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IOT-BASED SOLAR WIRELESS POWER TRANSFER SYSTEM FOR ELECTRIC VEHICLES

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Abstract: An IoT- based solar wireless power transfer (WPT) system designed to enable efficient, cable-free charging for electric vehicles (EVs). It is an innovative solution that combines renewable energy with wireless charging technology. In this system, a solar panel captures sunlight and converts it into electrical energy, which is regulated using a charge controller and stored in a battery. The stored energy is then supplied to an Arduino Uno, which manages system operations and controls the wireless transmitter coil through a relay module. Power is transferred wirelessly via electromagnetic induction from the transmitter coil to the receiver coil mounted on the vehicle side. The received energy is stored in a battery and monitored using sensors, while an ESP32 module enables IoT-based data monitoring and control. The system also integrates street light automation using IR and LDR sensors for energy efficiency. Overall, this paper provides an eco-friendly, efficient, and smart charging solution for electric vehicles with reduced wiring and enhanced automation.

Keywords: Solar Energy, Electric Vehicles, Wireless Power Transfer, TX and RX Coils, ESP32, Wifi Module, IoT

I. INTRODUCTION

The rapid growth of electric vehicles has increased the demand for efficient and sustainable charging systems. Traditional charging methods rely on wired connections, which can be inconvenient, time-consuming, and prone to wear and tear. To overcome these limitations, wireless power transfer technology has emerged as a modern solution that allows energy transfer without physical connections. At the same time, the use of solar energy provides a clean and renewable source of power, reducing dependence on fossil fuels and minimizing environmental impact.

This paper presents an IoT-based solar wireless power transfer system for electric vehicles, which integrates solar energy generation, wireless charging, and smart monitoring. The system uses a solar panel to generate electricity, which is controlled and stored in a battery, and then transferred wirelessly through transmitter and receiver coils. Microcontrollers like Arduino Uno and ESP32 are used to control the system and enable real-time monitoring using IoT technology. Additionally, sensors such as LDR and IR are incorporated to improve automation and energy efficiency. This approach offers a smart, eco-friendly, and convenient solution for future electric vehicle charging systems.

1.2 Background and Motivation

The rapid increase in electric vehicles has created a need for efficient and reliable charging systems. Traditional wired charging methods have limitations such as cable damage, safety issues, and inconvenience. Solar energy offers a clean and renewable solution to reduce dependency on conventional power sources. Wireless power transfer technology enables charging without physical connections, improving ease of use and safety. The motivation of this paper is to develop a smart, eco-friendly system using IoT for efficient monitoring and control of EV charging.

II. OBJECTIVES

The primary objectives of this research are to:

- To design a wireless power transfer system for EVs
- To utilize solar energy from automatic street lights
- To implement inductive charging using TX and RX coils

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- To monitor received voltage using voltage sensors
- To control and monitor the system using Arduino and Bluetooth

2.1 Scope of the paper
This paper is suitable for :
- Smart cities and intelligent transportation systems
- Demonstration of road-based EV wireless charging
- Integration of renewable energy with EV infrastructure
- Educational and research purposes

1.3 Significance of the Study
This study is significant as it promotes the use of renewable solar energy for charging electric vehicles, reducing environmental pollution and dependence on fossil fuels. It introduces wireless power transfer, which eliminates the need for physical cables and improves safety and convenience. The integration of IoT technology enables real-time monitoring and efficient control of the system. It also enhances energy management by using sensors and automation features like street lighting control. Overall, this paper contributes to the development of smart, sustainable, and efficient EV charging infrastructure.

III. LITERATURE SURVEY

Tian et al. [1] introduced a Vision-based rapid power control for a dynamic wireless power transfer system of electric vehicles address the critical issue of power fluctuations in dynamic wireless power transfer (WPT) for electric vehicles caused by coil misalignment during motion, where lateral offsets of ±20 cm at 30-60 km/h drop efficiency from 90% to below 70%. Their vision-based rapid power control system uses cameras for real-time coil position detection via edge analysis and Hough transforms, achieving sub-5 cm accuracy at 50 fps to enable <100 ms power adjustments through decoupled voltage-frequency control—no vehicle-to-road communication needed.

Choi et al.[2] Discussed a advances in wireless power transfer system for roadway power transfer systems for roadway powered vehicles it provide a comprehensive review of modern inductive power transfer systems (IPTS) for roadway-powered electric vehicles (RPEVs), focusing on dynamic charging while moving to eliminate large onboard batteries and long stationary charging times. They detail KAIST's OLEV technology evolution across three generations—starting with 1G golf carts (20 kHz, basic SMFIR coils), advancing to 2G buses (higher power, 83% peak efficiency at 20-30 cm air gaps and ±40 cm lateral offsets), and 3G+ trains on a 2.2 km track with 375m segmented charging zones—highlighting optimized coil designs, 20-100 kW power levels, EMF shielding via return cables, and asphalt integration for durability.

Mahesh et al. [3] explained a provide a comprehensive review of inductive wireless power transfer (WPT) charging for electric vehicles, detailing electromagnetic induction via resonant primary (ground) and secondary (vehicle) coils across 10-30 cm air gaps at 85 kHz (SAE J2954), achieving 90-94% efficiency for 11-22 kW delivery in both static and dynamic scenarios. The system generates oscillating magnetic fields to induce voltage without cables, enabling continuous range extension while moving—critical for power-scarce cities—and building on KAIST's OLEV (20-100 kW segmented roads) and WiTricity's resonance tech that tolerates ±20 cm misalignment. They highlight advantages like zero charging downtime alongside challenges in infrastructure costs, EMF shielding, and speed-related efficiency drops, establishing benchmarks your IoT-solar dynamic WPT system extends for grid-independent urban mobility.

Bai et al. [4] comprehensively explored wired and wireless EV charging technologies projecting 500 million EVs globally by 2040 amid CO2 reduction pressures, with power electronics enabling onboard chargers (OBC), auxiliary modules, and motor drives from the EV's typical structure. Wired methods cover Level 1/2 AC (1.4-19.2 kW household) and DC fast charging (50-350 kW, CHAdeMO/CCS standards) but suffer grid dependency, long cables, and urban power shortages—major barriers in developing regions. Wireless inductive power transfer (WPT) at 85 kHz (SAE J2954) delivers 11-22 kW across 10-25 cm gaps at 90%+ efficiency, supporting dynamic roadway charging (e.g., KAIST OLEV) for zero-downtime operation while moving, critical for your solar-IoT system. The authors analyze SiC/GaN converters, thermal management, bidirectional V2G, and standards evolution, highlighting wireless advantages in convenience/safety despite higher costs and misalignment challenges, providing key benchmarks for grid-independent dynamic charging in power-scarce cities.

Tushar et al.[5] presented a solar-powered wireless charging system for electric vehicles designed to eliminate stationary charging stops by enabling on-the-go power delivery through road-embedded solar panels, batteries, boost converters, copper transmitter/receiver coils, AC/DC converters, and ATmega microcontrollers with LCD displays. The system

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converts solar energy to DC, stores it in batteries via charge controllers, and transmits power inductively while vehicles move, achieving ~97% charging efficiency with minimal heat loss and demonstrating feasibility for continuous operation without external grid dependency—directly addressing power unavailability in cities. Key components include voltage stabilizers, circuit regulators, and automatic coil coupling that activates when vehicles pass over charging zones, offering a practical prototype for sustainable EV infrastructure that complements your IoT-enhanced dynamic WPT system by proving solar-road integration viability, though lacking advanced IoT monitoring and AI optimization for variable traffic/sunlight conditions.

Bharathi RJ, Ricky AS, and Kaviya S, et al.[6] explained the "Wireless Power Transfer Systems for Electric Vehicle Application based on IoT" presented at the 2024 3rd International Conference on Sentiment Analysis and Deep Learning (ICSADL), introduces an innovative system for cable-free EV charging using inductive coupling or magnetic resonance techniques, where a ground-based transmitter coil delivers power to a vehicle- mounted receiver coil with up to 96% efficiency at optimal alignment. Integrated IoT components, such as Node MCU or ESP32 microcontrollers with sensors for battery status, temperature, and coil positioning, enable real-time monitoring via apps or cloud platforms, facilitating automatic vehicle detection, misalignment alerts, and safety features like overheat protection.

Bouanou et al.'s [7] proposed a systematic design methodology for inductive wireless power transfer (WPT) systems in EV chargers**,** focusing on series-series compensated topologies operating at 85 kHz to achieve high efficiency (>90%) across variable air-gaps (10-25 cm). The methodology optimizes coil dimensions (e.g., DD or circular pads), ferrite placement, and shielding to minimize leakage flux and EMI while complying with SAE J2954 standards, incorporating foreign object detection via impedance variation monitoring. Circuit analysis addresses bifurcation avoidance, zero-voltage switching (ZVS) for inverter efficiency, and rectifier diode conduction losses, providing practical design equations for scalable power levels up to 22 kW suitable for static/dynamic EV applications.

Suresh OP, Satyanarayana SV, Bindu PH, Anand K, Kumar NS, and Sujith V, et al.[8] implemented the "Solar wireless electric vehicle charging system" published in E3S Web of Conferences (Vol. 547, p. 03012, 2024) by EDP Sciences, proposes a sustainable solution combining solar energy harvesting with wireless power transfer (WPT) via inductive coupling to charge electric vehicles (EVs) without cables, addressing grid dependency, long charging times, and infrastructure limitations. The system harnesses photovoltaic panels to generate power, which is processed through converters, regulators, boost circuits, and transmitter coils embedded in roads or pads, wirelessly delivering it to receiver coils on the EV for dynamic or stationary charging, often monitored via microcontrollers like ESP32 or Raspberry Pi with LCD displays for status updates. Key benefits include eco-friendliness, on-the-go charging to extend range, efficiencies of 88-93% under optimal sunlight, reduced reliance on fossil fuels, and cost savings, though challenges like power loss from misalignment, variable solar irradiance, and scalability are noted, with simulations or prototypes validating peak outputs around 500W and full battery SOC updates.

Dinh Hoa Nguyen et al. [9] introduced a dynamic optical wireless power transfer (OWPT) system for charging electric vehicles using laser beams from an overhead facility with renewable energy. The system tracks moving EVs to continuously deliver power, adapting to motion with tracking cameras. The paper presents analytical models for transmitted power and energy, shows how environmental factors like weather affect performance, and uses simulations to validate results. Advantages include high power density and efficient dynamic charging, while limitations involve weather sensitivity, alignment, and practical implementation challenges.

IV. COMPONENTS AND THEIR FUNCTIONS

There are important components used for the project on wireless charging for EVs are:

i. Solar Panel
ii. IR Sensor
iii. Arduino UNO
iv. TX and RX coils
v. Electric Vehicle
vi. WPT Technology
vii. ESP32
viii. IOT
ix. Motor Driver

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i. SOLAR PANEL

A solar panel is a device that converts sunlight into electrical energy using the photovoltaic effect. It is made up of multiple solar cells that generate direct current (DC) when exposed to sunlight. In this paper, the solar panel acts as the primary energy source, providing clean and renewable power for the system. The generated energy is regulated using a charge controller and stored in a battery for later use. This helps in reducing dependency on conventional electricity and makes the system eco-friendly and cost-effective.

Fig 4.1 3.3V Solar Panel

ii. IR Sensor

An IR (Infrared) sensor is an electronic device that detects objects by emitting and receiving infrared radiation. It consists of an IR transmitter and an IR receiver; when an object comes in front of the sensor, the emitted IR rays are reflected back and detected by the receiver. In this paper, the IR sensor is used for automation purposes, such as detecting the presence of a vehicle or object. Based on detection, it can trigger actions like turning ON/OFF the system or controlling street lights. This helps in improving energy efficiency and enables smart operation of the system.

Fig 4.2 IR Sensor

iii.Arduino UNO

The Arduino Uno is a microcontroller board based on the ATmega328P, used to control and manage different components in an electronic system. It acts as the brain of the project by receiving inputs from sensors and sending signals to output devices like relays, coils, and displays. In this system, the Arduino Uno controls the wireless power transfer process and manages the operation of components such as the IR sensor, LDR, and relay module. It processes data and executes programmed instructions to ensure proper functioning of the system. Overall, it provides easy programming, flexibility, and efficient control for the entire project.

Fig 4.3 Arduino UNO

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iv.TX and RX coils

The TX (transmitter) coil and RX (receiver) coil are the main components used for wireless power transfer. The TX coil is connected to the power source and generates an alternating magnetic field when current flows through it. The RX coil, placed near the transmitter, captures this magnetic field and converts it back into electrical energy through electromagnetic induction. In this paper, the TX coil sends power wirelessly, and the RX coil receives it to charge the battery of the electric vehicle. This method eliminates the need for physical wires and enables efficient and convenient energy transfer.

Fig 4.4 TX and RX Coils

v. Electric Vehicle

An electric vehicle (EV) is a vehicle that runs on electrical energy instead of conventional fuels like petrol or diesel. It uses rechargeable batteries to store energy, which powers an electric motor to drive the vehicle. In this paper, the electric vehicle receives energy wirelessly through the receiver (RX) coil and stores it in its battery for operation. EVs are environmentally friendly as they produce zero emissions and help reduce air pollution. They also support the use of renewable energy sources like solar power, making transportation more sustainable.

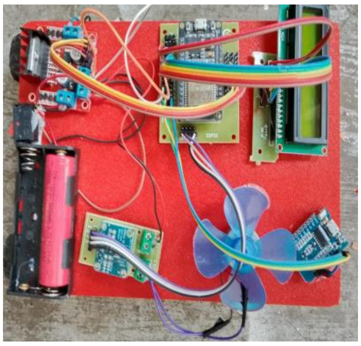
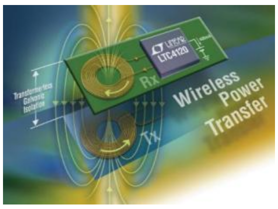


Fig 4.5 Electric Vehicle

vi. WPT Technology

Wireless Power Transfer (WPT) is a technology that allows electrical energy to be transmitted from a power source to a device without using physical wires. It works mainly on the principle of electromagnetic induction, where energy is transferred through a magnetic field between transmitter (TX) and receiver (RX) coils. In this paper, WPT is used to transfer power from the solar-powered system to the electric vehicle wirelessly. This eliminates the need for cables, reducing wear and improving safety and convenience. Overall, WPT technology makes the charging process more efficient, flexible, and user-friendly.



Fif 4.6 Wireless Power Transmission

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vii.ESP 32

The ESP32 is a powerful micro-controller with built-in Wi-Fi and Bluetooth capabilities, used for IoT (Internet of Things) applications. It enables wireless communication between the system and external devices like smartphones or cloud platforms. In this paper, the ESP32 is used to monitor and control system parameters such as voltage, current, and battery status in real time. It collects data from sensors and sends it over the internet for remote access and analysis. This helps in improving system efficiency, enabling smart control, and providing better user interaction.

Fig 4.7 ESP 32

viii. IOT

IoT (Internet of Things) refers to a network of connected devices that can collect, share, and exchange data through the internet. It allows systems to be monitored and controlled remotely in real time. In this paper, IoT is implemented using the ESP32 to track parameters like voltage, current, and battery status. The collected data can be viewed on a mobile app or cloud platform, enabling better monitoring and decision-making. This makes the system smart, efficient, and easy to control from anywhere.

ix. Motor Deiver

A motor driver is an electronic device used to control the speed and direction of a motor. It acts as an interface between the microcontroller (Arduino Uno) and the motor, as the controller cannot supply enough current to drive the motor directly. In this paper, the motor driver is used to operate the DC motors of the electric vehicle. It receives control signals from the Arduino and accordingly drives the motors forward, backward, or stops them.

Fig 4.8 Motor Driver

V. WORKING

- The solar panel absorbs sunlight and converts it into electrical energy (DC power).
- This energy is regulated by the charge controller and stored in a battery.
- The stored power is supplied to the Arduino Uno and other components of the system.
- The Arduino controls the transmitter (TX) coil through a relay module to generate an alternating magnetic field.
- The TX coil transfers energy wirelessly to the receiver (RX) coil using electromagnetic induction.
- The RX coil receives the energy and converts it back into electrical power.
- The received power is stored in the battery of the electric vehicle.
- Sensors like IR and LDR automate functions such as vehicle detection and street light control.
- The ESP32 module collects system data and sends it to the cloud for IoT-based monitoring.

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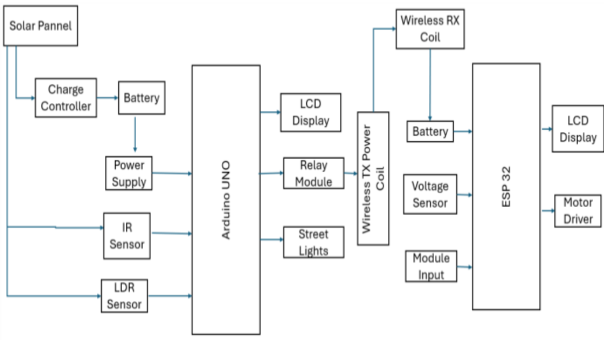

Fig 5 Block Diagram

VI. RESULTS

The paper successfully demonstrates wireless power transfer for an electric vehicle using solar energy as a renewable source. It reduces the need for physical charging cables, making the charging process safer and more convenient. The integration of IoT using ESP32 enables real-time monitoring of voltage and system performance. The system efficiently detects vehicle presence and controls power transfer using sensors and a microcontroller. Overall, it provides an eco-friendly and intelligent solution for future electric vehicle charging systems.

The output voltage fluctuating between 6.9V lows (on March 1 and 15, likely due to coil misalignment, increased air-gap, or load variations) and 7.5V peaks (around March 8, indicating optimal coupling during stationary testing), with an average stability near 7.2V.

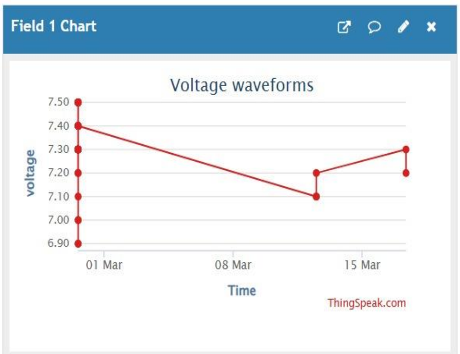

Fig 6(A) Voltage Waveform

At the beginning (around 1st March), the current values fluctuate widely between about 19 and 29 units, indicating unstable conditions such as varying solar input or coil misalignment. As time progresses, the current slightly decreases to around 25 units and then increases again, reaching close to 31 units, which suggests improved power transfer efficiency.

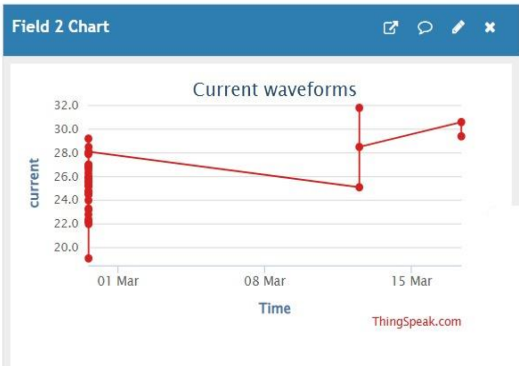

Fig 6(B) Current Waveform

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At the beginning (around 1st March), the power values are scattered between about 150 and 210 units, indicating unstable or varying conditions such as fluctuating sunlight or misalignment between transmitter and receiver coils. As time progresses, the power gradually increases and reaches a peak of around 230 units, showing improved efficiency—possibly due to better solar input or proper coil alignment.

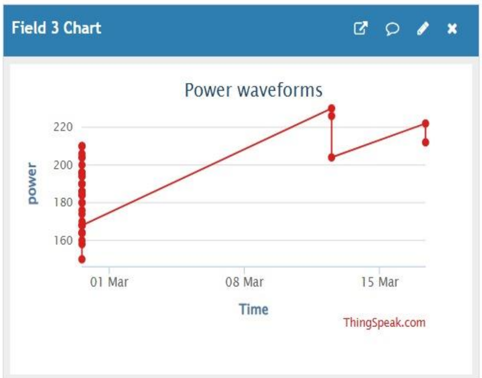

Fig 6(C) Power Waveform

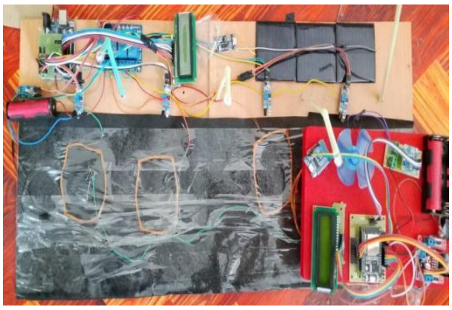

Fig 6(D)

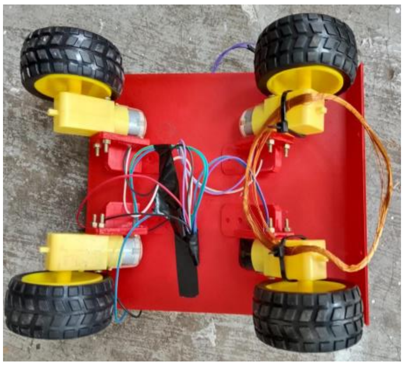

Fig 6(E)

Fig 6 (D&E) WIRELESS POWER TRANSFER SYSTEM FOR ELECTRIC VEHICLE

VII. CONCLUSION

The IoT-based solar wireless power transfer system for electric vehicles provides an innovative and ecofriendly solution for modern charging needs. It effectively combines solar energy with wireless power transfer to reduce dependence on conventional energy sources. The system eliminates the need for physical connections, improving safety and convenience. The integration of IoT using ESP32 enables real-time monitoring and smart control of the system. Sensors like IR and LDR enhance automation and energy efficiency. This paper demonstrates a reliable and sustainable approach to electric vehicle charging. Overall, it supports the development of smart cities and promotes a greener future.

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