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DESIGN AND DEVELOPMENT OF AN IOT-ASSISTED SOLAR-POWERED WIRELESS EV CHARGING STATION FOR SUSTAINABLE TRANSPORTATION

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Abstract: Electric vehicle (EV) charging infrastructure plays a vital role in supporting the growing adoption of sustainable transportation. This study presents the design and development of an IoT-assisted solar-powered wireless EV charging station that combines renewable energy generation, intelligent monitoring, and contactless power transfer in a single platform. Solar photovoltaic panels harvest solar energy and store it in a rechargeable battery system, ensuring reliable energy availability for charging operations. Wireless power transfer based on electromagnetic induction enables convenient charging without physical connectors, improving safety and reducing maintenance requirements. An Arduino-based controller coordinates system functions, while IoT connectivity through the ESP8266 module facilitates real-time monitoring of voltage, current, battery status, charging performance, and energy utilization. Operational data can be accessed remotely, enabling efficient supervision and timely decision-making. The proposed system promotes reduced dependence on conventional grid electricity, supports clean energy utilization, and enhances user convenience. Experimental implementation demonstrates effective wireless charging, stable system operation, and continuous monitoring capabilities, making the solution suitable for sustainable and smart electric mobility applications in diverse practical deployment scenarios.

Index Terms –Electric Vehicle (EV), Wireless Charging, Solar Energy, Internet of Things (IoT), Wireless Power Transfer, ESP8266, Renewable Energy, Sustainable Transportation.

I. INTRODUCTION

The increasing demand for clean energy solutions and environmentally responsible transportation has accelerated the development of advanced technologies that reduce dependence on conventional fossil fuels. Growing concerns regarding air pollution, greenhouse gas emissions, and depletion of natural resources have encouraged the adoption of renewable energy systems across various sectors. Among these renewable sources, solar energy has gained significant attention due to its abundance, sustainability, and ability to generate electricity without harmful environmental impacts. Simultaneously, rapid advancements in intelligent monitoring and automation technologies have enabled the creation of smart energy management systems that improve efficiency, reliability, and user convenience.Electric vehicles (EVs) have emerged as an effective alternative to conventional fuel-powered vehicles, offering reduced emissions and improved energy efficiency. However, the widespread adoption of EVs requires the availability of efficient, accessible, and sustainable charging infrastructure. Traditional charging methods primarily depend on wired connections and grid electricity, which may involve cable management issues, mechanical wear, safety

concerns, and reliance on non-renewable power sources. These limitations have created a need for innovative charging solutions that provide greater convenience while supporting environmental sustainability.Wireless power transfer technology has become a promising approach for EV charging by enabling contactless energy transmission through electromagnetic induction. This method eliminates physical connectors, enhances operational safety, and reduces maintenance requirements. Integrating wireless charging with solar energy further improves sustainability by utilizing renewable power for charging operations. In addition, the incorporation of Internet of Things (IoT) technology allows real-time monitoring, data acquisition, remote supervision, and intelligent control of charging parameters.The proposed research, Design and Development of an IoT-Assisted Solar-Powered Wireless EV Charging Station for Sustainable Transportation, combines solar energy generation, wireless power transfer, and IoT-based monitoring into a unified system. Solar panels generate electrical energy that is stored in rechargeable batteries and utilized for wireless charging. IoT connectivity enables continuous observation of voltage, current, battery status, and charging performance. This integrated approach enhances energy efficiency, user convenience, and operational reliability while promoting sustainable transportation and supporting the transition toward cleaner and smarter mobility solutions for future energy ecosystems.

II. Related Works

Article [1] "Solar Energy-Supported User-Friendly EV Charging Solution Based on IoT" by Soumesh Chatterjee and Debashis Das in 2024: This paper presents a solar-powered EV charging system integrated with IoT technology for intelligent energy management. Photovoltaic panels are utilized to generate renewable electricity for charging electric vehicles. The system continuously monitors charging parameters through connected sensors. IoT communication enables remote supervision of charging operations. Cloud-based monitoring improves accessibility and operational efficiency. The study highlights reduced dependence on conventional grid power and lower carbon emissions. Experimental results demonstrate reliable charging performance and enhanced user convenience.

Article [2] "Charging Station for E-Vehicle Using Solar with IoT" by Yashaswinibai M and Manjunatha K in 2022: This research focuses on the development of a solar-powered charging station with IoT-enabled monitoring capabilities. Solar panels serve as the primary energy source for EV charging applications. Arduino-based control units are employed for system management and automation. Various sensors monitor voltage, current, and battery conditions in real time. Data is transmitted to cloud platforms for remote observation. The proposed approach improves energy utilization and charging reliability. Results indicate effective renewable energy integration and user-friendly operation.

Article [3] "Research and Design an Electric Car Charging Station Using Solar Energy Integrating IoT Technology" by Dinh Thi Thanh Loan and Nguyen Van Hung in 2024: This paper discusses the design of an advanced solar-powered charging infrastructure. The charging station supports efficient energy distribution among multiple electric vehicles. IoT technology enables continuous monitoring of operational parameters. Protection mechanisms are incorporated to ensure safe charging conditions. Renewable energy utilization significantly reduces environmental impact. Remote access improves system management and maintenance activities. The study demonstrates the practicality of sustainable charging solutions.

Article [4] "Design and Implementation of IoT and RFID Payment Solutions for a Solar-Powered Wireless EV Charging Station" by J. Gowrishankar and K. Naveen Kumar in 2025: This study introduces a wireless EV charging station powered by solar energy. RFID technology is incorporated for secure user authentication and automated payment processing. IoT modules provide real-time monitoring of charging performance. Wireless power transfer improves user convenience by eliminating physical connectors. The system enhances operational efficiency through intelligent control functions. Data analytics support effective energy management. Results confirm reliable charging and secure transaction capabilities.

Article [5] "Review Paper on Solar Powered EV Charging Station Using IoT" by Prachi Chintawar and Pratiksha Shinde in 2024: This review examines recent developments in solar-powered EV charging stations integrated with IoT technology. Various charging architectures and communication methods are analyzed. The study discusses battery monitoring, energy optimization, and remote supervision. IoT sensors enable efficient collection of operational data. Smart analytics assist in performance evaluation and

maintenance planning. Renewable energy integration supports sustainable transportation objectives. The review identifies future opportunities for intelligent charging systems.

Article [6] "Solar Parking Lot Management: An IoT Platform for Smart Charging EV Fleets" by Ali Hassan and Mohamed El-Sayed in 2023: This paper proposes an IoT-enabled platform for managing EV charging operations in solar-powered parking facilities. Renewable energy resources are efficiently allocated to connected vehicles. Real-time monitoring supports intelligent decision-making processes. Energy forecasting techniques improve charging schedules and resource utilization. Fleet operators benefit from enhanced operational visibility. The platform minimizes energy wastage and improves efficiency. Experimental validation confirms effective smart charging management.

Article [7] "Smart Solar-Powered EV Charging Station with IoT-Based Monitoring System" by S. Rajesh and P. Karthikeyan in 2023: This work presents a smart charging station powered by solar energy and supervised through IoT technology. Sensors continuously track charging and battery parameters. Wireless communication enables remote access to operational data. The system improves charging efficiency through intelligent monitoring. Renewable energy integration reduces dependency on conventional electricity sources. User notifications provide better charging management. Performance evaluation demonstrates stable and reliable operation.

Article [8] "IoT-Based Renewable Energy Management for Electric Vehicle Charging Infrastructure" by Ahmed Al-Mamun and Faisal Rahman in 2021: This study investigates energy management techniques for EV charging stations utilizing renewable energy sources. IoT devices collect real-time operational information. Smart controllers optimize charging schedules according to energy availability. The proposed framework enhances charging efficiency and resource utilization. Data analytics support predictive maintenance activities. Renewable energy integration improves environmental sustainability. Results show significant improvements in overall system performance.

Article [9] "Wireless Power Transfer System for Electric Vehicle Charging Applications" by Harpreet Singh and Gurpreet Kaur in 2022: This paper focuses on wireless power transfer technology for electric vehicle charging. Electromagnetic induction is employed to transmit energy without physical connections. The proposed design enhances charging convenience and safety. System efficiency is analyzed under different operating conditions. Advanced control methods improve power transfer performance. The study discusses practical implementation challenges and solutions. Results demonstrate the feasibility of wireless charging technology.

Article [10] "Intelligent Solar EV Charging Station Using Internet of Things Technology" by M. Venkatesh and R. Balakrishnan in 2024: This research develops an intelligent EV charging station powered by solar energy and managed through IoT communication. Real-time monitoring ensures efficient charging operations. Cloud connectivity provides remote accessibility for users and operators. Battery conditions and energy consumption are continuously tracked. The system supports smart scheduling and energy optimization. Renewable power utilization reduces operational costs and emissions. Experimental results validate the effectiveness of the proposed solution.

Article [11] "Smart Wireless Charging Infrastructure for Sustainable Electric Mobility" by Noor Ahmad and Syed Farhan in 2025: This paper presents a sustainable wireless charging infrastructure for electric vehicles. Renewable energy sources are integrated to improve environmental performance. Intelligent controllers regulate power transfer operations. IoT connectivity enables real-time monitoring and diagnostics. The system enhances convenience by eliminating wired charging requirements. Operational data supports maintenance and performance optimization. Findings indicate improved efficiency and user satisfaction.

Article [12] "Development of Solar-Assisted IoT Enabled Electric Vehicle Charging Network" by R. Sivakumar and T. Pradeep Kumar in 2023: This study proposes a solar-assisted charging network for electric vehicles supported by IoT technology. Distributed charging stations are connected through wireless communication platforms. Energy generation and consumption data are continuously monitored. Smart control strategies improve charging efficiency and reliability. Renewable energy utilization contributes to

environmental sustainability. Remote management capabilities enhance operational flexibility. The proposed network demonstrates effective performance in practical charging scenarios.

III. Problem Statement

The rapid growth of electric vehicles has increased the demand for reliable and sustainable charging infrastructure. Conventional charging stations primarily depend on grid electricity and wired connections, which can lead to high energy costs, cable management issues, maintenance requirements, and increased dependence on non-renewable energy sources. Limited availability of eco-friendly charging solutions further restricts the efficient adoption of electric mobility. In addition, the absence of real-time monitoring and intelligent energy management reduces operational efficiency and user convenience. Therefore, there is a need for a smart charging system that utilizes renewable energy, supports wireless power transfer, and enables continuous monitoring to improve charging accessibility, efficiency, sustainability, and overall system performance.

IV. Objectives

The primary objective of this study is to design and develop an IoT-assisted solar-powered wireless EV charging station that promotes sustainable transportation through the use of renewable energy. The project aims to utilize solar photovoltaic panels for clean energy generation and efficient battery storage. Another objective is to implement wireless power transfer technology to enable safe and convenient charging without physical cable connections. The study also focuses on integrating IoT technology for real-time monitoring of charging parameters such as voltage, current, battery status, and energy consumption. Additionally, the system seeks to improve energy efficiency, reduce dependence on conventional grid electricity, enhance user convenience through remote monitoring, and provide an environmentally friendly charging solution suitable for future smart mobility applications.

V. Methodology

1)Solar Energy Generation : The methodology begins with the generation of electrical energy using solar photovoltaic panels. The solar panel converts sunlight into direct current electricity, providing a clean and renewable source of power. The generated energy is collected during daylight hours and supplied to the energy storage unit. This approach reduces dependence on conventional electricity sources and supports sustainable operation of the charging station.

2)Energy Storage and Power Management : The electrical energy generated by the solar panel is stored in a rechargeable battery for future use. A power management circuit regulates the charging and discharging process to maintain stable voltage levels. The stored energy ensures continuous operation of the charging station even during cloudy conditions or at night. This method improves energy utilization and enhances system reliability.

3)Arduino-Based Control System : The Arduino Uno serves as the central controller responsible for managing all system operations. It receives input data from sensors and controls various components of the charging station. The controller processes real-time information and executes programmed actions based on operating conditions. This ensures coordinated, efficient, and automated system performance.

4)Wireless Power Transfer : Wireless charging is achieved through electromagnetic induction using transmitter and receiver coils. The transmitter coil generates a magnetic field when supplied with electrical power from the system. The receiver coil captures the magnetic energy and converts it into usable electrical energy for battery charging. This contactless charging technique enhances convenience and eliminates the need for physical charging cables.

5)Sensor-Based Monitoring : Voltage and current sensors are incorporated to continuously monitor important electrical parameters. These sensors measure battery voltage, charging current, and power transfer conditions in real time. The collected information is transmitted to the Arduino controller for analysis and decision-making. Continuous monitoring improves operational safety and charging efficiency.

6)IoT Communication and Remote Monitoring : The ESP8266 Wi-Fi module enables Internet connectivity and real-time communication. System parameters such as voltage, current, battery status, and charging information are transmitted to an IoT platform. Users can remotely access and monitor charging

performance through connected devices. This feature enhances accessibility, supervision, and intelligent energy management.

7)Display and User Interface : A 16×2 LCD display is used to provide real-time information about system operation. Important parameters such as charging status, battery condition, and sensor readings are displayed continuously. The display offers immediate visual feedback to users regarding charging activities. This improves system usability and facilitates effective monitoring of charging performance.

VI. System Architecture

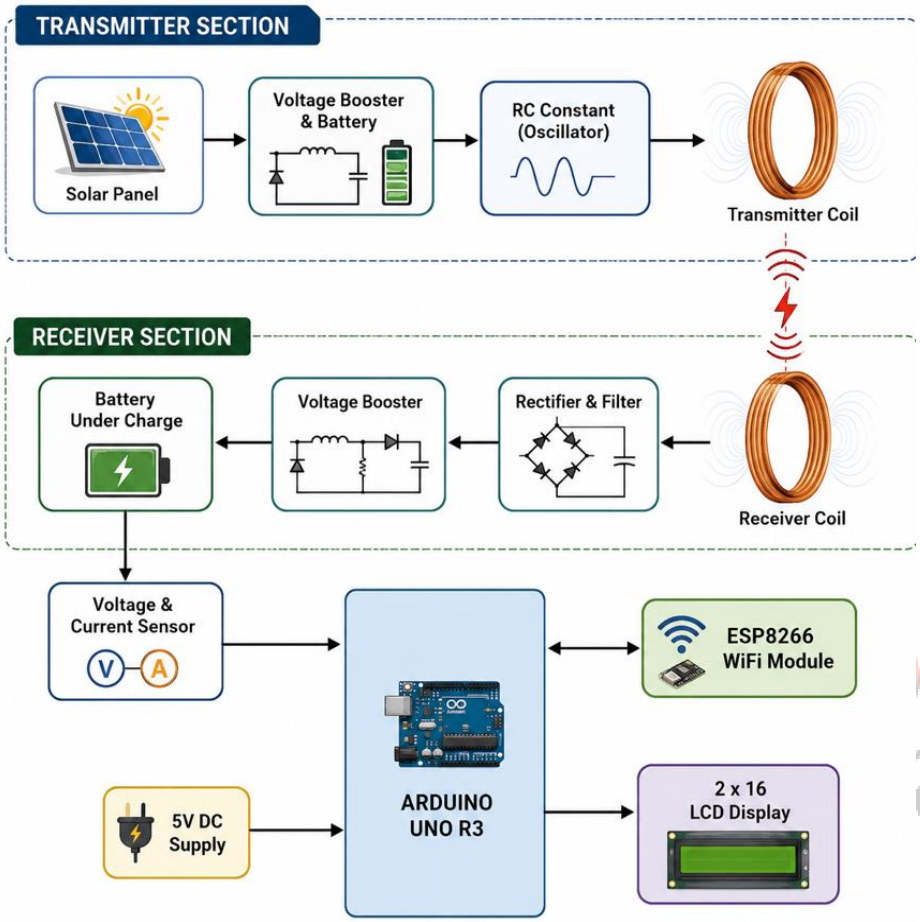

Fig 1: System System Architecture of IoT-Assisted Solar-Powered Wireless EV Charging Station for Sustainable Transportation

The system architecture consists of transmitter and receiver sections integrated with an Arduino Uno R3 controller, IoT communication module, and monitoring components. In the transmitter section, a solar panel generates renewable electrical energy, which is regulated and stored using a voltage booster and battery unit. An RC constant oscillator converts the stored energy into a high-frequency signal that energizes the transmitter coil. Through electromagnetic induction, wireless power is transferred from the transmitter coil to the receiver coil without physical contact. In the receiver section, the induced electrical energy is converted into usable DC power using a rectifier and filter circuit. A voltage booster further regulates the output before charging the battery. Voltage and current sensors continuously measure charging parameters and transmit the collected data to the Arduino Uno R3. The controller processes the information and communicates with the ESP8266 Wi-Fi module for IoT-based remote monitoring. Charging status, voltage levels, and system information are displayed on a 2×16 LCD display. A regulated 5V DC supply powers the control circuitry, ensuring stable, efficient, and intelligent wireless EV charging operation with enhanced user accessibility and energy management.

VII. Experimental Setup

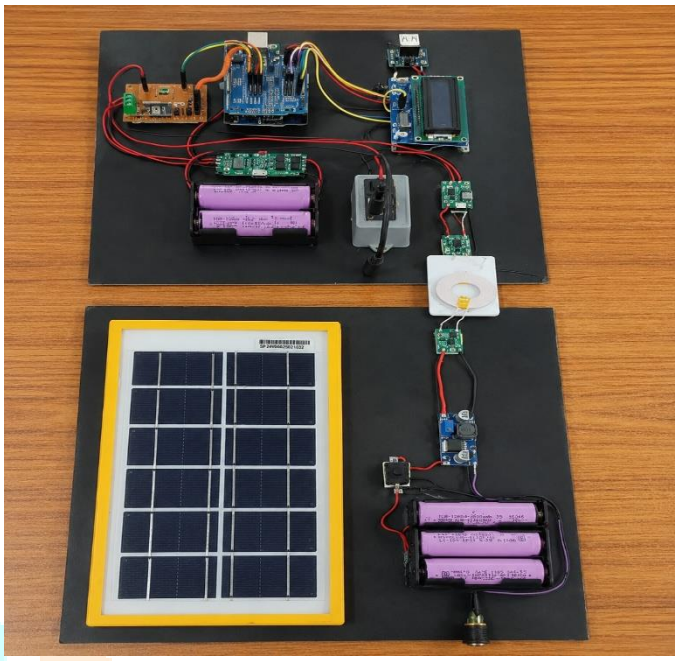

Fig. 2: Prototype Kit of IoT-Assisted Solar-Powered Wireless EV Charging Station for Sustainable Transportation

The developed prototype consists of a solar panel, rechargeable battery units, wireless transmitter and receiver coils, Arduino Uno R3, ESP8266 Wi-Fi module, LCD display, and power management circuits

VIII. Conclusion and Future Works

In this research, an IoT-assisted solar-powered wireless EV charging station was designed to provide a sustainable, efficient, and user-friendly charging solution. The integration of solar energy reduced dependence on conventional power sources, while wireless power transfer improved convenience and safety by eliminating physical charging cables. IoT technology enabled real-time monitoring of charging parameters and system performance. The proposed system demonstrated reliable operation, effective energy utilization, and support for environmentally friendly transportation. Future work can focus on increasing wireless power transfer efficiency, implementing fast-charging capabilities, integrating advanced energy management algorithms, and supporting larger EV batteries for wider commercial and smart city applications.

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