Electropath Charging System for EV

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Abstract - The Solar Powered EV Charging Road is an innovative solution designed to enable continuous wireless charging for electric vehicles (EVs) as they travel. The system integrates coils embedded under the road surface and corresponding coils installed under EVs. Electrical energy from solar panels is converted from direct current (DC) to alternating current (AC) to facilitate wireless power transfer via mutual induction.This enables seamless energy transmission from the road to the vehicle, allowing for efficient charging without the need for stops or plug-in stations. Solar panels along the roadside supply clean, renewable energy while also providing shade for pedestrians and vehicles. Each EV is equipped with an onboard power consumption monitoring unit for real-time energy tracking. Additionally, a cloud server monitors payments, and once the user's app balance is depleted, the charging process is terminated. The user can then only rely on the remaining battery charge. However, when the wallet is recharged, the system automatically relinks the car to the wireless charging system. A mobile application further helps users monitor power consumption and manage billing

Key Words: Wireless charger, Solar power, Mutual induction

1.INTRODUCTION

The Charging System for Electric Vehicles (EVs) is a revolutionary step toward sustainable transportation, integrating wireless power transfer and renewable energy sources. Traditional EV charging methods depend on stationary plug-in stations, requiring frequent stops that limit long-distance travel and create inefficiencies. This system introduces dynamic charging, enabling EVs to wirelessly receive power while in motion through mutual induction between coils embedded beneath the road and coils installed under the vehicle. By eliminating the need for frequent charging stops, this innovation enhances travel convenience and addresses range anxiety.

A key aspect of this system is its reliance on solar energy, making it not only efficient but also environmentally friendly. Solar panels installed along roadsides capture sunlight and convert it into direct current (DC) electricity, which is then transformed into alternating current (AC) to support the wireless charging process. By directly integrating renewable energy into charging infrastructure, the system reduces dependency on traditional power grids and promotes sustainability.

Additionally, the system features intelligent monitoring and billing solutions. Each vehicle is equipped with a power consumption monitoring unit linked to a cloud-based server that tracks energy usage and manages billing in real time. If a user's balance depletes, charging is temporarily halted until payment is made via a mobile application, which also provides insights into power consumption patterns.

The reliance on stationary charging stations presents significant challenges, including range anxiety, time inefficiencies, and dependence on non-renewable energy. This innovative system overcomes these barriers, offering a scalable, sustainable, and seamlessly integrated solution for the future of EV infrastructure. By enhancing efficiency, reducing environmental impact, and improving user convenience, dynamic wireless charging has the potential to transform electric mobility and accelerate the global transition to greener transportation.

2. LITRATURE REVIEW

Wireless power transfer (WPT) and dynamic charging technologies have been extensively studied to improve the efficiency and practicality of electric vehicle (EV) charging infrastructure. The integration of renewable energy sources, particularly solar power, with dynamic wireless charging systems presents an innovative approach to sustainable EV charging solutions. This literature review explores existing research on wireless EV charging, the role of renewable energy in charging systems, and the advancements in payment and monitoring systems.

Wireless charging for EVs can be categorized into static charging and dynamic charging. While static charging requires vehicles to stop at designated stations, dynamic wireless charging (DWC) enables continuous charging while the vehicle is in motion, reducing downtime and extending travel range.

Jeong et al. (2019) investigated the impact of Dynamic Wireless Charging (DWC) on EV battery size and lifespan. Their study proposed an optimized power track system to balance battery size with charging infrastructure, improving economic efficiency[1]. Similarly, Razu et al. (2021) explored different WPT methods and demonstrated a 92.4% efficiency rate for a charging system with a 3.74 kW transfer rate, proving that high-efficiency WPT systems are feasible[2].

Mohamed et al. (2022) provided a comprehensive analysis of wireless charging architectures, emphasizing the importance of coil placement, system compensation topologies, and the role of positioning in optimizing power transfer efficiency [3] Waite et al. (2024) introduced a current-fed inductive wireless charging transmitter designed for large-scale deployment, addressing load-independent coil current regulation, which enhances performance in real-world conditions[4]

The combination of solar energy with wireless charging systems presents an eco-friendly alternative to grid-dependent EV infrastructure. Traditional grid-powered charging can contribute to carbon emissions if non-renewable sources are used.

Fathollahi et al. (2022) proposed a long-term stochastic model for Dynamic Wireless Charging (DWC) infrastructure deployment that considers traffic flow and power distribution constraints. Their findings indicate that integrating renewable energy sources reduces reliance on fossil fuels while optimizing EV battery capacity[5].

A study by Ramakrishnan et al. (2024) reviewed strategies for enhancing WPT efficiency, emphasizing solar-powered WPT as a key area for development. They highlighted the need for high-efficiency power converters and smart grid integration to ensure reliability in solar-based wireless EV charging[6].

Automated payment systems and real-time monitoring play a crucial role in user convenience and system efficiency. In the context of dynamic EV charging, automated billing based on energy consumption ensures a seamless user experience.

Kanojia and Pathak (2018) developed an NFC-based toll payment system, which can be adapted for automated EV charging transactions. Their system demonstrated high reliability and security, making it an ideal model for integrating wireless charging payments[7].

The concept of IoT-based monitoring for EV charging was explored by several researchers. Mohamed et al. (2022) suggested using cloud-based energy monitoring systems, allowing users to track consumption and manage payments via mobile applications[3].

Despite advancements in wireless charging, challenges remain in terms of infrastructure cost, efficiency, and standardization.

Energy Loss and Efficiency: Maintaining high power transfer efficiency (PTE) across various vehicle speeds and coil misalignment remains a challenge. Razu et al. (2021) found that increasing the air gap between coils drastically reduces efficiency[2].

Economic Viability: Jeong et al. (2019) concluded that optimizing the placement of charging tracks can reduce battery size requirements, making EVs more cost-effective [1].

Scalability and Implementation: Fathollahi et al. (2022) highlighted the need for strategic deployment of DWC tracks to minimize power grid strain and ensure widespread adoption

3. METHODOLOGY

Developing a solar-powered wireless charging system for electric vehicles involves a structured methodology that integrates conceptual design, component selection, model construction, and system integration. The process begins with a comprehensive design phase where flowcharts and diagrams are created to visualize the interactions between key components, including solar panels, induction coils, an electric vehicle model, a mobile application, and a payment system. This design ensures that each element functions cohesively within the system. Once the design is finalized, suitable components such as miniature solar panels, induction coils, batteries, and microcontrollers are carefully selected to construct a compact yet fully functional desktop model. These components must be capable of efficiently demonstrating solar energy capture, wireless power transfer, and real-time monitoring through the mobile application.

The construction phase involves assembling the physical model by creating a road-like base with embedded transmitter coils beneath the surface and mounting solar panels to simulate real-world energy harvesting. A scaled-down electric vehicle model is designed with a receiver coil positioned to align with the transmitter, ensuring efficient power transfer through mutual induction. Electrical circuits are integrated to connect the solar panels, coils, and batteries, ensuring a smooth flow of energy. The mobile application is then developed using platforms like MIT App Inventor or Android Studio, enabling users to monitor charging status, track energy consumption, and manage virtual payments. A simulated payment system is incorporated within the app, allowing users to top up their virtual wallet, with charging automatically stopping when the balance is depleted and resuming upon wallet recharge.

After assembly, rigorous testing and calibration are conducted to verify system functionality. This includes evaluating the efficiency of solar energy capture, testing the wireless charging mechanism, and ensuring the app accurately reflects real-time charging status and energy usage. Any misalignments or inefficiencies are corrected to optimize performance. Finally, a detailed presentation is prepared to explain the working principles, technological benefits, and real-world applications of the solar-powered wireless EV charging system. The demonstration is rehearsed to ensure a seamless and engaging presentation, effectively showcasing the potential of this innovative technology in promoting sustainable transportation solutions.

4. SYSTEM ARCHITECTURE

4.1 BLOCK DIAGRAM

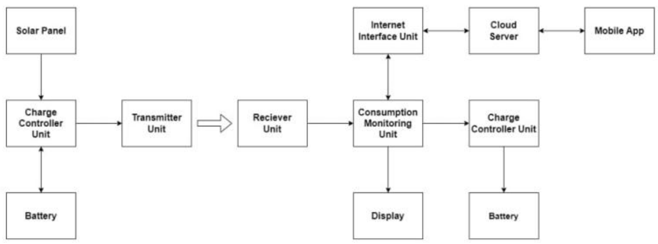

Figure 1:Block Diagram

The block diagram illustrates a wireless EV charging system powered by solar energy, ensuring efficient and contactless charging without the need for physical connectors. The process starts with a solar panel, which captures sunlight and converts it into electrical energy. This energy is regulated by a charge controller unit, which prevents overcharging and optimizes battery performance. The regulated power is then stored in a battery for later use.

For wireless energy transfer, the stored power is fed into a transmitter unit, which generates an electromagnetic field to transfer energy to the receiver unit installed in the EV. The receiver captures the transmitted power and converts it back into usable electricity. To ensure proper voltage and current regulation, the received power is processed through another charge controller unit, which stabilizes the power before storing it in the EV's battery.

A display unit provides real-time feedback on the charging status, allowing users to monitor the process visually. This system eliminates the need for wired charging infrastructure, enhancing convenience and reducing wear and tear on charging components. By utilizing solar energy, the system promotes sustainability and reduces dependence on grid electricity, making it an eco-friendly solution for EV charging.

This wireless charging setup is particularly beneficial for dynamic charging applications, where EVs can charge while in motion, improving range and efficiency. The integration of solar energy further enhances its viability, making it an ideal solution for smart and sustainable transportation.

4.2 SOFTWARE REQUIREMENTS

To develop a seamless and efficient Electropath Charging System for EVs, we have carefully selected the most suitable technologies for each component of the project. The Android app features a clean, user-friendly interface, designed with Adobe Illustrator to ensure intuitive navigation. For development, we utilize Kodular, a no-code platform that enables rapid and flexible app creation without requiring complex coding. The backend is powered by Firebase, which facilitates real-time data storage, user authentication, and cloud communication. Together, these technologies support essential features such as real-time monitoring, geofencing alerts, and controlled power distribution, making EV charging safer and more efficient. The following sections provide a detailed overview of these software components.

1. Adobe Illustrator

Adobe Illustrator is a powerful vector-based design tool that plays a crucial role in shaping the user interface (UI) of our Android app. It allows us to create sharp and scalable assets, including buttons, icons, and layouts, ensuring a visually appealing and easy-to-navigate app experience across different screen sizes. By leveraging Artboards, we can design multiple app screens within a single workspace, ensuring a consistent and well-structured layout.

Illustrator's Pen Tool and Shape Builder enable the creation of custom icons and buttons with precision, while the Color and Gradient tools help enhance the app's visual appeal. Additionally, Illustrator integrates seamlessly with Adobe XD and Photoshop, allowing for efficient prototyping and refinement before implementing the designs in Kodular. Since Kodular supports high-quality image formats like PNG, SVG, and WebP, Illustrator's asset export options ensure smooth integration into the app.

Other useful features, such as smart guides, layers, and responsive resizing, keep the design well-organized and adaptable to various screen resolutions. Additionally, Adobe Cloud syncing allows for seamless collaboration and easy updates on the go. By utilizing Adobe Illustrator, we not only ensure a functional UI but also craft an engaging, intuitive experience that simplifies monitoring and managing the Electropath Charging System for EVs.

2. Kodular

Kodular is a no-code development platform built on MIT App Inventor, offering a drag-and-drop interface that allows app development without the need for extensive coding knowledge. This makes it an ideal choice for our EV charging system, enabling quick integration of features such as real-time power monitoring, Firebase authentication, data visualization, and push notifications.

Kodular provides a vast collection of pre-built components, allowing us to design a smooth and functional user experience with buttons, maps, sensors, and more. For advanced functionalities, custom extensions can be incorporated to enhance the app's capabilities. The Kodular Companion app facilitates real-time testing, allowing developers to preview changes instantly without repeatedly reinstalling the application.

Kodular's built-in integration with Firebase ensures seamless data transmission, allowing instant updates on the status of the Electropath Charging System. By leveraging this platform, we can develop an efficient, user-friendly app that provides real-time insights into charging operations, improving both safety and efficiency.

3. Firebase

Firebase, a cloud-based platform by Google, serves as the backbone of our EV charging system, managing real-time data updates, user authentication, and instant alerts. Given the need for continuous monitoring of charging status, power distribution, and geofencing alerts, Firebase's Realtime Database ensures that any changes—such as an EV entering or exiting a charging zone—are immediately reflected in the app, keeping users informed at all times.

Firebase Authentication enhances security by restricting access to critical controls, such as power distribution management, ensuring that only authorized personnel can operate it. Additionally, Firebase Cloud Messaging (FCM) enables the system to send immediate alerts and notifications, allowing quick responses in case of system malfunctions or unauthorized access.

Seamless integration with Kodular simplifies data handling, eliminating the need for complex backend coding. If future expansion includes a web-based dashboard, Firebase Hosting can support it, while Firebase Analytics provides valuable insights into user engagement and system performance. With its real-time synchronization, robust security, and scalability, Firebase ensures the system remains reliable, keeping EV charging operations efficient, safe, and well-managed.

By combining Adobe Illustrator, Kodular, and Firebase, we have built an intelligent and efficient Electropath Charging System for EVs, enhancing charging infrastructure, improving safety measures, and streamlining energy distribution.

4.3 ALGORITHM

Step 1: Start

- Initialize the system and prepare all components for operation.

Step 2: Detect Current Sensor Signal

- Continuously monitor the current sensor for any signals indicating the need for charging.

Step 3: If Sensor Signal Detected

- If Yes: Proceed to Step 4.

- If No: Return to Step 2 and continue monitoring for signals.

Step 4: Check Server Database for Balance in Account

- Connect to the server and retrieve the current account balance linked to the user.

Step 5: If Balance > 0

- If Yes: Proceed to Step 8 to initiate charging.

- If No: Proceed to Step 6 to cease charging.

Step 6: Turn Off Relay

- Deactivate the relay that manages the connection to the charger, ensuring no power flows.

Step 7: Notify User via App

- Send a notification to the user's app, informing them that their charging attempt was unsuccessful due to insufficient balance.

Step 8: Turn On Charger Relay

- Activate the relay to connect the charging circuit, allowing power to flow to the device.

Step 9: Monitor Charging Time and Current Flow

- Continuously monitor the charging time and the current flow to ensure the device is charging correctly.

Step 10: If Balance = 0 during Charging

- If Yes: Proceed to Step 6.

- If No: Return to Step 9 to continue monitoring charging.

Step 11: End of Charging Cycle

- After a predefined charging time or once the device reaches full charge, proceed to Step 12.

Step 12: Check for User Interaction (Optional)

- Determine if the user wishes to continue charging or if they want to be notified of the completion.

Step 13: Disconnect Charger Relay

- Once charging is complete or if the user chooses to stop it, deactivate the charger relay to cut off the power.

Step 14: Log Charging Session

- Record details of the charging session into the server database, including total charge time and current flow.

Step 15: Notify User of Completion

- Send a final notification to the user's app informing them that charging has been completed successfully.

Step 16: Return to Step 2

- End the current cycle and return to Step 2 to monitor for new charging requests.

5. CIRCUIT DESIGN

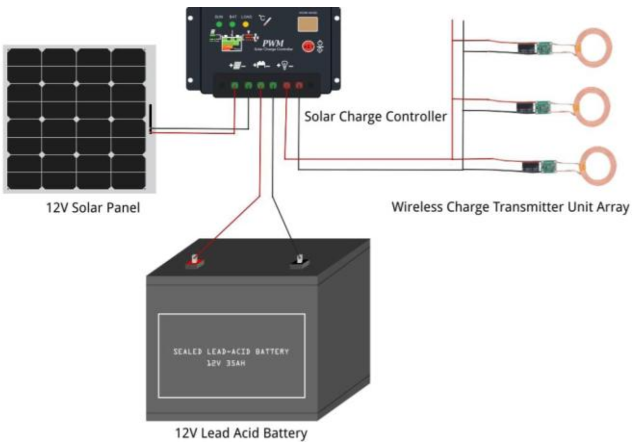

Figure 2: Circuit Diagram of Road part

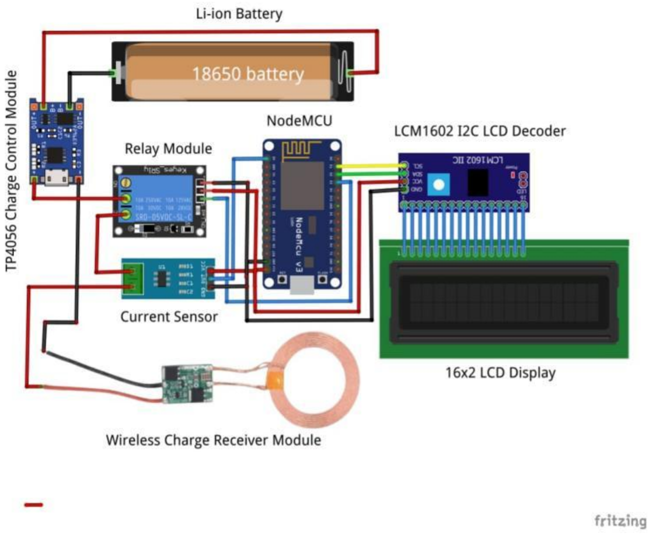

Figure 3:Circuit Diagram of Car part

The given circuit diagrams depict a dynamic wireless charging system for electric vehicles (EVs) using solar energy. The first diagram represents the roadside charging infrastructure, where a 12V solar panel generates electricity and feeds it into a solar charge controller that regulates power flow to a 12V lead-acid battery for energy storage. The stored energy is then supplied to a wireless charge transmitter unit array, consisting of multiple inductive coils that create an electromagnetic field on the road. This allows moving EVs to receive power wirelessly through inductive coupling.

The second diagram illustrates the in-vehicle charging system, which consists of a wireless charge receiver module that captures power from the road's inductive field. A current sensor monitors the incoming power, while a relay module controls power distribution. The TP4056 charge control module ensures safe and efficient charging of a Li-ion 18650 battery, which can power vehicle accessories or supplement the main battery. A NodeMCU microcontroller processes sensor data and displays real-time charging status on a 16x2 LCD screen via an I2C LCD decoder. This system enables continuous, on-the-go charging for EVs, reducing reliance on stationary charging stations and promoting renewable energy-based transportation.

6. WORKING AND IMPLEMENTATION

The Electro app is a user-friendly Android application designed for electric vehicle (EV) owners. It provides real-time monitoring of charging sessions, tracking battery percentage, energy consumed, and charging power. The app estimates the time to full charge, allowing users to plan accordingly. A built-in wallet system enables automatic payments, supporting multiple payment methods such as credit/debit cards, UPI, and bank transfers.

The app also features a charging restriction mechanism to prevent unauthorized charging. Users can access their charging history, gaining insights into past sessions and optimizing their charging habits. The Electro app offers a comprehensive solution for EV owners, enhancing convenience, efficiency, and financial discipline in managing their charging needs. With its intuitive interface and personalized experience, the app streamlines the EV ownership experience, making it easier for users to manage their vehicles and stay on top of their energy usage. Additionally, the app sends notifications for low battery and wallet balance, ensuring users stay informed and in control of their EV's charging needs. Overall, the Electro app is a valuable tool for EV owners, providing a seamless and convenient charging experience.

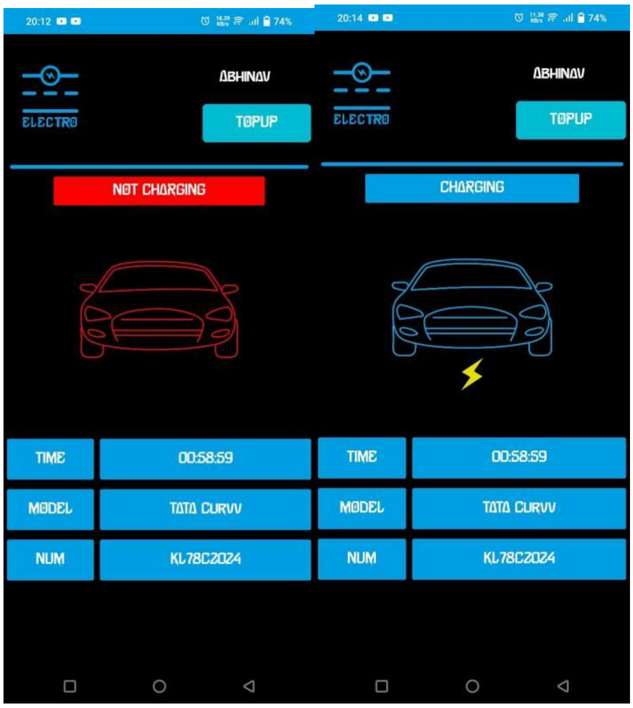

Figure 4: App Interface

7. CONCLUSION

In conclusion, the Electropath Charging System for EVs represents a ground breaking advancement in electric vehicle infrastructure by enabling dynamic, wireless charging. By embedding solar-powered coils beneath road surfaces and integrating corresponding coils within EVs, the system allows vehicles to charge seamlessly while in motion, addressing both range anxiety and the need for stationary charging points. This not only minimizes interruptions in travel but also significantly reduces reliance on large charging stations, which can be costly and space-intensive. The use of solar panels to power the system highlights its commitment to sustainability, providing a renewable energy source that aligns with global efforts to reduce carbon emissions. Furthermore, the integration of real-time energy tracking and automated payment management through a mobile application enhances user convenience and supports an efficient billing system. The app allows users to monitor power consumption, manage expenses, and automatically reconnect to the charging network upon recharging, thus enhancing the user experience and operational ease. Overall, the Electropath Charging System is a forward-looking solution that paves the way for widespread EV adoption by offering a scalable, eco-friendly alternative to traditional charging. Its innovative design can transform urban and suburban landscapes by reducing the environmental footprint of transportation and making sustainable travel more accessible. This technology holds the potential to catalyse further advancements in renewable energy applications and the electrification of transportation systems worldwide.

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