Wireless Road Charging For Electric Vehicles

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Abstract- *Electric vehicle (EV) usage is growing, making smooth, effective, and continuous charging solutions increasingly important. Conventional plug-in charging stations frequently force cars to stop for long periods of time, which adds to EV owners' range anxiety and causes delays. These restrictions are addressed with wireless road charging, sometimes referred to as Wireless Power Transfer (WPT), which uses wireless infrastructure installed in the road to allow cars to charge dynamically while driving.The suggested method offers a clever and creative way to mimic actual EV charging situations by fusing wireless charging technology with a robotic car that is operated via Bluetooth. The Vehicle Charging Unit (VCU) and the Vehicle Controlling Unit (VCU) are the two main parts of the system. The charging unit transforms the electromagnetic field into usable electric power for storage by using an inductive coupling to transfer energy from coils buried beneath the road surface to the vehicle's receiving coil.*

Keywords- Wireless Power Transfer (WPT), Electric Vehicle (EV) Charging, Dynamic Charging, Inductive Coupling

I. INTRODUCTION

By providing a cleaner, more environmentally friendly substitute for conventional internal combustion engine vehicles, electric vehicles, or EVs, are completely changing the transportation sector. The discomfort and downtime of static charging stations, however, are significant obstacles to the mainstream adoption of EVs. The lengthy stops and charging times required by these stations can interfere with travel schedules and cause "range anxiety," a prevalent worry among EV users about how far their vehicle can go between charges.Wireless power transfer (WPT) technology is becoming more and more recognized as a revolutionary way to get around these restrictions. WPT uses an inductive link between coils buried beneath the road and receiver coils mounted within the car to allow EVs to charge wirelessly while driving. By removing the need for frequent pauses, this type of dynamic charging greatly enhances the user experience and makes long-distance travel more feasible. In addition to improving convenience, the system promotes energy efficiency and the growth of intelligent transportation infrastructure.Wireless power transfer (WPT) technology is becoming more and more recognized as a revolutionary way to get around these restrictions. WPT uses an inductive link between coils buried beneath the road and receiver coils mounted within the car to allow EVs to charge wirelessly while driving. By removing the need for frequent pauses, this type of dynamic charging greatly enhances the user experience and makes long-distance travel more feasible. In addition to improving convenience, the system promotes energy efficiency and the growth of intelligent transportation infrastructure.

1.1 WIRELESS POWER TRANSFER (WPT)

A technology known as wireless power transfer (WPT) makes it possible to move electrical energy between locations without the use of conventional conductive lines or cables. This is accomplished by using electromagnetic fields—such as electric fields, resonance, or magnetic induction—to transfer power. An electromagnetic field produced by a power source (transmitter) is picked up by a receiver at the load side of a conventional WPT system. The receiver then transforms the energy it has captured back into electrical power.From small-scale charging devices like smartphones and electric toothbrushes to bigger systems intended to power cars and other high-power equipment, this technology has been investigated for a wide range of uses. The removal of physical connectors, decreased wear and tear, and a cleaner, safer environment due to the decreased risks of exposed electrical wire are just a few benefits of WPT systems. WPT is an important field for study and development because to its efficiency and convenience potential, particularly as the need for more adaptable and dependable energy transfer techniques grows worldwide.

1.2 ELECTRIC VEHICLE (EV) CHARGING

The process of adding electrical energy to an electric vehicle's battery is known as electric vehicle (EV) charging. Electric vehicles use electricity stored in a battery pack to power an electric motor, in contrast to conventional vehicles that use fuel and combustion engines. The viability of EVs as a popular mode of transportation is directly impacted by charging infrastructure, making it an essential component of the electric car ecosystem. To meet the diverse needs of EV customers, several kinds of charging systems have been created.These range from public charging networks that offer fast-charging alternatives at key places to home charging stations where people power their cars overnight. The charging technique, power output, and technology employed for the charger-to-vehicle connection all affect how efficient an EV charging system is. The goals of advancements in EV charging technology are to increase charging rates, prolong battery life, and provide more adaptable solutions that can handle the increasing number of EVs. The creation of effective, affordable, and easily available EV charging systems is viewed as a key component in advancing sustainable transportation as worries about climate change and the depletion of fossil fuels grow.

1.3 DYNAMIC CHARGING

In contrast to traditional charging techniques, which need the gadget to stay still in order to receive power, dynamic charging allows energy to be transferred to a vehicle or device while it is moving. In order to continually power moving machines or vehicles, this concept makes use of the idea of embedding energy-transmitting systems along a path or route, such as highways, rails, or conveyor belts. Because energy is seamlessly supplied as movement occurs, dynamic charging eliminates the need for frequent stopping or waiting for recharging.Since electric cars would no longer have to stop for extended charging times, this might greatly lessen the difficulties caused by range restrictions. Typically, dynamic charging systems use methods that transmit energy through electromagnetic fields, such as capacitive charging or inductive coupling. In addition to improving the operational effectiveness of transportation networks, this strategy may transform urban infrastructure by establishing "smart" roadways that can draw power from the ground directly. This is seen as a progressive solution to issues like the length of the existing charging procedures and the accessibility of charging infrastructure.

1.4 INDUCTIVE COUPLING

Using two coils, one serving as a transmitter and the other as a receiver, inductive coupling is a wireless energy transmission technique. The process starts when a magnetic field created by an alternating current in the transmitting coil causes a current to be induced in the surrounding receiving coil. This technique is based on the electromagnetic induction principle, which states that a change in the magnetic field causes a nearby conductor to experience a voltage. The coils' alignment, size, and proximity all affect how effective an inductive connection is.Applications for inductive coupling are numerous and include industrial equipment, medical gadgets, and wireless charging solutions for small electronics. Among its advantages are the removal of the necessity for direct physical connections, the reduction of connector wear and tear, and the reduction of safety risks related to exposed wires. Because there is no physical contact, the technology is also more resilient, making it appropriate for usage in settings where traditional connectors can be prone to damp, corrosion, or filth. Inductive coupling is being investigated for larger-scale applications, such as charging electric vehicles or powering remote equipment in difficult situations, since the need for simplicity and safety in energy transfer keeps increasing.

II. LITERATURE REVIEW

The fundamental ideas of Wireless Power Transmission (WPT) and its increasing significance in contemporary energy systems are put forth by Patakula Eekshita et al. in this work. They go over how WPT has evolved historically, emphasizing important technologies like capacitive and inductive coupling, and they look at how they are used in fields like industrial automation, home electronics, and electric cars. The study addresses issues including energy efficiency and alignment sensitivity while highlighting the advantages of wireless systems, such as lower maintenance costs and more convenience [1].

In this work, Muhammad Furqan Haider et al. suggest using magnetic resonance coupling to accomplish effective mid-range wireless power transfer. In contrast to conventional inductive techniques, the study shows that resonant frequency matching between the transmitter and reception coils greatly increases energy transfer rates and for more flexible alignment. With an emphasis on safety, effectiveness, and scalability, applications are investigated in domains such consumer electronics, medical devices, and electric car dynamic charging [2].

In this work, Sagolsem Kripachariya Singh et al. have suggested a thorough analysis of the most recent developments and new directions in wireless power transmission (WPT) technology. They go over several WPT methods, such as inductive, capacitive, resonant, and microwave-based systems, and talk about their benefits, drawbacks, and practical uses in industries like renewable energy, healthcare, and transportation. In order to promote further innovation in the industry, the study also identifies important obstacles like cost, efficiency, and electromagnetic interference [3].

In order to facilitate effective energy transfer over short to medium distances, Qiang Wang et al. have presented a wireless charging system based on coupled magnetic resonators. Because it enables dynamic charging without the need for physical hookups, the system is especially well-suited for electric cars (EVs) traveling over charging lanes. The authors offer optimization techniques for coil design, resonant frequency tuning, and power management circuits after analyzing the system's performance under various alignment and distance situations [4].

In this research, Vikash Choudhary et al. argue that modern society is critically dependent on electricity and imagine a time where easy wireless energy access will be the standard. They draw attention to the drawbacks of wired infrastructure and promote wireless power transmission (WPT) as a game-changing approach to energy delivery in the future. This work provides a motivating background for future WPT research, especially in distant and mobile applications like space-based solar power and electric vehicle charging [5].

III. EXISTING SYSTEM

Static plug-in charging stations are the mainstay of the current electric vehicle (EV) charging infrastructure, requiring cars to stop and connect to a power source for a predetermined amount of time in order to recharge their batteries. Fast-charging stations have been developed to shorten charging times, but they still need cars to stop and sit still. Users find this approach inconvenient, particularly when traveling long distances, and it exacerbates range anxiety. Furthermore, the requirement for frequent charging pauses strains the infrastructure for charging EVs and restricts their scalability in places where there aren't enough stations.With their reliance on stationary inductive charging pads that need precise parking over a charging coil, current wireless charging options are also in their early stages or restricted application. These systems still operate in a static mode and do not support in-motion or dynamic charging, while doing away with cords and connectors. In addition, there are still a number of important technical problems with current systems, including alignment problems, power transfer efficiency, and infrastructure expenses. More sophisticated and adaptable charging systems that can function while cars are moving, providing real-time energy transfer and enhancing the entire EV user experience are therefore becoming more and more necessary.

IV. PROPOSED SYSTEM

By implementing Wireless Road Charging, which allows EVs to charge while driving, the proposed system seeks to completely transform EV charging. Inductive or magnetic resonance coupling is used in Wireless Power Transfer (WPT) technology to accomplish this. Receiver coils in the EV pick up the electromagnetic field produced by transmitting coils buried beneath the road. The battery is then charged by converting the received energy into electrical power. The drawbacks of static charging, like the requirement to pause at charging stations and the resulting range anxiety, are successfully addressed by this technology.The system has a Vehicle Charging Unit (VCU) and a Vehicle Controlling Unit (VCU) to model and test this technology. The task of wirelessly transferring energy from the road surface to the driving vehicle falls to the Vehicle Charging Unit. When the car passes over a transmitting coil, a magnetic field is created. This energy is captured by the vehicle's receiver coil, which regulates and stores it to simulate the dynamic charging of a true EV.In contrast, the Vehicle Controlling Unit is a robotic car that can be operated over Bluetooth and mimics an electric vehicle. It has two motor drivers and motors that allow for directional, forward, and backward motion. The VCU is configured to adhere to a specific charging lane that has transmitting coils integrated in it. Researchers can examine the behavior and energy reception of the vehicle while it moves in real time over the charging path by controlling its movement remotely with a mobile application or Bluetooth-enabled controller.All things considered, the suggested solution offers a clever, effective, and environmentally friendly substitute for conventional charging infrastructure. It shows that dynamic charging options for the future of electric transportation are feasible by combining WPT technology with autonomous vehicle control. This strategy can encourage continuous EV operation, lessen the need for massive charging stations, and open the door for intelligent transportation systems. Additionally, it lays the groundwork for sophisticated urban mobility frameworks in which the roadways themselves might act as sources of energy for cars that are constantly in motion.

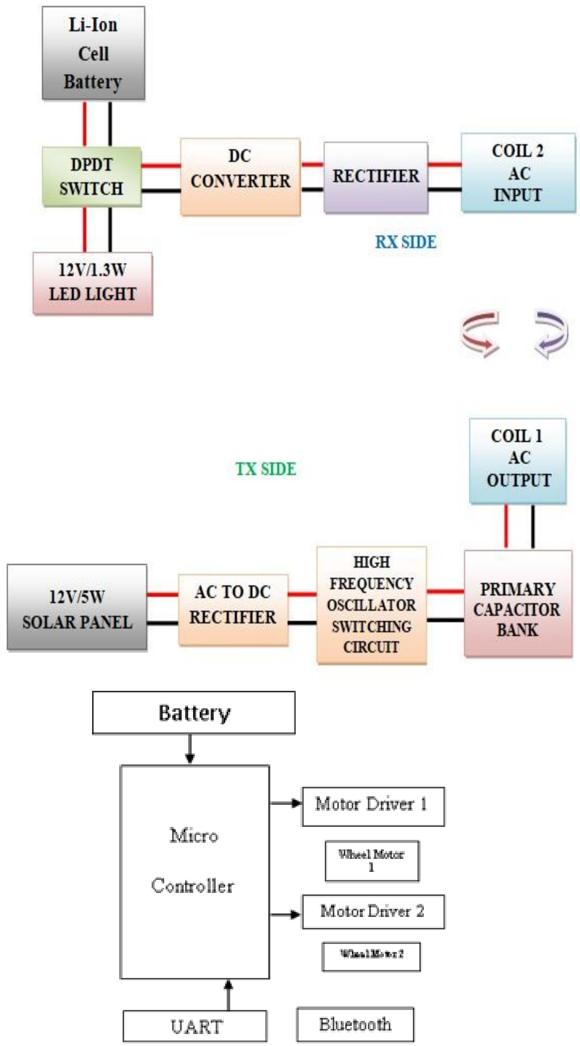

FIGURE 1. BLOCK DIAGRAM

V. WORKING

ARDUINO

The ATmega328 serves as the foundation for the Arduino Uno microcontroller board. It features a 16 MHz crystal oscillator, 6 analog inputs, 14 digital input/output pins (six of which can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. Everything required to support the microcontroller is included; to get started, just use a USB cable to connect it to a computer or power it with a battery or AC-to-DC adapter. The FTDI USB-to-serial driver chip is not used by the Uno, which sets it apart from all previous boards. Rather, it has the Atmega8U2 configured as a serial-to-USB converter. In Italian, "uno" means "one," and it was chosen to commemorate the impending introduction of Arduino 1.0.

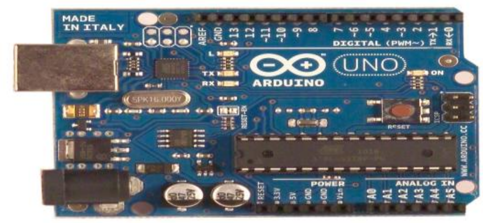

FIGURE 1. ARDUINO

POWER

An external power source or a USB connection can be used to power the Arduino Uno. An automatic power source selection is made. A battery or a wall-wart AC-to-DC adapter can supply external (non-USB) power. To connect the adapter, insert a 2.1mm center-positive connector into the power jack on the board. It is possible to insert battery leads into the POWER connector's Gnd and Vin pin headers. An external power source between 6 and 20 volts can power the board. However, if the voltage is less than 7V, the board can become unstable and the 5V pin might deliver less than 5 volts.

BATTERY

A battery is a device that transforms chemical energy stored in one or more electrochemical cells into electrical energy. Batteries have become a widespread power source for many home and industrial applications since Alessandro Volta invented the first battery (also known as a "voltaic pile") in 1800, and particularly after the technically advanced Daniell cell was developed in 1836. An estimate from 2005 states that the global battery market is worth US$48 billion annually and is growing at a pace of 6% annually. Primary batteries, also known as disposable batteries, are made to be used just once before being thrown away, but secondary batteries, also known as rechargeable batteries, are made to be recharged and used often.

FIGURE 2. BATTERY

UART

The computer hardware device known as a universal asynchronous receiver/transmitter, or UART /ˈjuːɑrt/, converts data between parallel and serial formats. Communication standards like TIA (previously EIA)RS-232, RS-422, or RS-485 are frequently used with UARTs. The universal designation means that the transmission speeds and data format can be changed. A driver circuit outside of the UART controls the electric signaling levels and techniques (differential signaling, etc.).Typically, a UART is a single integrated circuit (IC) or a component of an IC that is used for serial communications via a serial port on a computer or peripheral device. Nowadays, UARTs are frequently seen in microcontrollers. Two UARTs are combined into a single chip by a dual UART, or DUART. An example of an octal UART, or OCTART, is the NXP SCC2698, which integrates eight UARTs into a single device. A UART that can also communicate synchronously is now a common feature of many contemporary integrated circuits (ICs); these devices are known as USARTs (universal synchronous/asynchronous receiver/transmitter).

L293D MOTOR DRIVER IC

The most popular driver for bidirectional motor driving applications is the L293D H-bridge driver. A DC motor can run in either direction thanks to this L293D IC. Two DC motors can be controlled concurrently in any direction via the 16-pin integrated circuit L293D. It indicates that a single L293D IC can be used to operate two DC motors. since it contains two H-Bridge circuits. The L293D is also capable of driving large, silent motors. H-bridge motor control circuits can be made in a number of methods, including with transistors, relays, and L293D/L298. We shall first examine the definition of the H-Bridge circuit before delving into specifics.

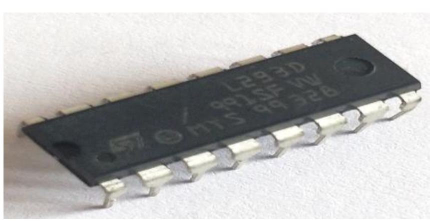

FIGURE 3. MOTOR DRIVER

DC MOTOR

Simply put, a DC motor is an apparatus that transforms electrical energy, or direct current, into mechanical energy. In addition to being crucial for the industry today, engineers should carefully examine the DC motor's operation, which has been covered in this article. We must first examine its constructional features in order to comprehend the dc motor's working principle.A dc motor's rudimentary design consists of a current-carrying armature that is positioned between the north and south poles of a permanent or electromagnet and connected to the supply end via commutator segments and brushes, as illustrated in the image below. Before delving into the specifics of the DC motor's working principle, it is crucial that we comprehend Fleming's left-hand rule, which establishes the direction of force acting on the motor's armature conductors.

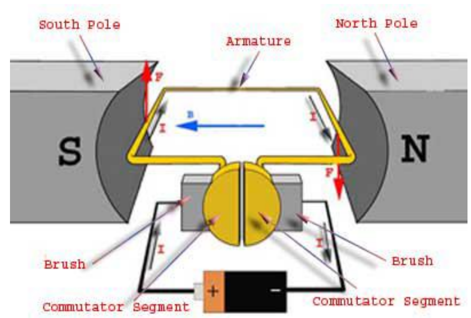

FIGURE 4. DC MOTOR

VI. IMPLEMENTATION

The implementation of the system consists of three core modules: Energy Generation & Management, Intelligent Control, and Mobility & Drive. In the Energy Generation & Management Unit, a step-down transformer is used to convert 230V AC mains power to a safer 12V AC. This AC is then rectified using a bridge rectifier and filtered using a smoothing capacitor to produce a DC voltage. A voltage regulator, such as the 7805 or 7812, ensures a stable output voltage (5V or 12V) that powers the electronic components like microcontrollers and sensors. The DC supply is further processed through a high-frequency oscillator and switching circuit, converting it into high-frequency AC for wireless power transmission. A primary capacitor bank helps maintain a steady current and supports quick energy bursts to the transmitter coil (Coil 1). The transmitted power is wirelessly received by the secondary coil (Coil 2), where it is converted back into DC, regulated, and stored in a Li-Ion battery. This battery serves as the primary power source for the rest of the system, powering control circuits, LEDs, and motors.

The Intelligent Control Unit is built around a microcontroller such as an ESP32 or Arduino Nano, which acts as the system's brain. It is powered by the stored energy from the Li-Ion battery and manages communication and control. A Bluetooth module (HC-05 or HC-06) is connected to the microcontroller via UART, allowing wireless communication with a smartphone or remote device. The microcontroller is programmed using Embedded C through the Arduino IDE to interpret commands such as ON/OFF for LEDs or directional controls for mobility. These commands are then translated into signals sent to a motor driver circuit (e.g., L298N), which controls two DC motors responsible for the system's movement. The Mobility & Drive Unit responds to Bluetooth commands—forward, backward, left, right, and stop—allowing remote-controlled motion. Additionally, the system integrates wireless charging, enabling the battery to recharge through the receiver coil without physical connections, ensuring continuous operation and efficient mobility.

VII. RESULT ANALYSIS

The system's capacity to effectively show controlled movement along a predetermined path and wireless energy transfer was the basis for evaluation. The receiver coil was able to gather and store the transferred energy with little loss after the charging unit successfully transferred energy across the air gap. Throughout the vehicle model's motion, the transmitter and receiver maintained a steady electromagnetic coupling, guaranteeing constant energy delivery.Smooth navigation and constant alignment with the implanted transmitting coils were demonstrated by the Bluetooth-controlled vehicle as it precisely followed the intended route. The system maintained energy reception even when the direction changed, demonstrating the effectiveness of the integration of wireless charging with remote-controlled navigation. The durability of the coupling design was demonstrated by observations that showed tiny misalignments had no discernible effect on the energy transfer. All things considered, the system proved that dynamic charging with wireless technology is feasible, underscoring its potential as an effective and environmentally friendly substitute for conventional stationary charging techniques.

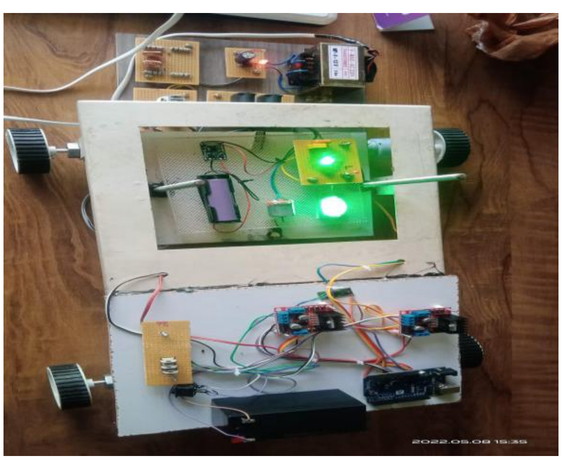

FIGURE 5. OUTPUT

VIII. CONCLUSION

The suggested technology offers a workable prototype for wireless road charging via inductive coupling, which is a major leap in EV infrastructure. By permitting a continuous energy supply while a vehicle is in motion, it solves typical issues including lengthy charging times, station dependency, and limited trip range, enhancing user convenience and advancing sustainable transportation objectives.The system's dual-module architecture, which consists of a Bluetooth-operated Vehicle Controlling Unit to simulate vehicle motion and a Vehicle Charging Unit for inductive energy transfer, appears to be both economically viable and technically possible for experimental use. The concept provides a scalable platform for future advancements and successfully illustrates how embedded infrastructure can work in unison with moving vehicles. The project establishes the foundation for a wider implementation of dynamic wireless charging in transportation networks by providing a functional prototype in addition to a conceptual framework.Wireless road charging has the potential to be a crucial part of next-generation smart transportation systems, improving vehicle autonomy and hastening the transition to widespread electric mobility, provided it continues to advance in areas like energy efficiency, material strength, and system safety.

IX. FUTURE WORK

Future iterations of this technology can concentrate on improving wireless energy transfer's stability and efficiency at a range of speeds and distances. Enhancements in magnetic coupling techniques, coil design, and alignment mechanisms may boost power delivery efficiency overall while reducing energy losses. In order to automate vehicle navigation along charging lanes without the need for external manual operation, research might also investigate the integration of sophisticated control algorithms.Understanding scalability and robustness will be aided by expanding the prototype to support other vehicle models and load scenarios. Performance would be further optimized by integrating energy management systems that dynamically modify power output in response to vehicle requirements. Longer operational lifespans can also be ensured by improving durability and environmental resistance through material improvements for both transmitting and receiving equipment. In order to improve safety and coordination and open the door to more intelligent and effective transportation ecosystems, future research can also look into communication protocols between vehicles and road infrastructure.

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