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IOT DRIVEN RESONANT INDUCTIVE COUPLING FOR DYNAMIC WIRELESS ELECTRIC VEHICLE CHARGING

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Abstract: **Dynamic wireless charging is transforming the way electric vehicles (EVs) are powered. Using IoT-enabled resonant inductive coupling, this technology allows EVs to charge wirelessly—whether stationary or in motion—eliminating the need for physical cables. By reducing charging time and enhancing convenience, it helps overcome a key barrier to EV adoption. The integration of IoT adds real-time monitoring of voltage, current, and coil temperature, offering actionable insights through intuitive dashboards. With minimal energy loss and advanced cooling systems to maintain reliability, this system delivers both efficiency and consistent performance. Scalable and sustainable, dynamic wireless charging supports the vision of smart cities and cleaner transportation, paving the way for a more connected, eco-friendly future.**

Keywords: Resonant Inductive Coupling, Electric Vehicles (EVs), Power Transfer Efficiency, Charging Downtime Reduction, Sustainable Transportation.

1. INTRODUCTION

As the shift toward sustainable transportation accelerates, electric vehicles (EVs) are becoming more popular but charging convenience remains a key challenge. Traditional plug-in systems require vehicles to stop and charge for extended periods, which can be a barrier to broader adoption. In response, **wireless charging** has emerged as a promising solution, particularly **dynamic wireless charging**, which allows EVs to charge while in motion.

Several wireless charging methods have been developed over time. **Inductive Power Transfer (IPT)** is the most established, using electromagnetic induction between coils, though it requires precise alignment. **Capacitive charging** offers a compact design but is less efficient and limited in power. **Radio Frequency (RF)** enables long-range charging but is best for low-power applications. The most promising is **Resonant Inductive Coupling (RIC)**, which improves energy transfer even when the coils are misaligned or farther apart making it ideal for dynamic, on-the-go charging.

Here's how it works: electricity from the grid is converted to high-frequency AC and sent through coils embedded in the road. As vehicles drive over them, onboard receiver coils pick up the energy and convert it into a steady DC current to charge the battery.[1][2]

A major advancement in this technology is the integration of **IoT**. Smart sensors monitor voltage, current, and coil temperature in real time, ensuring efficient operation and helping detect faults before they become problems. This data can also be shown on the driver's dashboard, improving safety and user experience.[3]

Ultimately, dynamic wireless charging powered by RIC and IoT offers a scalable, efficient, and user-friendly solution. It supports the vision of smart cities and could redefine how we power electric vehicles in the years ahead.[4]

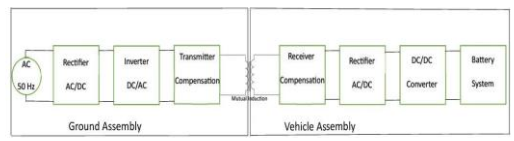

Fig.1 Wireless Charging Infrastructure

2. METHODOLOGY

Dynamic wireless charging (DWC) powered by IoT and resonant inductive coupling (RIC) offers a cutting-edge solution to the limitations of traditional plug-in EV charging. At the heart of this system is **resonant inductive coupling**, where energy is wirelessly transferred between coils—one embedded in the road and the other installed beneath the vehicle. Both coils are tuned to the same resonant frequency (typically 20–100 kHz) to ensure efficient power transfer, even when vehicles are in motion or misaligned.[5]

The system uses **high-frequency AC power** (often centered around 85 kHz per SAE J2954 standards), generated by inverters and optimized through simulation software. The alternating current creates a magnetic field that induces voltage in the vehicle's receiver coil, which then converts it into DC power to charge the battery. Power sources can range from standard AC grids to renewable sources like solar panels.

Communication between the road unit and the vehicle is essential for functions like alignment, billing, licensing, and system control ensuring safe and reliable operation. Safety measures, including electromagnetic interference (EMI) shielding, protect nearby electronics from disruption.

The integration of **IoT technology** takes this system a step further. Sensors placed in the coils monitor real-time data such as voltage, current, and temperature. This information is sent to a cloud

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platform, where it's analyzed and displayed via dashboards or mobile apps. With this feedback, the system can automatically adjust power levels based on factors like vehicle speed or battery charge level. It also enables **predictive maintenance**, flagging potential issues before they cause failures.[3][5]

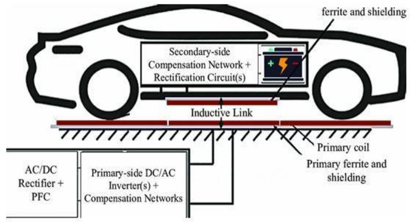

Fig.2 Typical representation of wireless power transfer.

2.1 FLOW CHART

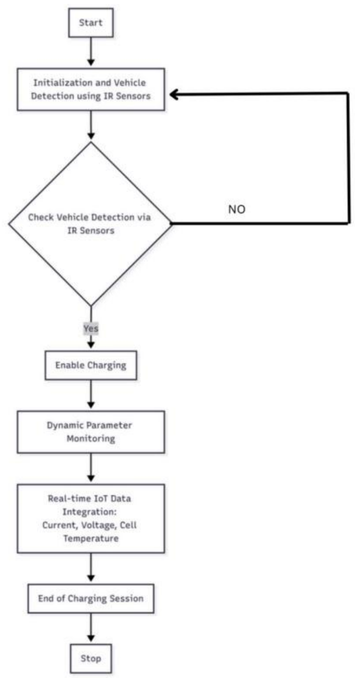

Fig.3 Basic representation of the process

3. INDUCTIVE RESONANT COUPLING

Resonant Inductive Coupling (RIC) is an advanced wireless power transfer method that significantly improves efficiency by using magnetic resonance between two coils. Unlike conventional inductive charging which loses effectiveness as the distance between coils increases RIC keeps the power transfer strong even when the coils are not perfectly aligned or spaced further apart.

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The core idea behind RIC lies in tuning both the transmitter and receiver coils to resonate at the same natural frequency. When this happens, energy can move between them more efficiently, even across moderate distances. This is especially useful for electric vehicles (EVs), which may not always maintain perfect alignment with the charging coils, such as when moving along a wireless charging lane.

Here's how it works in practice: when an alternating current (AC) flows through the transmitter coil embedded in the road, it generates an oscillating magnetic field. If a vehicle with a receiver coil tuned to the same frequency passes over it, the magnetic field induces a current in the receiver coil. This current can then be converted into DC power to charge the EV's battery.

The principle behind this process is electromagnetic induction, where a changing magnetic field creates voltage in a nearby conductor. By matching the resonant frequency of the two coils, the energy transfer becomes much more efficient, even if the magnetic coupling between the coils isn't very strong.[6]

The system's resonant frequency is determined by the formula:

$$fr = 1 / (2\pi\sqrt{LC})$$

Here, **L** represents the inductance of the coil, and **C** is the capacitance added to create the resonant circuit. Another important factor is the coupling strength between the coils, represented by **mutual inductance (M)**, which is calculated as:

$$M = k\sqrt{(L1 \times L2)}$$

In this formula, **k** is the coupling coefficient (a measure of how well the coils are linked), and **L1** and **L2** are the self-inductances of the transmitter and receiver coils.

By using this approach, RIC makes wireless charging far more practical and efficient especially for dynamic scenarios where vehicles are moving bringing us closer to the reality of smart roads and continuous EV charging without plugs or stops.[7]

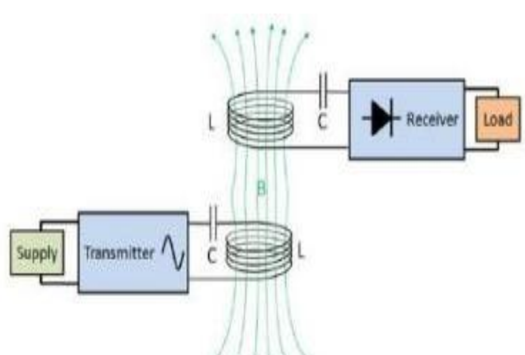

Fig. 4 Resonant Inductive coupling

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4. POWER ELECTRONICS CONVERTERS AND CONTROLLERS

Dynamic wireless charging systems for electric vehicles (EVs) rely heavily on advanced power electronics to ensure that energy is transferred efficiently, safely, and consistently while the vehicle is in motion. In earlier designs, power conversion was managed using push-pull converters with IGBT switches. However, with the evolution of semiconductor technology, especially the rise of high-efficiency MOSFETs for medium-voltage applications, the industry has shifted towards full-bridge MOSFET converters. These offer faster switching capabilities, reduced power losses, and better performance at the high frequencies needed for wireless power transfer.

On the transmitter side, power from the electrical grid is first converted from standard AC to high-frequency AC. This is then transmitted via magnetic fields using coils embedded in the roadway. The high-frequency operation is critical for enabling efficient inductive coupling between the transmitter and receiver coils over small air gaps. The receiver side on the vehicle captures this magnetic energy through a coil and converts it into a smooth DC output using rectifiers and voltage regulators, making it suitable for charging the EV battery.

Central to this entire operation are the controllers. These smart control units manage every aspect of power delivery—from inverter switching and output voltage control to battery management and fault detection. They adjust in real time based on sensor feedback to maintain optimal alignment, efficiency, and safety. This intelligent coordination ensures that the charging process remains stable even under variable load or misalignment conditions.

Together, these advanced power electronics and control systems form the backbone of dynamic wireless charging, enabling EVs to charge seamlessly while driving. This not only addresses the issue of range anxiety but also supports a more continuous and user-friendly charging experience—an essential step toward making electric mobility more practical and scalable in everyday use.[9]

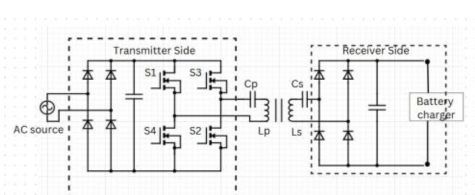

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Fig. 8 Resonant Inductive Power Transfer circuit diagram

5. INTEGRATION OF INTERNET OF THINGS

The Internet of Things (IoT) is transforming wireless electric vehicle (EV) charging systems by enabling smarter, safer, and more efficient operations through real-time data monitoring and control. By embedding intelligent sensors and communication capabilities into both the transmitter and receiver units, IoT bridges the gap between raw power transfer and intelligent system management.[3][4][5]

The integration of IoT significantly enhances the performance, efficiency, and intelligence of wireless charging systems for electric vehicles. By embedding IoT-enabled sensors within charging infrastructure, systems can monitor critical parameters such as voltage, current, alignment, and temperature in real time, allowing dynamic adjustments to maintain optimal charging conditions. These sensors transmit data wirelessly using technologies like Wi-Fi, Bluetooth, or LPWAN to cloud platforms, enabling remote diagnostics, system updates, and performance analysis without physical intervention. Predictive maintenance becomes possible through advanced analytics, which identify early signs of wear or failure, allowing issues to be addressed proactively before causing major disruptions. Intelligent thermal management is another key benefit, where temperature sensors trigger cooling mechanisms such as fans or phase change materials to maintain safe operating temperatures.

Furthermore, IoT facilitates misalignment detection between coils, alerting users or adjusting the system to sustain efficient energy transfer. The charging experience is also streamlined through automated billing and user authentication, making transactions seamless and secure. On a broader scale, IoT enables smart grid integration, supporting real-time load balancing and efficient power distribution, especially during peak hours. Environmental conditions such as humidity or electromagnetic interference are also monitored, ensuring adaptive power delivery for consistent performance.

Additionally, the bidirectional communication made possible through IoT supports Vehicle-to-Grid (V2G) systems, turning EVs into mobile energy sources. For commercial and autonomous vehicle fleets, IoT offers centralized control and scheduling, allowing vehicles to autonomously navigate to charging stations and ensuring infrastructure is used efficiently. Together, these capabilities position IoT as a transformative force in making wireless EV charging more intelligent, reliable, and adaptable to future mobility demands. [9]

7. HARDWARE MODEL OF PROTOTYPE

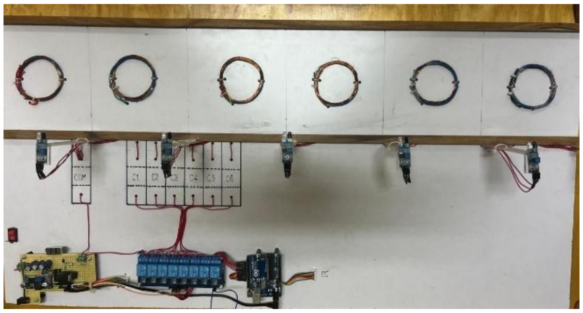

Fig. 9 Overview of the transmitter track

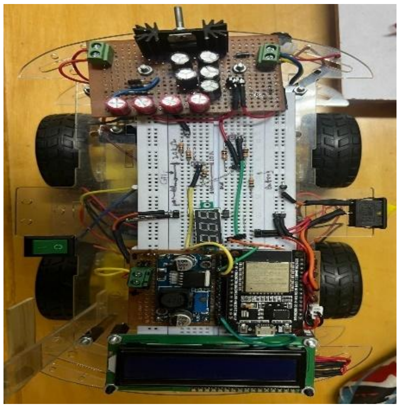

Fig. 10 Overview of the receiver car

Parameter	Specification
Input Power Supply (IP)	12 V DC
Number of Coils	6 (Transmitter side), 1 (Receiver side)
Turns Ratio (T:R)	1:1
Number of Turns (Tx:Rx)	100 : 100
Battery Capacity (Car)	12 V, 5000 mAh (5 Ah)
Coil Configuration	Resonant Inductive Coupling
Charging Type	Dynamic Wireless Charging
IC 4047 Frequency	85 kHz
Air Gap for Max Efficiency	7 mm

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Distance Between Each Coil	5 cm

Table 1 :Specification of the prototype

6. FUTURE SCOPE AND CHALLENGES

The potential for Inductive Resonant Coupling (IRC) in dynamic wireless EV charging is vast, driven by advances in power electronics, smart grids, and IoT. As demand for electric vehicles (EVs) increases, wireless power transfer (WPT) technology will evolve, enabling vehicles to charge while on the move. Future developments aim to improve power transfer efficiency, reduce energy loss, and enhance alignment correction to address misalignments between the receiver and transmitter coils. AI and IoT-based systems will optimize charging patterns based on traffic and battery needs, while advanced materials like gallium nitride (GaN) and silicon carbide (SiC) will improve power conversion and reduce infrastructure size.[13]

While dynamic wireless charging for electric vehicles (EVs) holds great promise, there are several challenges that need to be overcome for it to become widely adopted. One of the biggest obstacles is the high infrastructure cost setting up transmitter coils in the roads and the necessary power systems requires a significant financial investment. Another challenge is the lack of standardization, as different EV models and charging stations may not be compatible with each other, making it difficult to create a universal charging solution. Electromagnetic interference (EMI) from the strong fields used for wireless power transfer could also interfere with nearby electronic devices, which means strict regulations will be necessary. Ensuring consistent energy transfer efficiency is another concern, as the distance between the vehicle and charging coils, as well as the speed of the vehicle, can affect how well power is delivered. Misalignment of the coils is also an issue; even a small shift can cause significant energy loss. There are also safety concerns related to prolonged exposure to electromagnetic fields, which could pose risks to both human health and the environment. Moreover, scaling this technology for heavy-duty vehicles like trucks and buses presents its own challenges in terms of power limitations. Weather and road conditions can affect the durability of the infrastructure, and with the wide variety of EV battery types, there’s a need for charging solutions that can adapt to different vehicles. Lastly, integrating wireless charging into the power grid requires advanced load management to avoid power fluctuations and ensure that everything runs smoothly.[13][14]

7. CONCLUSION

The project *"IoT-Driven Resonant Inductive Coupling for Dynamic Wireless Electric Vehicle Charging"* aims to provide a smarter, more efficient, and user-friendly wireless charging solution for electric vehicles (EVs). Using resonant inductive coupling, it enables seamless power transfer between vehicles and charging infrastructure without the need for physical connections. This technology can be applied to stationary platforms or embedded in roadways for dynamic charging as vehicles move.

By integrating IoT, the system offers real-time monitoring of key parameters like voltage, current, and temperature of the coils. This data is displayed on mobile apps or vehicle dashboards, ensuring safety, optimizing charging efficiency, and enabling predictive maintenance.

Ultimately, this project represents a step toward a more sustainable future by reducing charging downtime, alleviating range anxiety for EV users, and supporting the transition to electric mobility. It lays the groundwork for future innovations in wireless EV charging, creating more efficient, connected infrastructure that aligns with the growing demand for sustainable transportation.

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