EV WIRELESS CHARGING STATION

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ABSTRACT

Electric Vehicles (EVs) require efficient, reliable, and cost-effective charging systems to support widespread adoption and optimal performance. Wireless charging technology has emerged as a promising alternative to traditional wired systems by eliminating the need for physical connectors, enhancing user convenience, and promoting eco-friendliness.

This paper introduces a novel approach termed the Static Wireless Charging System (SWCS), designed to improve the practicality and efficiency of EV charging. The system is based on magnetically coupled resonant power transfer, where energy is wirelessly transmitted from a stationary transmitter coil to a receiver coil aligned on the vehicle. A key feature of this design is the selective switching mechanism, which activates the transmitter coil only when precise alignment with the receiver coil is detected. This method significantly reduces energy loss and improves charging efficiency.

The paper outlines the system architecture, operational principles, and control mechanisms that optimize performance and safety. It also presents a comprehensive overview of existing wireless power transfer (WPT) techniques and classifies various methodologies relevant to EV charging. Finally, the study highlights recent technological advancements and suggests future research directions aimed at enhancing the effectiveness of static wireless charging for EV.

1. INTRODUCTION

Electric Vehicles (EVs) have emerged as a key terminology implies a complete system that includes component in the transition toward sustainable both the vehicle and its corresponding charging transportation, offering a viable path to reduce environment, rather than an isolated unit. greenhouse gas emissions and dependence on fossil fuels. While traditional plug-in and conductive charging systems have supported EV adoption thus far, they are limited by factors such as long charging times, heavy battery requirements, and physical infrastructure constraints.

To overcome these limitations, research has increasingly turned toward wireless charging solutions. Inductive charging, based on Wireless Power Transfer (WPT), allows energy to be transmitted without direct physical contact. Although this technology has long been applied to consumer electronics and medical devices, its adaptation to electric mobility presents a significant step forward in improving user convenience and operational efficiency.

Early implementations of wireless EV charging were primarily stationary, where vehicles were charged while parked in garages or public parking areas. These systems reduced the need for cables and mechanical connectors, improving user experience and minimizing wear and tear. However, from an operational standpoint, stationary wireless charging systems still resembled conventional plug- in models, offering no substantial advantage in terms of real-time energy access or driving continuity.

This limitation has prompted a shift toward more dynamic alternatives. A notable development in this area is Static Wireless Charging, which enables EVs to be charged while temporarily stationary— such as at traffic signals, toll booths, or designated charging zones—without the need for active user intervention. Unlike dynamic charging (while in motion), static charging provides a practical middle ground by reducing charging delays and expanding range without requiring extensive infrastructure modifications.

The integration of static wireless charging introduces a new set of design, control, and infrastructure challenges. These include efficient alignment of transmitter and receiver coils, real- time power transfer management, and the strategic placement of charging zones. This paper focuses on addressing these challenges by presenting a comprehensive analysis of Static Wireless Charging Systems (SWCS), including their architecture, control mechanisms, and implementation feasibility.

For clarity, the term "wireless charging EV" in this study refers specifically to electric vehicles utilizing static wireless charging infrastructure.

2. LITERATURE REVIEW

Wireless Power Transfer (WPT) has gained momentum as a viable alternative to conventional plug-in charging systems for Electric Vehicles (EVs), offering convenience, safety, and automation. The underlying technology, primarily based on Inductive Power Transfer (IPT), allows energy transfer through a magnetic field generated between a transmitter (Tx) and a receiver (Rx) coil. Various studies have investigated the critical parameters influencing WPT systems, including coil design, compensation topology, power electronics, and misalignment tolerance.

Budhia et al. (2011) [1] emphasized the significance of coil configurations and magnetic coupling for achieving high power transfer efficiency. Their work demonstrated that double- D (DD) coil structures provide superior alignment tolerance compared to circular coils. Similarly, the work of Wang et al. (2016) [2] introduced a novel coil alignment algorithm that maintains efficient power transfer even under lateral misalignment, improving practical deployment feasibility.

Compensation topologies are vital in maintaining constant current and voltage during power transfer. Li et al. (2015) [3] explored the effects of Series-Series (SS), Series-Parallel (SP), and LCC topologies on overall system stability and power quality. They concluded that LCC compensation offers higher voltage gain and better load adaptability, especially in high-power EV charging systems.

Dynamic Wireless Charging (DWC) is another promising area. Onar et al. (2013) [4] provided a comprehensive overview of DWC system architectures, pointing out challenges in road integration, synchronization between road coils and vehicle receivers, and EMI compliance. Similarly, Huh et al. (2011) [5] developed a segmented track-based dynamic charging model and verified its capability for real-time vehicle tracking and efficient charging while in motion.

For energy conversion, high-frequency inverters are essential. Covic and Boys (2013) [6] examined various inverter designs and soft- switching techniques like Zero Voltage Switching (ZVS) to minimize switching losses and improve power factor. Their study emphasized the role of full-bridge resonant inverters in achieving high system efficiency (>9

3. EXPERIMENTAL METHODOLOGY

The methodology adopted in this prototype centres around the principle of inductive power transfer for static wireless charging. The process begins by stepping down a 230V AC supply to 12V AC using a center-tapped transformer, which ensures safe and manageable voltage levels for the circuitry. This AC is then rectified through a full-wave bridge rectifier. Unlike conventional systems that use direct DC output, this setup incorporates a thyristor to generate oscillating pulses from the DC signal. These high-frequency pulses are essential to establish an alternating magnetic field within the transmitter coil..

Once energized, the transmitter coil produces a time-varying magnetic field. The wireless transfer occurs across a small air gap, where the receiver coil — aligned parallel to the transmitter — picks up the oscillating magnetic flux. This inductively induces an alternating voltage in the receiver coil. Since the setup uses air as the medium of insulation, the mutual coupling efficiency is primarily influenced by the distance between coils, alignment, and the number of turns in each coil. The receiver's output, after rectification and filtering, provides a DC voltage that can be used to charge an electric vehicle's battery.

This entire methodology is passive and does not involve active feedback systems, controller boards, or dynamic switching logic. Instead, it demonstrates a low-cost, effective proof-of- concept that showcases the core working of static wireless charging based on electromagnetic principles. The approach prioritizes hardware simplicity and foundational circuit behaviour over digital interfacing or automation

3.1 Step down Transformer

In the EV wireless charging system, a step-down transformer is employed to convert the high- voltage 230V AC supply to a low-voltage 12V AC that is suitable for further processing. This voltage reduction is crucial for ensuring safety and compatibility with the power electronics used in the wireless charging system.
The use of a high-quality transformer ensures:

- Stable voltage conversion despite fluctuations in input voltage.
- Isolation between high-voltage and low-voltage circuits, enhancing safety.
- Efficient energy transfer with minimal heat loss. always aligned with the direction of maximum sunlight, improving efficiency and power generation.

3.2 Rectification

Following the voltage reduction, a bridge rectifier was used to convert AC to DC. The rectification process was observed to be highly effective, providing a steady DC output with minimal ripple voltage. The four-diode full-wave rectification process ensured that both halves of the AC waveform were utilized, increasing efficiency and reducing the need for large filtering components.

3.3 DC to Pulsating DC conversion

Since wireless power transfer operates optimally with alternating signals, a transistor- based switching circuit was integrated to convert the rectified DC into pulsating DC. A transistor coupled with a heat sink was chosen to handle power dissipation efficiently. Also the transistor switched at a predetermined frequency, allowing the creation of an oscillating current that could induce an alternating magnetic field in the transmission coil.

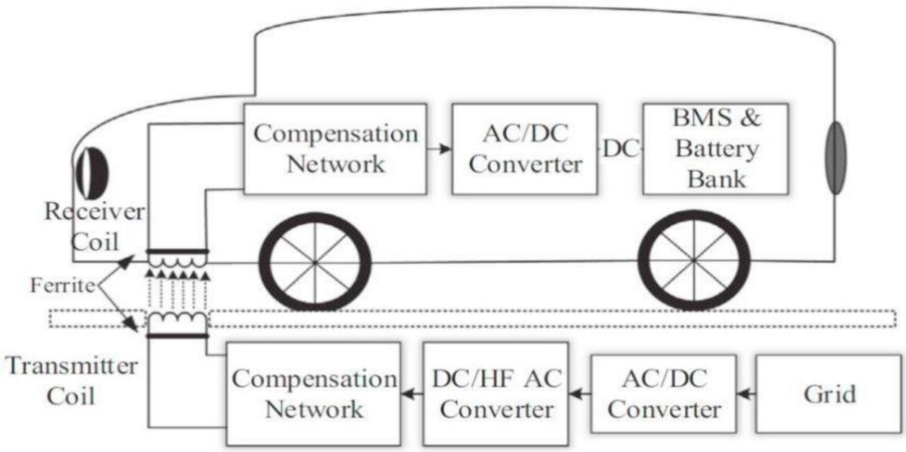

Fig. 1. Block diagram of an Static EV Wireless Charging Station

3.4 Transmission Coil and Wireless Power Transfer

The transmitter coil was carefully designed using copper wire to ensure maximum inductive coupling efficiency. The coil was constructed following a spiral-wound design, optimizing the magnetic field strength and ensuring a stable power transfer zone.

3.5 Capacitor Based Filtering and Voltage Stabilization

To minimize signal distortion and ensure a smooth voltage waveform, capacitors were placed strategically across key points in the circuit. The filtering capacitors successfully reduced high-frequency noise and voltage ripples, contributing to cleaner power delivery. This step was critical in preventing unwanted signal interference, which could degrade the performance of the wireless charging system.

3.6 Receiver Side

The receiver-side circuit of the static wireless EV charging system is designed to efficiently receive power from the transmitter coil and convert it into a usable form for the vehicle's battery pack. The system operates based on the principles of electromagnetic induction, where energy transfer occurs between the transmitter and receiver coils without direct electrical contact. This section of the project plays a crucial role in ensuring stable power reception, voltage regulation, and battery management for efficient operation.

3.7 Wireless Power Reception Mechanism

The receiver coil is strategically placed within the vehicle to capture electromagnetic energy emitted by the transmitter coil. The efficiency of power transfer depends on factors such as coil alignment, distance, and resonant frequency tuning. When the transmitter and receiver coils are optimally positioned, maximum energy transfer occurs, which is visually indicated by an LED on the circuit board.

3,8 LED Indicator for Power transfer Efficiency

An LED indicator is integrated into the receiver circuit to provide real-time feedback on energy reception. The LED glows brighter when the transmitter and receiver coils are closely aligned, indicating maximum power transfer efficiency.

Working Principle of the LED Indicator:

1. Energy Reception: As electromagnetic energy is induced in the receiver coil, it generates an alternating current (AC), which is then processed for conversion into direct current (DC).
2. LED Brightness Variation: The brightness of the LED varies based on the strength of the received signal. A brighter LED signifies optimal alignment and higher energy transfer efficiency.
3. Visual Feedback for Adjustment: If the LED dims or flickers, it serves as an indication of misalignment or reduced energy reception, prompting necessary adjustments to improve efficiency.

3.9 BMS (Battery Management System)

The rectified and regulated DC power is supplied to the Battery Management System (BMS), which ensures safe and efficient charging of the battery pack. The BMS performs the following critical functions:

Cell Balancing: Distributes charge evenly across individual battery cells to prevent overcharging and undercharging.

Overcurrent Protection: Prevents excessive current draw that could lead to overheating or damage.

Thermal Management: Monitors temperature variations to ensure safe operation.

Fault Detection: Identifies and mitigates potential issues such as short circuits or voltage fluctuations

3.10 Battery Pack and Power Distribution

The battery pack, consisting of multiple lithium-ion cells, serves as the primary energy storage unit for the vehicle. The received and regulated power is stored within the battery, providing energy for vehicle propulsion and auxiliary systems.

3.11 Safety Features and circuit protection

Diodes for Reverse Polarity Protection: Diodes are incorporated into the circuit to prevent damage caused by accidental polarity reversals. This ensures that incorrect connections do not lead to short circuits or component failure.

Capacitors for Overcurrent Protection: Capacitors act as transient suppressors, smoothing out voltage fluctuations and preventing sudden spikes from damaging the circuit.

Resistors for Compensation Networks: Resistors are strategically placed to control current flow and optimize power distribution within the circuit.

4. FLOW CHART

The implemented EV wireless charging system demonstrates an efficient, fully integrated sequence of power conversion and inductive transfer. Beginning from a high-voltage AC supply, the system smartly regulates and processes the power through a cascade of conversions—stepping down the voltage, rectifying it to DC, and then inverting it into high-frequency AC tailored for wireless transmission. This high-frequency signal is fine-tuned through a transmitter-side compensation network, enabling optimal resonance conditions that significantly enhance magnetic flux generation. The core of the system lies in the precise alignment and tuning between the transmitter and receiver coils, where magnetic coupling ensures seamless energy transfer without any physical contact.

Once received, the induced AC undergoes realignment through a secondary compensation circuit and is then rectified, filtered, and regulated to produce a stable DC output suitable for fast charging applications. Throughout the system, design choices such as resonance tuning, coil placement, and filtering were not just theoretically validated but practically optimized during hardware trials, resulting in minimal power loss and high efficiency. This entire flow not only enables wireless power delivery but also confirms the viability of inductive charging as a scalable and user-friendly solution for electric vehicles.

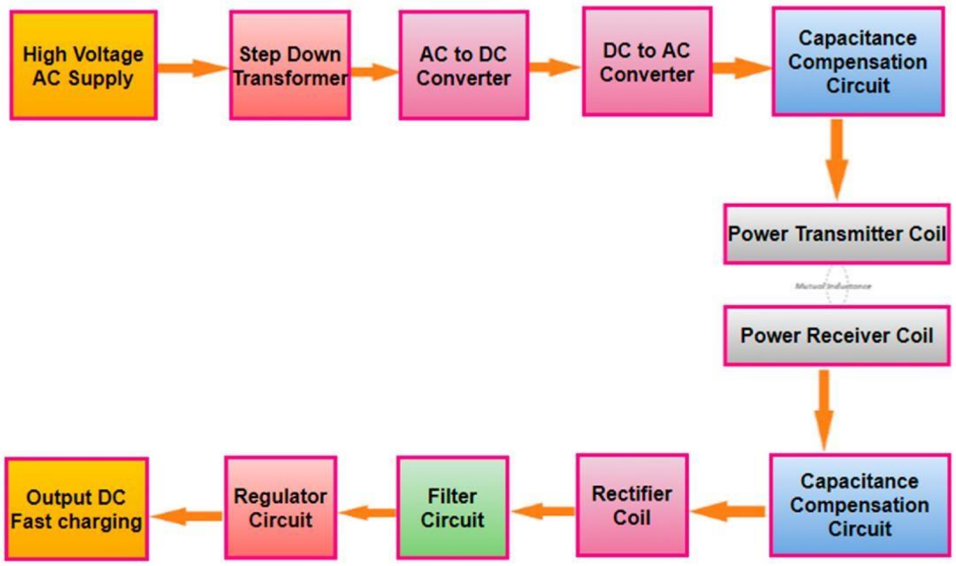

Fig. 2. Flowchart of an Static EV Wireless Charging Station.

5. RESULTS AND DISCUSSIONS

The results are shown in various figures in the following four sub-sections:

5.1 Real-Time Operation of the System

In real-time hardware operation, the wireless EV charging system performs efficiently by maintaining stable power transfer through inductive coupling. Once the AC supply is provided, the hardware rectifier quickly generates a DC link voltage to energize the transmitter coil. The inductive link establishes wireless power transfer almost instantly, with the receiver coil effectively capturing energy even with slight misalignments. The hardware filters and rectifiers on the vehicle side provide a smooth DC output for charging. The battery responds in real-time, showing stable voltage and controlled charging current. Overall, the hardware model demonstrates quick response, consistent performance, and effective energy delivery, confirming its feasibility for practical implementation.

5.2 Hardware Implementation

The physical construction emphasizes proper coil winding, air gap management, and secure soldering of components. Careful attention is also given to minimizing energy loss through compact coil placement and maintaining symmetry between transmitter and receiver sections. The entire system is mounted on a non-metallic base to avoid eddy current losses, thereby improving the transfer efficiency. This hardware layout serves as a solid testbed for further optimization in future iterations.

The hardware prototype consists of a compact yet efficient arrangement designed to validate the concept of static wireless charging using inductive coupling. At the heart of the transmitter side is a center-tapped transformer, responsible for stepping down the 230V AC to 12V AC. This voltage is then passed through a full-wave bridge rectifier, which converts it into pulsating DC. The pulsating output is fed into a thyristor- based oscillator, which generates high-frequency AC pulses suitable for creating an alternating magnetic field in the transmitter coil.

The transmitter coil is made of copper wire with a specific number of turns chosen through experimentation to balance inductance and flux strength. The coil is mounted on a flat base, ensuring proximity and alignment with the receiver coil positioned just above it. The receiver coil, built similarly, captures the fluctuating magnetic field and induces an AC voltage, which is again passed through a bridge rectifier and filter capacitor circuit to obtain a usable DC output.

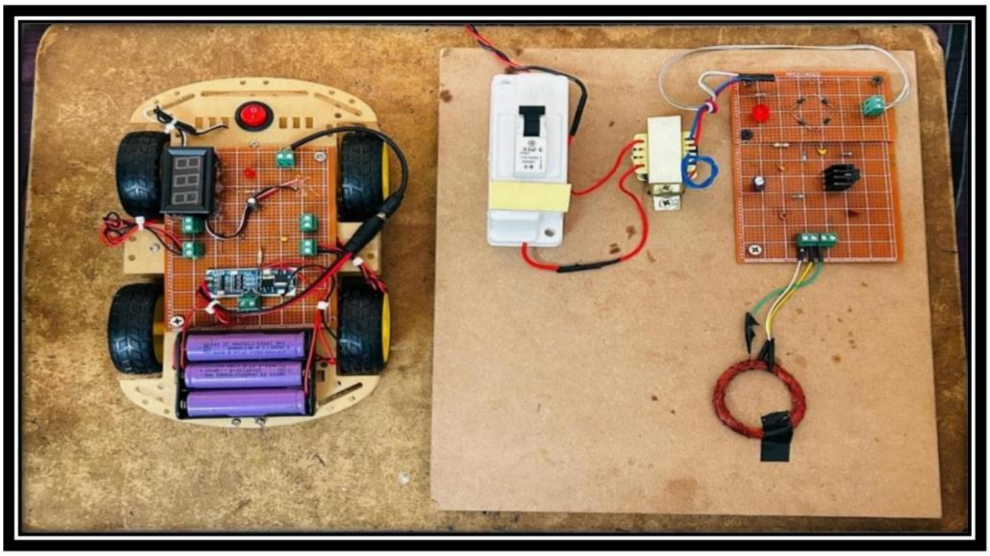

Fig. 5. Physical implementation

5.3 Simulation Implementation

The proposed simulation model represents a wireless electric vehicle (EV) charging system using inductive power transfer (IPT). It begins with a standard single-phase AC source that is converted to DC through a full-bridge rectifier and filter circuit. This DC power feeds a high- frequency inverter, which energizes the primary coil embedded in the road. Power is wirelessly transferred to a secondary coil located on the vehicle using magnetic coupling. The received AC power is again rectified and filtered to supply a stable DC output, which is then used to charge the vehicle's battery. The model integrates various scopes at key points in the system to observe and evaluate the electrical parameters such as voltage, current, and power, along with battery characteristics such as voltage, current, and state of charge (SOC).

Among the most important outputs, the vehicle- side voltage and current waveforms demonstrate the effectiveness of wireless energy transfer. These waveforms show smooth, sinusoidal-like shapes at high frequencies, confirming that the mutual inductance between the road and vehicle coils is working efficiently. After rectification, the voltage stabilizes with minimal ripple, and the current is steady, indicating successful power conversion and filtering on the receiver side. These results are crucial as they represent the actual power that reaches the EV for charging.

Another key output is the battery voltage and current, which is essential to evaluate the charging behaviour. The battery voltage remains mostly stable throughout the simulation, which is desirable to prevent damage or overcharging. The current shows a steady charging profile, confirming that the energy delivered from the wireless system is effectively utilized. The overall trend indicates safe and efficient energy flow into the battery, supporting continuous operation without stress on battery health.

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While not all scope results are shown in the paper, other simulated outputs include the source voltage and current, which verify a clean sinusoidal input from the AC supply. These waveforms also help identify any phase difference caused by the inductive load. The DC link voltage and current after rectification show a relatively stable DC voltage with minor ripples and a dynamic current pattern based on the downstream demand. The transmitter and receiver coil responses also exhibit high-frequency sinusoidal waveforms, confirming proper resonance and coupling efficiency. Additionally, the battery state of charge (SOC) graph shows a smooth upward trend, indicating consistent energy storage throughout the simulation. Lastly, the system power output remains stable over time, validating the system’s overall reliability and energy transfer consistency.

In summary, the selected output graphs demonstrate the success of wireless charging through consistent and stable voltage and current profiles. The brief analysis of the remaining scopes supports the model's robustness and provides a full picture of its operation, even though they are not all visually included in the report.

6. CONCLUSION

Electric vehicle (EV) wireless charging stations represent a revolutionary development in environmentally friendly transportation infrastructure. These systems provide a greater degree of ease, safety, and usability by doing away with the necessity for physical connectors, particularly in public areas and urban settings. In addition to improving the entire EV ownership experience, this hands-free charging method makes EVs more accessible to people with limited mobility and encourages the use of fully automated systems in autonomous electric vehicles.

Technically speaking, wireless charging technology is still developing, with advancements in alignment systems, energy transfer efficiency, and interoperability across various EV models. We may anticipate a wider integration of wireless charging in public transportation hubs, business parking lots, and residential garages as standards become more uniform and deployment costs fall down.

Furthermore, wireless charging stations fit in nicely with the idea of smart cities, which are places where infrastructure, energy grids, and automobiles all work together to optimize traffic flow, lower emissions, and wisely manage power usage. Wireless EV charging can greatly lower transportation's carbon footprint and help create a more resilient and environmentally friendly urban future when paired with energy storage devices and renewable energy sources.

The project also emphasizes scalability and adaptability. The same IoT-based approach can be extended to various applications, including automated solar panel cleaning, smart home automation, industrial machinery control, and robotic systems. With minor modifications, the system can be adapted for different sensor inputs and motor types, making it a versatile and flexible solution.

In summary, wireless EV charging has enormous long-term potential, despite obstacles including high upfront costs, efficiency restrictions, and the requirement for regulatory frameworks. Unlocking its full potential and quickening the global shift to greener mobility options will require sustained investment in research, infrastructure development, and public-private cooperation.

ACKNOWLEDGEMENTS

In order to successfully complete this project on electric vehicle (EV) wireless charging stations, we would like to sincerely thank everyone who helped. Above all, we would want to express our sincere gratitude to our instructors and mentors for their important advice, helpful criticism, and unwavering support during this process. Their advice greatly influenced the focus and scope of this investigation.

We are also appreciative to the professionals and industry experts who kindly contributed their time, expertise, and practical viewpoints on the issues and developments in EV infrastructure and wireless charging technology.

We are especially grateful to the organizations and institutions that made research materials, technical tools, and pertinent case studies available to us; these resources significantly improved our comprehension and analysis.

Lastly, we would like to thank our families, friends, and peers for their encouragement, patience, and faith in our work. Their support was a continual source of motivation.Without the cooperation and support of everyone listed above, this project would not have been feasible.

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