Design and Implementation of Solar-PoweredWireless Charging System for Electric Vehicles Using Inductive Coupling

Mr.T.Subrahmanyam[1], Ms.D.Dhana sree[2], Ms.D.Satvika[3], Mr.J.Gnanendra[4],Mr.K.Rajesh[5], Ms.U.Vasundara

[1]Mr.T.Subrahmanyam , M.Tech, Assistant Professor Of Electrical and Electronics Engineering , Anil Neerukonda Institute Of Technologies and Sciences[ANITS],

[2, 3,4,5,6,7] Students, Department Of Electrical and Electronics Engineering , Anil Neerukonda Institute Of Technologies and Sciences [ANITS]

Abstract:-

This electronic document is a "live" template and Electric Vehicles (EVs) are playing a critical role in the shift toward cleaner and greener transportation. One major challenge in EV adoption is charging efficiency and infrastructure. This paper proposes a standalone solar-powered wireless charging system using inductive coupling, suitable for both stationary and dynamic EV charging. The system integrates a solar panel as the primary source, a TP4056 charging controller, an Arduino Nano microcontroller, and wireless transmission coils to transfer energy wirelessly from a ground-based transmitter to an onboard receiver. Simulation and hardware prototype testing show promising results, confirming the feasibility of deploying sustainable, contactless EV charging solutions in real-world environments.

Key Words:- Wireless Power Transfer, Solar Energy, EV Charging, Inductive Coupling, TP4056, Arduino Nano.

1.INTRODUCTION:-

Large scale deployment of Internal Combustion Engine (ICE) based vehicles in transport system lead to the release of harmful fumes into an atmosphere lead to global warming and climate change, which is main concern of global community. Therefore, to lessen dependence on fossil fuel based energy sources and to reduce its harmful impacts on the atmosphere, there is a need for alternative solutions such as EVs charged on renewable energy source. The currently available technology for EV battery charging consists of plug-in charging (conductive charging or wired charging) and Wireless charging (contactless) methods. One of the main concern with conductive charging is high power cables, to plug EV, those are difficult to handle. Hazards can happen due to damaged cables or mishandling.An alternative new technology is WPT, introduced by Nikola Tesla in 19th century, with the time this technology developed and became competitive solution for wired charging systems.The wireless charging system is capable of working without human intervention. It is also safe due to the fact that there is no cables present in the system. The hazards caused by using cables can be avoided. This advantages makes Wireless technology suitable for large-scale deployment. Also makes it fully automated charging infrastructure in electrified transport system. The main drawback of wireless charging system is its charging time. That can be resolved by different changes in the system. Many years ago, WPT systems using high intensity, time-varying electromagnetic fields were presented. But at that time, there was little need for the WPT, because cable power distribution systems were generally more efficient and less expensive for electrical devices. Today, wireless short-range power transfer devices using electromagnetic induction are used more and more in industrial products for contactless charging . However, due to the limitation of the transfer distance of the energy, this technology cannot charge EVs to cover distances of more than one-fifth (1/5) the dimension of the power transmitter . An improved method based on resonant coupling showed efficient results for extending the transfer distance to more than 2 or 3 times the size of the transmitter or receiver . A long track is embedded on the roadside, and the receiver pad(s) is positioned under the vehicle in a DWC system. The track embedded on the roadside might be a long continuous track or continuous segmental charging pad . The receiver pad which is installed under the vehicle initiates the charging process whenever it is positioned over the transmitter track. The control of the energizing process of a long track is simple, but the power loss due to a portion of the noninteractive track is high. The energization process of the segmental pad structure is complex. Still, the particular pad is energized only during the receiver pad is positioned over it, and the remaining pads are in ideal condition. Efficient power transfer between Tx and Rx coil is achieved by establishing effective or strong resonant magnetic coupling links. The effectiveness of magnetic coupling links is enhanced by reducing the misalignment between the Tx and Rx coils. operating with enhanced efficiency is critical for WPT systems because even a minor decrease in efficiency in such a system results in significant power loss. As a result, the key control objectives are to regulate the voltage and current at the output while also maximizing efficiency. The dynamic impedance matching approach is often employed in high frequencies and low power conditions. By using various topologies the PTE of the WPT system achieves around 90 %, however it may get decreases abruptly when misalignment occurs between the couplers. Therefore, the investigations are required for the betterment of the misalignment tolerance. From another perspective, it is important to implement smart charging schemes that oversee and regulate charging processes. These schemes could be developed based on various criteria, including time of day, energy prices, renewable energy availability, charging network characteristics, real-time specifications, and energy providers' policies.A power and communication system has been designed for bidirectional flows of electricity and information.

Objective:- The primary objectives of this project center around enhancing user convenience, promoting sustainability, improving safety, and enabling smart infrastructure. By eliminating the need for plug-in charging, the system offers automatic, weatherproof charging that integrates

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seamlessly into daily routines, making it ideal for urban environments. It supports green transportation by enabling easier EV adoption and compatibility with renewable energy sources like solar power, contributing to reduced carbon emissions. The system also enhances safety by minimizing electrical hazards and exposed components. Furthermore, it lays the groundwork for smart infrastructure, allowing integration with IoT and smart grids, and paving the way for autonomous EVs and dynamic, in-motion charging solutions.

1.1. Block Diagram:

The system is designed to operate in two parts: a solarpowered charging station with a transmitter coil, and a receiver coil integrated into the vehicle. The transmitter coil generates an alternating magnetic field when energized, which in turn induces a voltage in the aligned receiver coil. The induced power is rectified and regulated to safely charge the vehicle's battery. A microcontroller-based control system ensures smart operation, real-time monitoring, and efficient power distribution. Additional modules such as Bluetooth and LCD interfaces enhance interactivity and feedback for users.

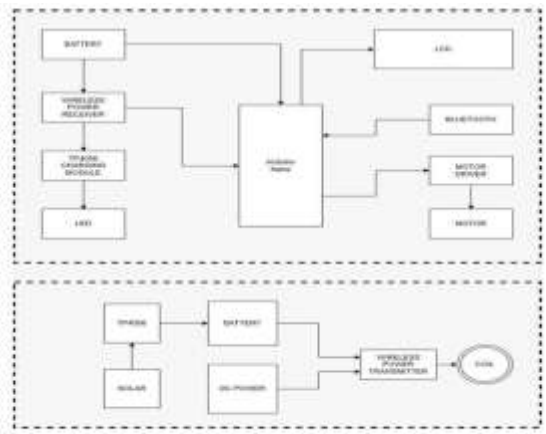

Figure 1: Block Diagram

1.3.Description:

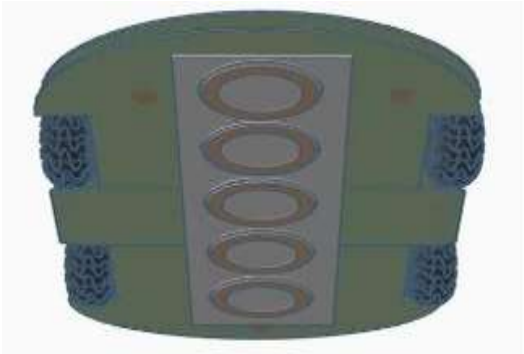

Figure 2:Receiver side Design

In the first view, the bottom of the EV model reveals the placement of circular receiver coils. These coils are strategically embedded in the vehicle chassis to align with the coils installed along the road surface. When the vehicle moves over the track, the receiver coils come in close proximity to the energized transmitter coils, enabling magnetic coupling.

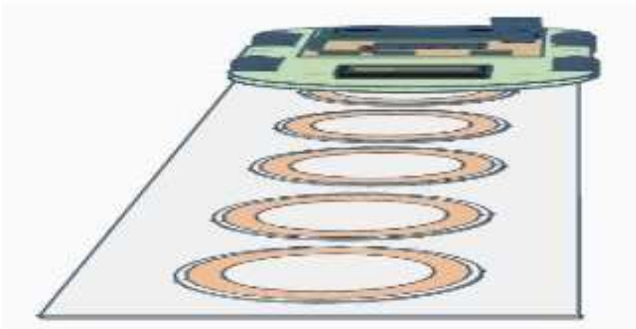

Figure 3: Prototype for Road Figure

The second perspective offers a top-down view of the entire wireless charging system in action. The road is equipped with a series of circular copper transmitter coils that are spaced evenly to correspond with the spacing the receiver coils on the vehicle.

2.COMPONENTS:-

2.1.Lithium Batteries:

The batteries are IMR 18650 lithium-ion rechargeable cells, which are commonly used in high-drain devices like electric vehicles (EVs), power tools, laptops, solar storage systems, and portable electronics. The "IMR" designation indicates that these are Lithium Manganese Oxide ($LiMn_2O_4$) based cells—known for high discharge rates and thermal stability, making them a safe choice for demanding applications.

2.2.Solar Panel:

A solar panel is a renewable energy device that converts sunlight into electrical energy using photovoltaic (PV) cells made of semiconductor materials like silicon. When exposed to sunlight, these cells generate a direct current (DC), which can be used to charge batteries or power electronic circuits. In small-scale applications like embedded systems or wireless charging setups, compact panels (e.g., 6W–12W) are commonly used to charge lithium-ion batteries or supply regulated power. Solar panels offer a clean, sustainable, and eco-friendly power source, making them ideal for off-grid and energy-efficient solutions such as the solar wireless EV charging system.

2.3. Coils:

The 5V 2A Large Current Wireless Charger Module Transmitter Receiver Charging Coil Module is perfect for designing and building a variety of small electronic devices, wireless charging, and power supplies because of its compact size, ease of use, high efficiency, and affordable price. This technology is useful for a wide range of applications, including wireless charging for mobile phones, video game consoles, tanks, digital audio players, digital still and video recorders, electric razors. adult entertainment products, machine learning, healthcare, and many more. The products are entirely sealed, which makes them dust and waterproof-proof, a contactless charging power source enables this.

2.4.MOTOR:

The small DC motor used is typically a 6V or 12V brushed DC motor, which is a common choice for low-power embedded applications due to its simplicity, efficiency, and ease of control. These motors operate by converting electrical energy into mechanical rotation using a fixed stator magnet and a rotating armature. The rotation speed can be controlled using Pulse Width Modulation (PWM), and direction can be managed through an H-bridge motor driver like the L298N module.The motor generally operates within a voltage range of 6V to 12V, with a typical current draw of 200mA to 1A under load, and a no-load current of around 100–150mA. Its power output usually ranges from 1W to 10W, depending on the torque and speed requirements. These motors are capable of delivering speeds between 1000–3000 RPM, and their torque can vary from 50 to 300 g·cm, which is suitable for driving small wheels, fans, or mechanical parts in prototypes. In your Solar Wireless EV Charging System, the DC motor likely simulates or represents the propulsion unit of an electric vehicle, demonstrating how the charged power can be used to drive a load.

2.5.Metallic Sync:

A metallic heat sync is a passive heat exchanger made typically of aluminum or copper, designed to absorb and dissipate heat generated by electronic components or batteries into the surrounding air. It improves the thermal performance of a system by maintaining components at safe temperatures and preventing overheating.

2.6.DOT MATRIX OR VEROBOARD

A. Green Screw Terminals (x5):

Used for external wiring to connect power in, coils, battery, or load (like motor/LEDs).These are 3.5mm pitch 2-pin terminals, usually rated for up to 10A.

B. TO-220 Packages (x3):

These look like voltage regulators or power transistors.Possible ICs: 7805 (5V Regulator), L7809, or MOSFETs (IRF540/IRFZ44N).

Likely used for:

- Voltage regulation
- Switching inductive loads or wireless power coil
- DC-to-DC conversion
- C. Inductor Coil (Yellow Toroidal):

Suggests a boost converter or power regulation circuit.Works with MOSFETs to create oscillations for wireless power transmission.

D. Capacitors and Diodes:

Electrolytic capacitors (for smoothing voltage) Likely rectifier or Schottky diodes (for polarity protection or AC-to-DC conversion).

E. LED Indicator (Yellow):

Used to show power status, charging activity, or circuit ON/OFF.May be connected to one of the transistor/MOSFET circuits or regulators.

F. Black Rocker Switch:

Main power ON/OFF switch for the board.

3.METHODOLOGY:-

The transmitter side circuit begins with a solar panel (SOL1), which captures sunlight and converts it into electrical energy. The positive terminal of the solar panel is connected to the input of a TP4056 charging module, a lithium-ion battery charging circuit. The TP4056 regulates the input solar voltage and current and ensures safe and controlled charging of the battery (BAT2) connected to its B+ and B− terminals. This battery stores energy during sunlight hours and powers the transmitter circuit when needed. The output terminals of the TP4056 (OUT+ and OUT−) are connected to the input of a transmitter coil module, labeled as the TRANSMITTER MODULE. This module converts the regulated DC from the battery into an AC magnetic field through inductive winding, allowing the system to wirelessly transmit energy via electromagnetic induction.

On the receiver side, the model consists of a power receiver coil placed in close proximity to the transmitter coil. The receiver module captures the alternating magnetic field generated by the transmitter and converts it into usable voltage. The output of the power receiver is connected to a voltage regulator circuit, ensuring a constant and safe voltage supply to downstream components. This regulated power is then fed into the TP4056 charging module, which safely charges the onboard battery (BAT1) mounted on the EV. The battery powers various electronics within the vehicle and ensures continuous operation even when the vehicle moves beyond the charging field.

At the core of the receiver circuit lies the Arduino Nano microcontroller (NANO1). The VCC and GND pins of the Arduino are powered by the battery through the regulated output. Multiple digital pins of the Arduino are used to interface with peripheral components. A 16x2 LCD module (LCD1) is connected to the Arduino to display real-time system status such as voltage level, charging progress, and system health. The LCD is connected via pins D2 to D7 of the Arduino and is powered by VCC and GND through a variable resistor (RV1), which adjusts the contrast of the display.

A Bluetooth module (M1) is also integrated into the design and connected to the Arduino using digital pins for RX and TX communication. This module enables wireless data transmission, allowing remote monitoring and control of the EV charging system via a mobile device or PC. The VCC and GND of the Bluetooth module are connected to the regulated output to ensure stable operation.

The system also includes a motor driver IC (U1), specifically the L298N dual H-bridge motor driver. The motor driver is connected to the Arduino through digital pins (IN1 to IN4), enabling bidirectional control of two DC motors, which represent the EV's drive system. The driver receives power from the onboard battery, and its output terminals are connected to two DC motors, allowing the vehicle to move forward or backward based on control logic from the Arduino.

Additionally, there is an LED (D1) with a current-limiting resistor (R1) connected to indicate charging status or system power. Multiple resistors (R2, R3) are used for controlling signal levels and providing biasing to some components. The system is grounded through a common GND rail, ensuring safe and stable circuit behavior.

4. Hardware Model Results:

The proposed hardware model demonstrates a solarpowered wireless charging system for electric vehicles using inductive power transfer. The system eliminates the need for physical charging cables and relies on renewable solar energy, making it eco-friendly and efficient. The vehicle is built on a 4-wheel chassis, with key electronic modules and energy systems integrated for operation and testing.

The system comprises two main parts: the wireless power transmitter section and the receiver section mounted on the vehicle. The transmitter section includes a solar panel, which acts as the primary energy source. The solar panel charges a battery through a TP4056 charging controller module. The regulated power is then fed to a transmitter coil, which is carefully wound and placed on the baseboard. This coil generates an alternating magnetic field when current flows through it.voltage in the receiver coil, which is then converted to DC using a rectification circuit. The resulting DC output is used to charge the onboard lithium-ion battery pack (comprising three 3.7V 1200mAh cells in series), which stores the energy needed to drive the vehicle.

To monitor the system voltage during operation, a digital multimeter is used. The images show measured voltage readings of around 9.91V, confirming that the wireless charging system effectively transfers power to the battery. The glowing red LED indicator further validates successful power reception and battery charging.

Additionally, the vehicle contains a custom-designed PCB housing various components like resistors, capacitors, and driver ICs. A motor driver module (L298N) is connected to the battery and controls the DC motors attached to the wheels, facilitating movement. The microcontroller, Bluetooth module, and LCD (if used) are responsible for data processing and wireless monitoring of voltage and status.

The solar wireless electric vehicle (EV) charging system moves beyond just a theoretical concept and demonstrates real-world viability through its working prototype. The integration of renewable solar energy with wireless power transfer (WPT) technology offers a tangible solution to address the limitations of traditional EV charging methods, such as dependence on plug-in systems, charging station availability, and extended charging times.

In practical execution, this system utilizes a solar panel as the primary energy source, efficiently harnessing sunlight to generate clean, renewable electricity. This energy is . stored in a battery and used to power the transmitter coil. The transmitter coil, when energized, creates an alternating magnetic field which acts as the medium for inductive power transfer. The receiver coil on the EV aligns with this field, inducing a voltage that is rectified and used to charge the onboard battery. The model mimics real-world scenarios by incorporating motion, battery management, solar integration, and electronic control systems. It shows how such a system could be scaled up and embedded into smart city infrastructure where vehicles charge wirelessly while moving or waiting in traffic. This makes charging more accessible, safer (no exposed wires), and environmentally friendly, thereby promoting green energy adoption and seamless EV operation.

Overall, the real-time functioning of this prototype validates the feasibility and practicality of implementing wireless solar charging in electric vehicles and encourages further development into full-scale road-integrated smart charging networks.

In the process of building this project, various challenges were encountered — from maintaining precise coil alignment to managing power transfer efficiency over varying distances. However, these challenges provided valuable learning opportunities and insights into system design, electronics interfacing, and the importance of component selection. Through this hands-on experience, the team gained a deeper understanding of the fundamental concepts behind electromagnetic induction, energy storage, circuit protection, and real-world hardware implementation. The successful operation of the model under practical conditions confirms the theoretical framework established at the beginning of the project.

5.CONCLUSION:

In conclusion, the IoT-based wristband using ESP32 presents an innovative and practical solution to address the growing healthcare needs of the elderly population. By integrating vital health monitoring sensors with real-time data transmission capabilities, the device ensures continuous observation of the user's condition while offering timely alerts during emergencies. The use of the ESP32 microcontroller enhances the system's efficiency through its powerful processing and wireless communication features, making the wristband compact, affordable, and energy-efficient.

This project successfully demonstrates how IoT technology can be applied to improve the safety, independence, and overall well-being of elderly individuals. It also lays the foundation for future developments in remote health monitoring and smart healthcare solutions. With further improvements and real-world deployment, such a wearable system can play a crucial role in reducing response times during health crises and enhancing the quality of life for senior citizens.

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