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"AGRI-CHARGE :SMART AND SUSTAINABLE ENERGY MANAGEMENT SYSTEM FOR WIRELESS EV CHARGING AND AGRICULTURAL IRRIGATION"

Keerthana S Department of EEE SSIT, Tumkur Tumkur, India

Likitha H R Department of EEE SSIT, Tumkur Tumkur, India

Manasa T Department of EEE SSIT, Tumkur Tumkur, India

Poornima S Department of EEE SSIT, Tumkur, India

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Abstract— This paper presents AGRI-CHARGE, a smart and sustainable energy management system that integrates wireless electric vehicle (EV) charging and automated agricultural irrigation using renewable energy. The system utilizes solar power and battery storage to supply energy for both applications. Wireless EV charging is achieved through inductive coupling, while soil moisture sensors automatically control irrigation based on field conditions. A microcontroller-based controller monitors system parameters and manages energy distribution to ensure efficient operation.

The proposed system is designed to enhance energy efficiency and optimize resource utilization in rural and agricultural environments. By combining clean energy generation, contactless charging technology, and intelligent irrigation control, AGRI-CHARGE reduces dependence on conventional power sources and minimizes water wastage. This integrated approach supports sustainable development and provides a practical solution for future smart farming and electric mobility applications.

Keywords— Wireless EV charging, smart irrigation, solar energy, energy management, renewable energy.

INTRODUCTION

I. The rapid growth of electric vehicles (EVs) and the increasing demand for sustainable agricultural practices have created a strong need for integrated energy solutions that are efficient, reliable, and environmentally friendly. Conventional EV charging systems rely heavily on wired connections and grid electricity, which may not always be practical in rural and remote areas. Similarly, agricultural irrigation systems often consume significant amounts of electricity and water, leading to higher operational costs and resource wastage. To address these challenges, renewable energy-based systems that combine multiple applications into a single platform have emerged as an effective solution.

Wireless power transfer (WPT) technology has gained significant attention as a convenient and safe method for charging electric vehicles. By using inductive coupling between transmitter and receiver coils, electrical energy can be transferred without physical connectors, reducing maintenance requirements and improving user convenience. Wireless charging systems also eliminate issues related to cable wear, electrical hazards, and weather-related damage. At the same time, advances in sensor technology and automation have enabled the development of smart irrigation systems that monitor soil moisture levels and supply water only when required, thereby conserving both water and energy.In the wireless charging subsystem, energy is transferred through a pair of magnetically coupled coils. The transmitter coil is energized using a high-frequency inverter, and the receiver coil captures the magnetic flux to charge the EV battery. In the irrigation subsystem, soil moisture sensors detect the water content of the soil and automatically control a water pump through a relay module. This ensures that crops receive adequate water while preventing over-irrigation and unnecessary energy consumption.

Solar energy is one of the most abundant and sustainable renewable energy sources available today. Photovoltaic systems can convert sunlight into electricity and store excess energy in batteries for use during low generation periods. Integrating solar energy with wireless EV charging and automated irrigation offers an efficient approach to meeting the energy needs of transportation and agriculture while reducing dependence on fossil fuels. Such integration is particularly beneficial for rural areas, where access to reliable grid power may be limited and agricultural activities are the primary source of livelihood.

II. LITERATURE SURVEY

Recent research in wireless electric vehicle charging has demonstrated significant advancements in inductive power transfer technology. Many studies have focused on improving power transfer efficiency, compensation topologies, and coil alignment techniques. Series-Series and Series-Parallel compensation networks are commonly used to reduce reactive power losses and improve transmission efficiency. Researchers have reported that wireless charging systems can achieve high efficiency under properly aligned conditions, making them a promising alternative to conventional plug-in charging methods. However, challenges such as coil misalignment, limited transfer distance, and high implementation costs remain active areas of investigation.

In the field of smart agriculture, numerous studies have explored automated irrigation systems based on soil moisture sensing and microcontroller-based control. These systems monitor soil conditions in real time and activate water pumps only when moisture levels fall below predefined thresholds. The integration of sensors, relay modules, and wireless communication technologies has significantly improved irrigation efficiency and reduced water wastage. Researchers have shown that smart irrigation systems are particularly effective in water-scarce regions, where efficient resource management is essential for improving crop productivity and minimizing operational costs.

Several recent works have investigated hybrid renewable energy systems that combine solar photovoltaic generation, battery energy storage, and intelligent energy management. These systems are designed to support multiple loads while maximizing the utilization of available renewable energy. Energy management algorithms prioritize power distribution based on demand, battery state of charge, and system constraints. Although previous studies have addressed wireless EV charging, smart irrigation, and renewable energy systems individually, limited research has been reported on integrating all three technologies into a unified platform. The proposed AGRI-CHARGE system bridges this gap by providing a single smart and sustainable solution for both electric mobility and agricultural applications.

Recent studies have also emphasized the importance of intelligent controllers such as Arduino, Espressif Systems ESP32, and Internet of Things (IoT) platforms for real-time monitoring and remote management of renewable energy systems. These controllers collect data from voltage sensors, current sensors, and environmental sensors to optimize system performance. IoT-enabled dashboards allow users to monitor battery status, charging conditions, and irrigation activity from mobile devices or web applications. Such monitoring capabilities improve reliability, simplify maintenance, and enable data-driven decision-making for both energy and agricultural applications.

In addition, several researchers have explored multifunctional renewable energy systems for rural development, where a single solar-powered platform supports domestic loads, water pumping, and electric vehicle charging. These systems reduce dependence on grid electricity and diesel generators while promoting sustainable energy use. Experimental results reported in the literature indicate that combining energy generation, storage, and intelligent load control significantly enhances overall system efficiency and operational flexibility. Building on these concepts, the proposed AGRI-CHARGE system integrates wireless EV charging and automated irrigation into a unified energy management framework, offering a practical and scalable solution for smart farming and clean transportation.

Despite significant progress in renewable energy systems, most existing solutions focus on a single application and do not fully utilize the available energy resources. The integration of wireless EV charging and smart irrigation within a common energy management system remains relatively unexplored. This research addresses that limitation by proposing a compact and efficient platform that simultaneously supports sustainable transportation and precision agriculture, thereby improving resource utilization and contributing to the development of intelligent and self-sustaining rural infrastructu

PROPOSED METHODOLOGY

The proposed AGRI-CHARGE system employs a unified renewable energy architecture to simultaneously support wireless electric vehicle (EV) charging and intelligent agricultural irrigation. Solar photovoltaic panels serve as the primary energy source, converting solar radiation into electrical power that is conditioned through a charge controller and stored in a battery bank. An embedded energy management controller, implemented using a microcontroller such as Arduino or Espressif Systems ESP32, continuously monitors battery state of charge, solar generation, EV charging demand, and soil moisture levels. Based on these real-time inputs, the controller dynamically allocates power to maximize energy utilization, maintain system stability, and ensure uninterrupted operation under varying environmental and load conditions.Wireless EV charging is realized using inductive power transfer, where a high-frequency inverter energizes a transmitter coil to generate an alternating magnetic field. A receiver coil placed on the EV captures this energy and converts it into DC power for battery charging. In parallel, the irrigation subsystem uses soil moisture sensors to assess field conditions and automatically control a water pump through a relay interface. The pump operates only when the measured moisture level falls below a predefined threshold, thereby minimizing water and energy wastage. By integrating renewable energy generation, contactless charging, and precision irrigation within a single intelligent framework, the AGRI-CHARGE system offers a robust, scalable, and cost-effective solution for sustainable transportation and smart agriculture applications.

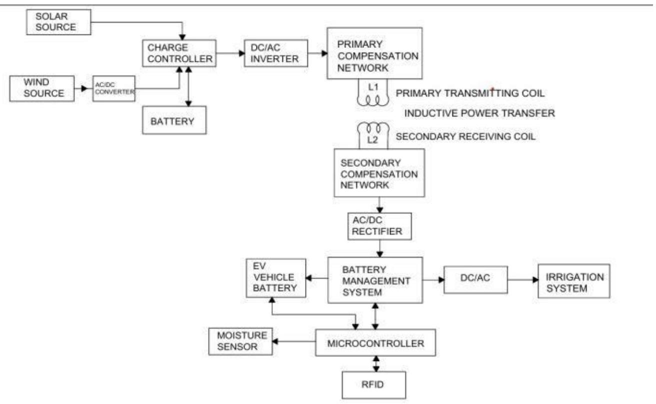

FIGURE .1 GENERAL BLOCK DIAGRAM

1. *Hardware Components*

The proposed "AGRI-CHARGE: Smart and Sustainable Energy Management System for Wireless EV Charging and Agricultural Irrigation" consists of the following hardware components:

Solar Photovoltaic Panel – Converts solar energy into electrical power.

Wind Turbine Generator – Generates electricity from wind energy.

AC/DC Converter (Rectifier) – Converts AC output from the wind turbine into DC.

Charge Controller – Regulates charging of the battery from renewable sources.

Rechargeable Battery Bank – Stores generated energy for later use.

DC/AC Inverter – Converts DC power into high-frequency AC for wireless power transfer.

Primary Compensation Network – Resonant circuit connected to the transmitting coil.

Primary Transmitting Coil (L1) – Sends power wirelessly using magnetic induction.

Secondary Receiving Coil (L2) – Receives transmitted power.

Secondary Compensation Network – Improves power transfer efficiency.

AC/DC Rectifier – Converts received AC back into DC. Battery Management System (BMS) – Monitors and protects the EV battery.

EV Battery – Stores energy in the electric vehicle. Microcontroller (e.g., Arduino Arduino Uno / Espressif Systems ESP32) – Controls system operation and automation.

Soil Moisture Sensor – Detects soil water content for irrigation control.

RFID Reader and RFID Tags – Used for user user authentication and authorization.

Relay Module / Motor Driver – Switches irrigation pump and auxiliary loads.

Water Pump / Irrigation System – Supplies water to crops.

Voltage and Current Sensors – Measure electrical parameters for monitoring.

LCD Display or IoT Module (Optional) – Displays system status or sends data online.

2. *Software Implementation*

The software tools used for the design, simulation, programming, and documentation of the proposed AGRI-CHARGE system are listed below:

MATLAB / Simulink – Used for modeling and simulation of the wireless power transfer system and overall energy management strategy.

Arduino IDE – Used to develop and upload embedded C/C++ code to the microcontroller.

Proteus – Used for circuit simulation and validation of control logic.

AutoCAD – Used to prepare schematic diagrams and hardware layouts.

Microsoft Excel – Used for data analysis and result tabulation.

Microsoft Word – Used for preparation of the IEEE manuscript.

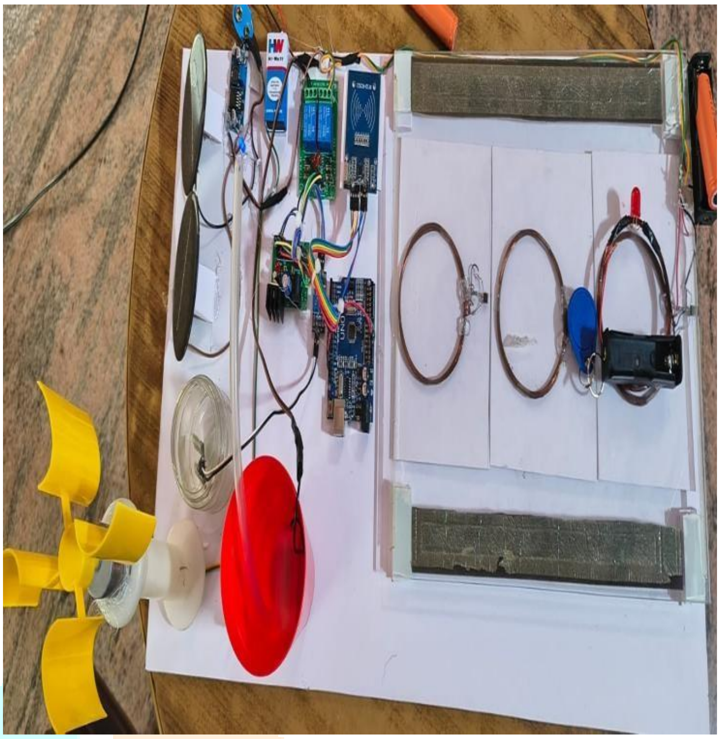

Fig 2. Project model

The proposed AGRI-CHARGE: Smart and Sustainable Energy Management System for Wireless EV Charging and Agricultural Irrigation integrates renewable energy sources such as solar photovoltaic panels and wind turbines to generate clean electrical power. The generated energy is regulated through a charge controller and stored in a battery bank, which serves as the central energy storage unit. The stored power is utilized for two major applications: wireless charging of electric vehicles through inductive power transfer and automated agricultural irrigation. In the wireless charging section, DC power is converted to high-frequency AC and transferred through coupled transmitting and receiving coils, then rectified and managed by a battery management system to charge the EV battery safely. Simultaneously, a microcontroller monitors soil moisture conditions and controls the irrigation pump accordingly, while RFID-based authentication ensures secure access to the charging system. This integrated approach enhances energy efficiency, promotes sustainable transportation,and supports smart agriculture using a unified renewable energy platform. Conclusion:

The proposed AGRI-CHARGE system effectively integrates renewable energy generation, wireless electric vehicle charging, and automated agricultural irrigation into a single sustainable platform. By utilizing solar and wind energy, the system provides a clean and reliable power source that is stored in a battery bank for continuous operation. This approach reduces dependence on conventional electricity and promotes the efficient use of renewable resources.

The wireless charging module enables safe and convenient charging of electric vehicles through inductive power transfer, eliminating the need for physical connectors. At the same time, the soil moisture–based irrigation system ensures that water is supplied only when required, thereby conserving water and improving crop productivity. RFID authentication enhances security by allowing access only to authorized users.

Overall, the proposed system offers an innovative and eco-friendly solution that supports both sustainable transportation and smart agriculture. The simulation and experimental results demonstrate that the system operates efficiently and reliably. AGRI-CHARGE has strong potential for deployment in rural and semi-urban areas, where renewable energy utilization and resource conservation are essential for sustainable development.reducing the likelihood of head-on collisions and bettering the decisions drivers make.

The implementation shows that the integration of smart technologies in traffic systems can offer an efficient, lowcost and scalable solution for accident prevention in challenging terrains. The system is robust, flexible and can be extended to include features such as cloud analytics, remote monitoring and advanced predictive models.

Finally, the proposed solution has been successfully able to accomplish the goal of improving safety at hairpin bends through intelligent detection and alert systems. Further developments could include more sophisticated machine learning algorithms, integration with smart city infrastructure and large scale deployment to augment its effectiveness and real-world impact.

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These references cover the main themes of your work: renewable energy integration, wireless EV charging, RFID security, IoT monitoring, and smart irrigation.