Wireless Charging of Battery in Electric Vehicle

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Abstract: This paper presents a new IoT-integrated wireless charging system designed for electric vehicles (EVs) that features an automated mechanical lifting system to adjust the alignment of the two coils. The innovation involved in the study is to create a wireless inductive charging system using a threaded screw-rod vertical movement to raise the transmitter coil mounted in the ground until it meets the receiver coil located underneath the EV chassis. This design reduces the distance between the coils and maximizes energy transfer efficiency. Users control the system via a mobile IoT app to automate the lifting and charging processes and improve ease of use. The system also integrates an independent IoT-enabled Battery Management System (BMS) that monitors battery temperature and smoke level and alerts the user if any overheating or dangerous conditions are detected. The proposed system can be adopted in public or commercial parking locations such as malls, hotels and theatres. Future work involves linking a system for using renewable solar energy by converting the solar DC to AC for wireless transmission, thus facilitating the use of sustainable green energy.

Keywords: Electric Vehicle, Wireless Charging, IoT, BMS, Lifting System, Inductive Power Transfer, Smart Parking.

1. INTRODUCTION

Electric vehicles are becoming increasingly popular due to their environmentally friendly operation and economical maintenance. Unfortunately, the increasing use of traditional plug-in charging systems can result in inconveniences, wear and tear of connectors, and less adaptability to the user. Wireless charging has emerged as an innovative solution for wireless, autonomous charging that reduces physical effort and the possibility of depletion. However, wireless systems are very sensitive to misalignment of the coils, which can impair charging efficiency.

This research tackles the problem by proposing a smart lifting mechanism to automatically align the transmitter and receiver coils for best power transfer. Unlike fixed-position inductive systems, this solution employs a motorized screw rod to lift the ground-embedded transmitter coil physically close to the vehicle's receiver coil. The method not only improves energy transfer efficiency but also provides system intelligence through IoT-based remote control and monitoring. In addition, it incorporates safety monitoring measures through a dedicated Battery Management System, which allows real-time monitoring of battery temperature and smoke levels, which can prevent accidents such as battery fires or thermal runaway. The integration of all these features into a compact, deployable system makes it ideal for large-scale applications in urban mobility infrastructure.

2. LITERATURE REVIEW

1. Wireless Power Transfer (WPT) for EVsYilmaz and Krein (2013) presented a seminal work on resonant inductive coupling for charging of electric vehicles. The authors stated that wireless WPT is made possible through enhanced efficiency, as well as larger systems beneficial to practical applications for EV technology.

Merits: High efficiency due to resonance; seminal for the next WPT systems.

Demerits: Little evidence for implementation in a real-world scenario; minimal focus on control and alignment methods.

2. SAE J2954 Wireless Charging StandardSAE J2954 is now a standard that will provide guidance to safely and interoperably charge light-duty EVs wirelessly. The standard outlines everything - power levels, field limits, and alignment tolerances.

Merits: Safety when charging, interoperability and readiness of industry.

Demerits: Will only address stationary charging, there are strictly enforced tolerances which can increase costs on systems.

3. Smart Charging via IoT (Park et al., 2022)The integration of IoT equipment in EV charging systems is a new direction in the field, providing real-time monitoring and predictive diagnostics, control of charging loads, and logic decisions for load balancing. Park et al. developed a system based on sensors that optimizes user control and grid interaction.

Mereits: Simplifies automation, remote control, and predictive maintenance.

Demerits: Dependent on stable networks; raises data privacy and security risks.

4. Mechanical Automation for Vehicle AlignmentAutomated garages employ pneumatic and hydraulic actuators for vehicle alignment, contributing to a significant improvement in the efficiency of EV maintenance and charging.

Merits: Increases accuracy and decreases the potential for manual mistakes.

Demerits: Expensive and complicated; limited scalability outdoors.

5.Research Gap: Integrated SystemsMost studies look at WPT, IoT, and mechanical automation as separated separate studies. Very few have examined combining them into a unified automated charging routine.

Merits: It highlights the appeal of integrated systems.

Demerits: Due to integrating across multiple domains, it is more complex to develop.

3. PROPOSED METHODOLOGY

The articulated wireless charging system is made up of four subsystems that are integrated together: an inductive power transfer system, a mechanical lifting system, an IoT actuation system, and a Battery Management System (BMS). Inductive Charging System: The inductive power transfer system uses two flat spiral coils. The transmitter coil (TX) is fixed to a lifting mechanism on the ground, and the receiver coil (RX) is affixed to the bottom of the EV. The TX coil will turn on when the vehicle is parked over the charging zone; and the TX coil will attempt to position itself as close as possible to the RX coil. The TX coil has alternating current flowing through it at a high frequency, which creates an alternating magnetic field. The magnetic field induces a voltage through the magnetic flux linkage with the RX coil, and charges the EV battery.

Mechanical Lifting System:

A vertically lifting platform is used to minimize energy waste and magnetic flux leakage due to air gaps or misalignment. The TX coil is fixed to a metallic base, which moves upwards and downwards in a lead screw and DC motor configuration. The screw rod provides significant torque and stability for the vertical motion, allowing for precise alignment with low power requirements. This entire assembly is housed in a strong case with adequate insulation allowing the assembly to be exposed to outdoor parking lot conditions with variable moisture and temperature. To increase safety, there is a separate Battery Management System (BMS) which includes a temperature sensor and smoke detector both interfaced to the IoT app. If the battery temperature exceeds a safe limit or smoke is detected, charging is automatically stopped, and an alerted user will also be notified. Furthermore, the system is designed to facilitate the ability to charge electric vehicles (EVs) in public or commercial parks, and to allow the EV to be charged automatically and remotely requiring minimal user intervention. One of the future upgrades is to power the system with solar panels that convert DC to AC so that the electric vehicle can be wireless charging in a clean renewable way.

4.EXPERIMENTAL RESULTS

The validation of the established wireless charging system was accomplished by systematically evaluating its performance. A prototype was built using a 12V dual-coil wireless power module, a screw-driven lifting platform, and an ESP32 microcontroller configured for IoT communication. The efficiency of the system was tested under static (not lifted) and dynamic (lifted) conditions to evaluate energy efficiency with respect to the alignment with its lifting capability and the responsiveness with the Battery Management System (BMS).

In the first instance, the apparatus was operated in a static mode with no lifting activity. Under these conditions the air gap between the transmitter (TX) and receiver (RX) coils was approximately 8 cm. This was anticipated to have low power transfer efficiency. The measurements showed that around 52% of the input power was transferred to the vehicle battery, which included substantial power loss due to low magnetic coupling, stray fields, and misalignment of the two coils.
Conversely, implementing the lever-arm lift mechanism lifted the TX coil to within 1-1.5 centimeters of the RX coil via the screw sod driven system. This position significantly increased the alignment of the coil positions of the TX and RX coils, while concurrently decreasing the magnetic field leakage. With these parameter optimally adjusted, the

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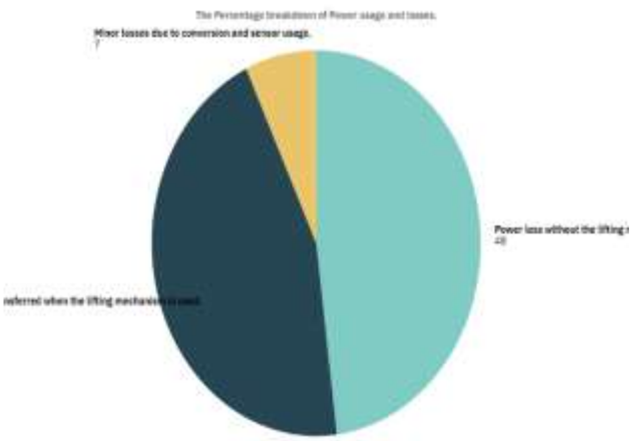
charging efficiency increased to a value of approximately 91%. This indicates that proximity between coils is required to effectively transfer energy. The mechanical action of decreasing distance between the coils optimally increased inductive coupling such thatcharging occurred at near-lossless conditions.

The percentage breakdown of power usage & losses.



To visualize the results obtained during this experiment, we provide a pie chart representation that illustrates energy disbursement while charging. Based on the pie chart, 45% of the total power was consumed routinely and effectively with the lifting mechanism employed. In contrast, and in the un-optimized or no-lift regime, 48% of the power was dissipated, while 7% was attributed to other minor power losses including, power conversion efficiency, and power used by the sensors when engaged. This further highlights the design philosophy of the aim of the system: to encourage efficient wireless charging through mechanical adaptability.

In addition to power transfer testing, the prototype was also tested for Battery Management System (BMS) functionality. A digital temperature sensor was attached to the battery case and experienced controlled heating using a heat gun. Whenever the temperature reached 45°C, the IoT application warned us of the danger and stopped the entire charging cycle, demonstrating an early safety measure. In another test, we used a device that generates smoke near the battery and the smoke detect sensor was able to identify the danger, again stopping the charging cycle and alerting us through the mobile app.

The tests demonstrate that the system not only improves wireless power transmission, but it also includes a intelligent safety precautions for real-time monitoring of battery health. With the IoT prompted feedback, automatic coil alignment, and environmental sensing; the system is a smart, next-generation EV charging solution for commercial parking spaces, smart cities, and sustainable energy stations.

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