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Solar Based Wireless Energy Transfer on Road

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Abstract: ***The rapid transition from internal combustion engine vehicles to electric vehicles (EVs) has significantly increased the demand for efficient and user-friendly charging solutions. Wireless Power Transfer (WPT) technology offers a promising alternative to conventional plug-in charging by enabling contactless energy transfer through inductive coupling. In this system, the EV can be charged simply by positioning it over a charging pad, eliminating the need for physical connectors and human intervention. The concept of wireless power transmission, originally proposed by Nikola Tesla, has evolved significantly with advancements in magnetic resonance–based WPT. Modern WPT systems can achieve high power transfer efficiency (above 90%) over distances ranging from several millimetres to a few hundred millimetres, making them suitable for both stationary And dynamic EV charging applications. This paper presents an overview of WPT technologies applicable to EV charging and highlights their potential to reduce charging time, enhance safety, and improve user convenience. Wireless EV charging is expected to play a crucial role in the future development and widespread adoption of electric mobility.***
Key points: Solar energy, Efficient, Dynamic, Transmission etc.

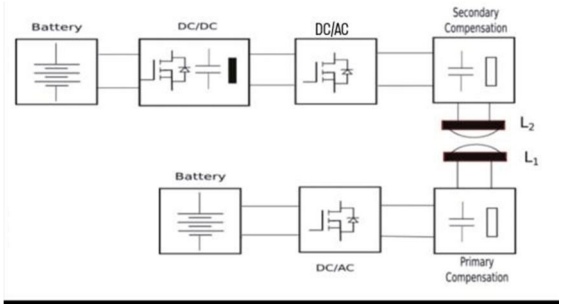
I. INTRODUCTION

We live in a world of technological advancement. New technologies emerge each and every day to make our life simpler. Despite all these, we still rely on the classical and conventional wire system to charge our everyday electronic gadgets.

The conventional wire system creates a mess when it comes to charging several electric vehicles simultaneously. It also takes up a lot of electric sockets at the charging port. At this point, a question might arise. ―What if a single technology can be used to charge these electric vehicles simultaneously without the use of wires and not creating a mess in the process? We gave it a thought and came up with an idea. The solution to this problem is inductive coupling, a simple and effective way of transferring power wirelessly.

Road transportation is the majorly used transportation in the entire world. Usage of the car has drastically increased and the need for petrol and diesel has increased. So recently, Electric vehicles (EVs) are becoming popular, as they decrease reliance on fossil fuels and reduce greenhouse emissions. The problem of the Electric Vehicle is nothing else but the electricity storage technology, which is the major drawback today due to its unsatisfactory energy density, limited lifetime, and high cost. So, our project proposes a novel idea to charge the Electric vehicle wirelessly through the inductive power transfer principle using the transmitting and receiving coil while simultaneously decreasing the battery size and improving the convenience and without the requirement of the cable. The electric vehicle can be charged both by the static wireless power transmission (SWPT) and dynamic wireless power transmission (DWPT) method.

II. LITERATURE REVIEW



Several studies have discussed Wireless Power Transfer (WPT) for Electric Vehicles (EVs). Supriyadi and Edi Rakhman [1] analyzed the effect of wire diameter and number of coil turns on power transfer. Their study showed that increasing the number of windings increases transferred power. Using a 0.5 mm enameled copper wire with 26 turns at 470 kHz, an efficiency of about 1.51% was obtained at a distance of 1 cm, which was sufficient to power a 1 W LED.

UthayaBanu and Arunkumar [2] reviewed different WPT technologies used to reduce flux leakage and improve efficiency in EV charging systems while integrating renewable energy sources. Yatnalkar and Narman [3] discussed the importance of wireless charging in reducing EV charging time and highlighted key parameters such as coil distance, alignment, battery capacity, and charging duration. Recent research also focuses on integrating IoT with EV charging and parking systems. IoT enables monitoring of charging status, storing data on cloud platforms, and accessing information through smartphones, making the system more user-friendly and efficient [4]–[6]. In addition, smart parking systems combined with EV charging infrastructure can optimize parking space usage and charging schedules, improving energy management and user convenience [7].

Wireless charging techniques such as inductive and resonant coupling are widely used due to their reliability, safety, and ease of operation. However, most wireless charging systems are suitable when vehicles are stationary, such as in parking areas. Smart parking systems using IoT can further improve efficiency by enabling parking slot monitoring and reservation while reducing fuel consumption and urban pollution [8]–[9].

III. PROBLEM STASTMENT

The rapid growth of Electric Vehicles (EVs) has increased the demand for reliable, efficient, and sustainable charging infrastructure. Conventional plug-in charging methods require long charging times, frequent human intervention, and dedicated charging stations, which limit vehicle mobility and create range anxiety for users. Although wireless power transfer (WPT) offers improved safety and user convenience, its application is mostly restricted to stationary vehicles in parking areas.

At the same time, the increasing dependence on grid-based electricity for EV charging places additional stress on power systems and often relies on non-renewable energy sources. Solar energy, being clean and renewable, has significant potential to support EV charging; however, its integration with dynamic wireless charging on roadways is still limited and underdeveloped.

The main challenges in implementing a solar-based wireless energy transfer system on roads include low power transfer efficiency, coil misalignment due to vehicle movement, limited charging distance, high system cost, and lack of standardized infrastructure. Additionally, real-time energy management and continuous power delivery while vehicles are in motion remain critical technical issues. Therefore, there is a need to design and develop an efficient solar-powered wireless energy transfer system embedded in road infrastructure that can charge EVs dynamically or semi- dynamically. Such a system should reduce dependency on conventional charging stations, improve driving range, utilize renewable energy effectively, and support future smart transportation systems in an energy-efficient and sustainable manner.

IV. SCOPE OF THE PROJECT

The scope of this project is to design and demonstrate a solar-powered wireless energy transfer system for electric vehicles (EVs) using inductive coupling technology. The system aims to provide an alternative charging method that reduces dependence on conventional plug-in charging stations and promotes the use of renewable energy. The project focuses on generating electrical energy from solar panels, storing it in a battery, and transferring the energy wirelessly through transmitter coils embedded in the road. A receiver coil mounted on the vehicle receives the power and converts it into usable electrical energy to charge the battery or operate electrical loads. The proposed system mainly covers short-distance wireless power transfer, system efficiency analysis, and demonstration of charging capability when the vehicle is positioned over the charging area. It also includes the study of coil design, alignment, operating frequency, and transfer distance to improve energy transfer efficiency. Additionally, the project explores the integration of renewable energy with wireless charging infrastructure, which can help reduce carbon emissions, improve energy utilization, and support future smart transportation systems. However, the project is limited to prototype-level implementation and experimental analysis. Large- scale road infrastructure deployment, high-power commercial EV charging, and advanced grid integration are beyond the scope of this study.

V. METHODOLOGY



1) Solar Energy Generation Solar panels are installed near or alongside the roadway to capture solar energy. The generated DC power is regulated using a charge controller to ensure stable voltage and current output. This step enables the utilization of renewable energy as the primary power source for the system.
2) Energy Storage System The regulated solar energy is stored in a rechargeable battery unit. This storage system ensures continuous power availability during low solar irradiance conditions and provides a stable supply for wireless power transmission.
3) Power Conditioning and Conversion The stored DC power is converted into high-frequency AC power using an inverter or oscillator circuit. High-frequency operation is essential to improve inductive coupling efficiency between the transmitter and receiver coils.
4) Wireless Power Transmission Transmitter coils are embedded beneath the road surface and energized with high-frequency AC power. When an EV equipped with a receiver coil passes or stops over the charging zone, power is transferred wirelessly through inductive or resonant coupling without physical contact.
5) Wireless Power Reception The receiver coil mounted on the EV captures the magnetic field generated by the transmitter coil. The received AC power is rectified and filtered to obtain usable DC power suitable for battery charging or auxiliary loads.
6) Monitoring and Control (Optional) Basic monitoring units can be integrated to measure parameters such as voltage, current, power transfer efficiency, and charging status. This data can be used for system optimization and future integration with smart transportation or IoT-based platforms.
7) Performance Evaluation The system performance is evaluated based on parameters such as power transfer efficiency, transmission distance, coil alignment, and charging capability. Experimental results are analyzed to validate the feasibility of solar- based wireless energy transfer on roads.

VI. WORKING PRINCIPLE AND PROCESS

The proposed system operates on the principle of electromagnetic induction, where electrical energy is transferred wirelessly from a transmitting coil embedded in the road to a receiving coil mounted on the electric vehicle (EV). The system uses solar energy as the primary power source, making the charging process renewable and environmentally friendly.
Solar panels generate DC electrical energy from sunlight. This energy is regulated and stored in a battery system. The stored DC power is then converted into high-frequency AC power, which is supplied to the transmitter coil. When alternating current flows through the transmitter coil, it produces an alternating magnetic field. This magnetic field induces an electromotive force (EMF) in the receiver coil placed within the magnetic field range, enabling wireless power transfer without physical contact.

A. *Process Description*

1) Solar Energy Collection Solar panels installed near the roadway capture sunlight and convert it into DC electrical energy.
2) Energy Regulation and Storage A charge controller regulates the solar output and stores the energy in a battery to ensure continuous power availability.
3) High-Frequency Power Conversion The stored DC power is converted into high-frequency AC power using an inverter or oscillator circuit to enhance inductive coupling efficiency.
4) Wireless Power Transmission The high-frequency AC power energizes the transmitter coil embedded beneath the road surface, generating an alternating magnetic field.
5) Wireless Power Reception When an EV passes over or stops above the charging zone, the receiver coil mounted on the vehicle captures the magnetic field and induces AC voltage.
6) Rectification and Battery Charging
7) The received AC power is rectified, filtered, and regulated into DC power, which is used to charge the EV battery or supply onboard electrical loads.
8) System Monitoring (Optional) Electrical parameters such as voltage, current, and charging status can be monitored to ensure safe and efficient operation.

VII. RESULTS OR APPLICATION

The proposed solar-based wireless energy transfer system was successfully designed and tested at a prototype level. Experimental results demonstrate that electrical power can be transmitted wirelessly from the road-embedded transmitter coil to the receiver coil mounted on the electric vehicle without physical contact.

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The system achieved stable power transfer over a short air gap, sufficient to operate low-power electrical loads such as LEDs and small DC motors, validating the feasibility of the wireless charging concept. The use of high-frequency AC excitation improved coupling efficiency between the coils. Proper alignment between transmitter and receiver coils resulted in higher power transfer efficiency, while misalignment reduced the received power.

The integration of solar energy reduced dependency on grid power and ensured clean energy utilization. Energy storage units enabled continuous operation even during low sunlight conditions. The overall results confirm that solar- powered wireless charging on roads is technically feasible for stationary or low-speed vehicle charging scenarios.

A. Applications

The proposed system can be applied in various real-world scenarios, including:

1) Smart Roads Road embedded with wireless charging coils can provide energy to EVs while parked or moving at low speeds.
2) Parking Areas and Toll Plazas Vehicles can be charged wirelessly while waiting or parked, improving charging convenience.
3) Electric Bus Stops Wireless charging at bus stops can extend driving range without long charging downtime.
4) Campus and Industrial Vehicles Suitable for charging low-speed EVs used in campuses, factories, and warehouses.
5) Renewable Energy-Based Charging Infrastructure Supports sustainable transportation by integrating solar energy with EV charging systems.
6) uture Smart Transportation Systems Acts as a foundation for intelligent and automated EV charging network

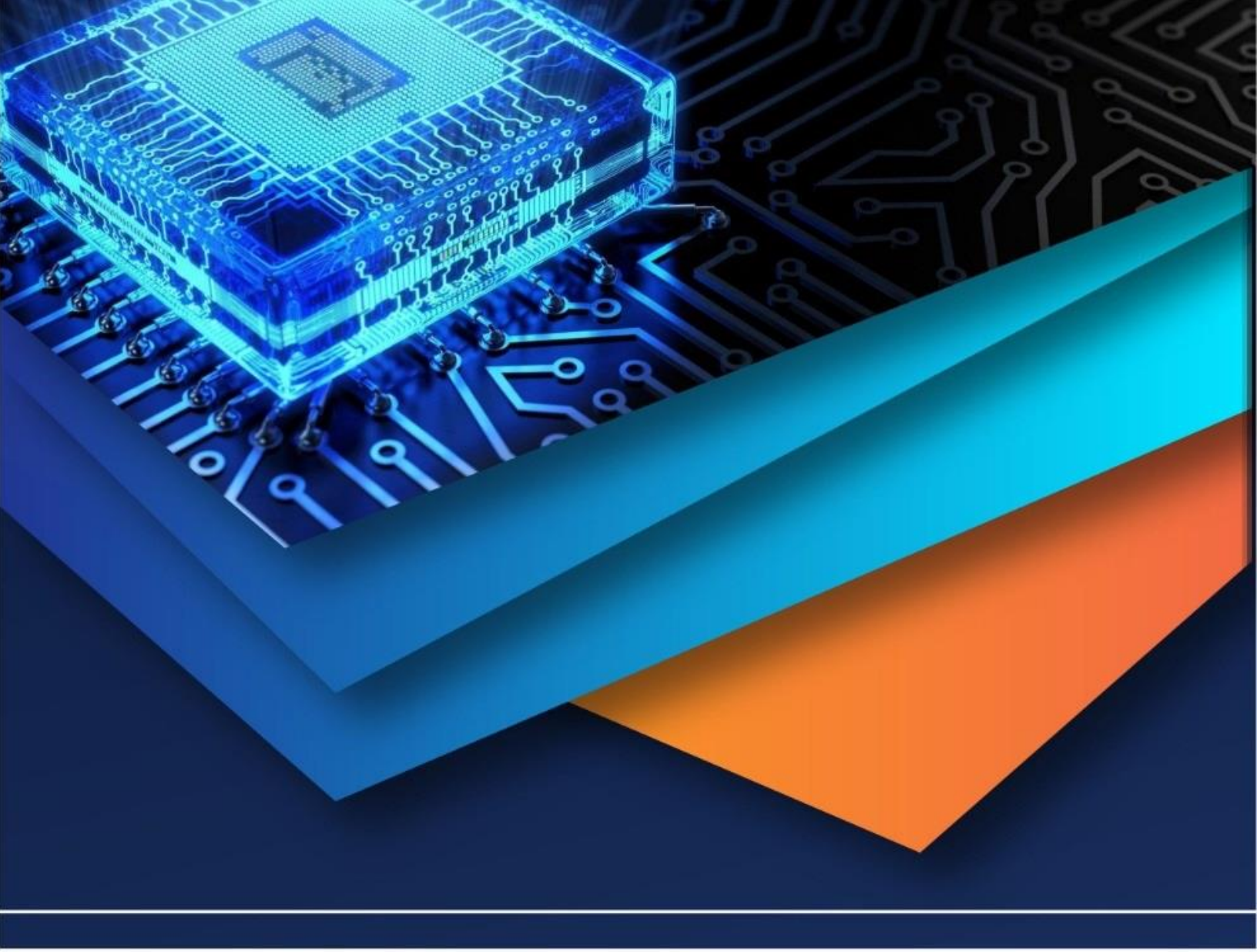
VIII. CONCLUSION

The proposed solar-based wireless energy transfer system for electric vehicles demonstrates an innovative and sustainable approach to EV charging. The system utilizes solar energy as a renewable power source and transfers electrical energy wirelessly through inductive coupling between transmitter and receiver coils. This method eliminates the need for physical cables and improves user convenience and safety. The experimental prototype confirms that wireless power transfer is feasible for short- distance charging applications. The integration of solar panels with wireless charging infrastructure helps reduce dependency on conventional grid power and promotes the use of clean energy in transportation systems. Although the system currently operates at a prototype level with limited power transfer distance and efficiency, it shows strong potential for future development. With further improvements in coil design, power electronics, and alignment techniques, the efficiency and performance of the system can be enhanced. Therefore, the solar-based wireless energy transfer on road concept can play an important role in the development of smart transportation infrastructure, enabling efficient, eco-friendly, and convenient charging solutions for the growing number of electric vehicles.

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