coil systems, including Single Input Single Output (SISO), Parallel Multi Input Single Output (P-MISO), and Controlled Parallel Multi Input Single Output (CP-MISO) coils systems. An intriguing way to attain a broader and more flexible charging area is through multi-coil systems.

The authors of this paper [11], proposed reviews commercial systems and experimental prototypes, concentrating mainly on the developments in high-power wireless charging systems. Challenges that are anticipated include the use of sophisticated materials, measuring and mitigating electric and electromagnetic fields, customizing, communicating, power metering, and cybersecurity.

In article [12], the authors proposed a research, thorough investigation is carried out to clarify the limitations of actual driving circumstances and to suggest a solution that could address the misalignment issue and the dynamics imposed by the charging process and by EVs travelling over road-embedded charging pads. With the use of simulations and experiments, the generalized state space averaging method is used to simulate the dynamic wireless charger's fundamental component.

In article [13], this research presents a unique multicopying LCC-compensated solution for addressing power fluctuations in an EVDWC (Electric Vehicle Dynamic Wireless Charging) system. The technique makes use of a three-coupling integrated magnetic coupler. The first coupling connects the main coils, whereas the second and third couplings, between the primary and secondary compensation inductor coils, respectively, utilize compensation inductor coils embedded into the main coils. Cross-couplings and parameter-matching criteria are taken into account during the design phase.

In article [14], this study offers a flexible multi-transmitter coupling system that makes use of an auxiliary switch and a hexagonal array coil. A mutual inductance model is used to evaluate coupling behavior during misalignment. For the best coil mode activation, a unique primary current-based control strategy is proposed. Results from experiments support the notion. This approach displays robustness under various misalignment circumstances and considerably improves transmission efficiency at the coil border as compared to circular and square arrays.

In article [15], Dynamic Wireless Power Transfer (DWPT) solves the problem of recharging the batteries of electric vehicles (EVs) while they are moving. This idea is demonstrated by a cutting-edge electric bus charging system at Utah State University that makes use of a grouped-coil architecture. The two methods are compared in this research; one makes use of Wi-Fi technology, and the other of Dedicated Short-Range Communication (DSRC) technology.

In article [16], electricity can be transmitted wirelessly (WPT), with Magnetic Resonant Coupling (MRC) serving as a crucial method. MRC provides secure, effective long-distance power transfer, and uses include wireless EV charging. The MRC WPT, EV wireless charging (static and dynamic), system design, prototypes, impedance matching, and international standards are all covered in this review. Also covered are coil design, efficiency, and continuing research.

The author of this paper [17], address the main obstacles to the widespread adoption of electric vehicles (EVs), specifically range constraints and charging times, by concentrating on the development of Inductive Power Transfer (IPT) for EV charging.

The author of this paper [18], address this issue. Long-haul trucks present a challenge to climate agreements because of their heavy reliance on fossil fuels, even as the use of passenger electric vehicles rises. The study presents an approach to electrical infrastructure design that enables trucks and passenger cars on highways to be charged both statically and dynamically.

3. Methodology

The Arduino UNO plays a major role in this project. Well, let's discuss about the Arduino UNO's operating system. **Figure 4**, Developed by Arduino CC, the Arduino Uno is an open-source microcontroller board that was first made available in 2010 [12]. The Microchip ATmega328P microcontroller serves as its foundation. The digital and analogue input/output pin sets on the board allow for communication with a variety of expansion boards and other devices. There is virtually little functionality on the Arduino platform. For its work, it mostly uses three items:

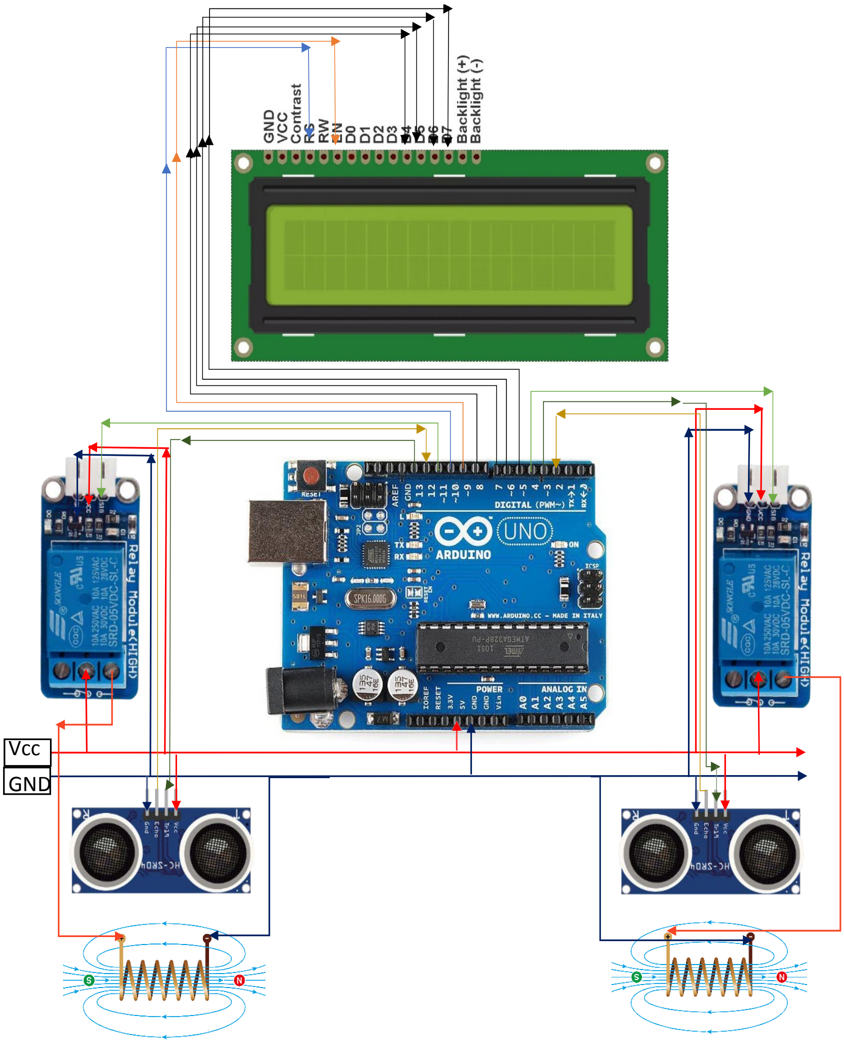

Figure 4. Circuit diagram of WPT system.

- Sources of information: Sensors and switches that supply data to the controller are connected to it. For these, the phrase "inputs" might refer to a variety of signals, such as telecommunication signals, variable voltage signals, or on/off signals [11] [12].
- Programming: The board has been configured to take into account suggestions and make decisions based on the information it receives. Programming can be as simple as turning on lights when a switch is flipped, or it can be as complex as sending meteorological data to a web browser. You can use the Arduino IDE, VS Code, or Python to program certain boards.
- Outputs: Lastly, the output is the signal that an Arduino sends to a component. The output, like the input, can also be an on/off, variable voltage, or communication signal.

Solar Power System: Using photovoltaics (PV) or concentrated solar power, solar energy can be converted directly into electrical power or indirectly. Light is converted into an electric current by photovoltaic cells using the photovoltaic effect. Concentrated solar power systems, commonly utilized to power a steam turbine, concentrate a wide area of sunlight into a hot spot [12] [13].

Wireless power transfer is based on the same inductive power transfer theory as conventional transformers. In order to facilitate coupling, the two coils of a transformer are surrounded by ferrite material and are very close to one another; inductive chargers, on the other hand, have an air gap between the coils. Throughout the procedure, the following actions are taken:

- The transmitter circuit sends the high-frequency AC current to the coil. Alternating current is created by converting the mains voltage, ideally to high-frequency AC.
- The induced magnetic field causes a current to flow through the adjacent receiver coil.
- The transmitter coil creates a magnetic field as a result of the AC.

The source and receiver coils are equipped with resonators that operate at the same frequency to guarantee magnetic coupling and boost the effectiveness of energy transfer. This means that there is no need for connections made of metal or other materials when electricity is transferred over an air gap [10] [11] [13]. The resonance frequencies of the receiving coil and the transmitter must coincide for this to happen. The generated AC is converted to direct current so that the battery can be charged. As long as the two objects are close enough to resonate at the same frequency, power transmission can still occur. This eliminates the need for perfect alignment. Between the two components, resonant repeaters are added to provide larger power transmission distances.

4. Experimental Verification

Multiple power sources, such as solar, electric, and battery power, may be used in this article. Essentially, our power supply consisted of five volts. This project is based on automated electricity transfer systems. Our power plant has the capacity to simultaneously charge two electric cars [13] [14].

Consequently, we employed two ultrasonic sensors and two relays to recognize and turn on the electric cars. We employed the Arduino UNO R3 microcontroller. For system control, we employed pins 2 through 13. Upon receiving a triggered input for Slot 1, Ultrasonic transmits its received output (Echo) to Pin-13 from pin-12. A pin-11 input is received by the relay. In Slot 1, Ultrasonic receives a triggered input from Pin 2 and transmits its received output (Echo) to Pin 3. Relay receives an input from pin 4. (10, 9, 8, 7, 6, 5) is where display obtains (rs, en, d4, d5, d6, d7). This Arduino UNO R3 is used to operate the entire system via these pins.

When an electric car approaches our station, our vehicle detector (ultrasonic sensor) uses electromagnetic waves to send and receive signals (Trig Pin and Echo Pin). Our relay will only transmit this once it learns that a car has arrived for charging. After it has passed through the relay and been received, the power will be transmitted via the Tesla coil (Sender). Currently you can charge the electric car. The Tesla Coil (Receiver) can currently be used to charge an electric vehicle. Dynamic positioning and alignment algorithms are crucial for guaranteeing effective power transmission in DWPT systems with movable components, such cars or drones [14] [15].

5. Hardware Implementation (Figure 5 & Figure 6)

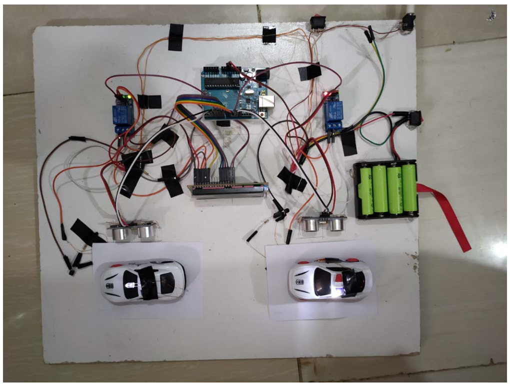

Figure 5. Project top view.

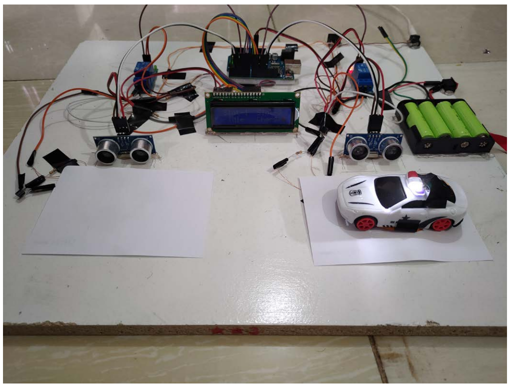

Figure 6. Project down view.

System Description of Hardware Implementation

- The Arduino Uno board can be built with power pins, analog pins, ATmegs328, ICSP header, reset button, power LED, digital pins, test led 13, TX/RX pins, USB interface, and an external power supply. **Figure 7**, a USB cable or an external power source can be used to power the Arduino Uno. (parameters) 7 to 12 volts is the recommended voltage range [14] [16].
- The 14 digital pins on the Arduino Uno can be used as input & output with the help of the functions like pin Mode (), digital Write(), & Digital Read( ).
- Memory The memory of this Atmega328 Arduino microcontroller includes flash memory-32 KB for storing code, SRAM-2 KB EEPROM-1 KB.
- **Figure 8** shows that the main characteristic of LCDs is that the liquid crystal molecule tends to untwist when an electrical current is given to it. This alters the angle at which light enters the polarized glass molecule and modifies the angle of the top polarizing filter [15].
- The operation of an ultrasonic sensor is essentially the same as that of a sonar or radar, which assesses target or object properties by interpreting the echoes of sound or radio waves that are received in a corresponding manner, **Figure 9** depicts [16] [17].
- **Figure 10**, the electromagnetic induction theory underlies the operation of relays. A magnetic field is created around the electromagnet when current is applied to it. The relay in action is seen in the above image. DC current is applied to the load through a switch [16] [17].
- **Figure 11** describes The Tesla coil works based on achieving a phenomenon known as resonance. To optimize the amount of energy transmitted into the secondary coil, this occurs when the main coil fires current into it at precisely the appropriate moment [16].

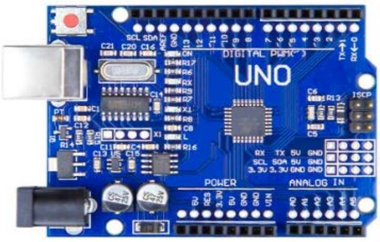

Figure 7. Arduino UNO R3.

Figure 8. LCD display.

Figure 9. Ultra-sonic sensor.

Figure 10. Relay (5 volt).

Figure 11. Mini Tesla coil.

- **Figure 12**, Solar panel, the photovoltaic cells within a solar panel absorb solar radiation when it is exposed to sunlight. Electricity flows as a result of this energy's creation of electrical charges that move in response to the cell's internal electrical field.
- **Figure 13**, a battery system needs to store energy. In a car, a battery-assistance battery-powered ignition system is used to ignite the spark plug. It is typically utilized in four-wheel drive vehicles, although these days it is also used in two-wheel drive vehicles that have an ignition coil powered by a 6- or 12-volt battery [17] [18].
- **Figure 14**, Jumper wires are wires having connector pins on either end that can be used to join two places together without the need for solder.
- **Figure 15** Energy Source is an input voltage, usually AC (alternating current), is converted into a regulated 5V DC (direct current) output by a DC 5V power supply [18].

Figure 12. Solar panel.

Figure 13. Battery.

Figure 14. Jumper wires.

Figure 15. Energy source.

6. Future Plan

An efficient system for automatic electric vehicle charging stations in a static environment was presented in this paper. Our initiative will be successful in the future because we intend to make this static environment dynamic. Thus, it will save money, time, and labor. The small-signal equivalent admittance is taken into consideration when building the system dynamic model, and the stability of the system is subsequently theoretically examined to show how the traditional control system is unstable and to confirm that the suggested method is effective. Results from analysis and experiments demonstrate that, even in the event that the system characteristics and operating conditions change, the suggested dynamic WCS may maintain a faster dynamic response with less oscillation and overshoot than the conventional PI controller.

Additional efforts will be made to enhance the assessment and implementation of this suggested approach. First, under the constraints of the current prototype construction and testing settings, the system's dynamic performance will be evaluated when other valuables, such as the operating frequency, source, and load voltages, are modified. Then, by installing coils on the road, the impacts of the mutual inductance (or coupling coefficient) on the functioning of the control system will be further investigated empirically rather than being restricted to computational research.

The cars can now be charged without stopping or connecting to a probe. Instead, as they travel along the road, they may charge themselves. This article provides an overview of our nation's opinion on the most recent occurrences.

7. Conclusions

Technological developments have made WPT more trustworthy and efficient. As a consequence, its suitability for use in a variety of applications, such as industrial automation and electric cars, has improved. Due to the incorporation of Internet of Things (IoT) devices into electric vehicles, WPT has grown. Giving these gadgets the steady electricity, they require via wireless charging is a practical and efficient solution. For WPT technology, research and development costs have gone up dramatically. This is expected to drive further expansion in the coming years, since it has spurred the development of creative and cutting-edge applications. Overall, it is anticipated that during the next few years, the trend of wireless power transfer will continue to grow because of developments in technology, a rise in use throughout several sectors and an increase in the demand for mobile devices.

Since green power must be incorporated into the power source, solar panels can be utilized to charge the accumulator in cars. Concurrent power exchange via PWT was carried out between the cars and the transmitter coil. Maintaining comprehensive control over this system is the toughest challenge. While creating electric and magnetic models for a WPT system with capacitor changes, analysis of transfer power, efficiency, and coupling coefficient was done. We found that the resonance frequency, transmitted power, and efficiency follow clear trends.

It initially appeared as though the demands for regularity made by these two wants were incompatible. Two resonance frequencies: low resonance frequency for high transmitted power and high resonance frequency for high transmitted power, Time-saving and labor-saving features such as the Vehicle Detected System and Automated Wireless Power Transmission System were implemented. On the other hand, fuel is what enables electricity. The globe is a challenging place right now. The solar system is considered green energy because of this. For the project, we employed solar energy, electricity, and batteries, among other power sources.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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